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When Technology Meets Practice: How Real-World Use Reshaped an XR-Enhanced Chronic Pain Programme Across Primary Care Sites

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Abstract

Extended reality (XR) interventions for chronic pain have shown promising results in controlled and early feasibility settings, but evidence on their transition into routine primary care remains limited. This real-world multicentre implementation case study examined REDOCVR, an XR-enhanced chronic pain programme, as it moved from pilot feasibility toward routine delivery across primary care centres in Catalonia, Spain, between February 2024 and May 2026. REDOCVR integrated augmented and virtual reality content into existing group-based chronic pain programmes led by psychologists and physiotherapists. Data sources included operational records, patient-reported outcomes from completed research groups (n = 103), two semi-structured professional discussion groups (n = 10), professional usability and workflow indicators (n = 11), and external scale-out material from one formative familiarisation site and one prospective readiness appraisal site. REDOCVR reached 225 participants across research and routine implementation groups. Real-world use showed that scalability was constrained mainly by workflow integration, device logistics, technical usability and organisational support, rather than by clinical content or patient acceptance. Professional feedback informed a planned unified application redesign and supported concentrating XR into four therapeutically selected sessions to reduce preparation time, simplify headset allocation and make technical support easier to plan. Patient-reported feasibility remained favourable, while clinical and medication-related outcomes showed favourable descriptive patterns but were interpreted only as contextual indicators. Moving XR-supported interventions from pilot to practice requires professional autonomy, workflow alignment, simplified technical architecture and institutional support for device management, training and maintenance.

Keywords: Extended reality, Chronic pain, Primary care, Implementation science, Workflow integration, Workplace adoption

1 Introduction

1.1 The workplace challenge of XR in healthcare

When new technologies enter healthcare settings, adoption depends less on technical sophistication than on alignment with organisational routines and established workflows (Greenhalgh et al. 2017). Extended reality (XR), encompassing virtual reality (VR), augmented reality (AR) and mixed reality (MR), has been explored across several healthcare domains (Spiegel et al. 2024; Iqbal et al. 2024; Zuo et al. 2024), yet implementation outcomes depend on organisational context, workflow integration and professional capacity, not clinical effectiveness alone (Proctor et al. 2011; Kouijzer et al. 2023).

This workplace perspective is particularly relevant for immersive technologies. Deployment requires attention to device logistics, institutional demands and supervision within routine care rather than controlled laboratory settings (Morgan et al. 2025). In chronic pain, implementation research has identified limited evidence on healthcare professionals' perspectives, despite their central role in sustained adoption (Elser et al. 2024; Kouijzer et al. 2023). The central challenge is not only to demonstrate that XR can work under ideal conditions, but to determine whether it can move from project-based pilots to routine service delivery in real-world healthcare organisations.

1.2 REDOCVR: integrating XR into existing care pathways

REDOCVR is an XR-supported adaptation of multidisciplinary psychoeducational chronic pain groups delivered in primary care centres in Catalonia, Spain. Rather than introducing XR as a separate service, the programme integrates immersive content into existing group sessions led by psychologists and physiotherapists, supporting mindfulness, cognitive reframing and movement-based activities within routine care pathways (Ferrer Costa et al. 2025b).

The initial REDOCVR feasibility study reported high adherence, positive usability and exploratory improvements in emotional well-being, anxiety and depressive symptoms, supporting feasibility under routine care conditions (Ferrer Costa et al. 2025b). However, feasibility within research-led sites does not ensure broader adoption. Scaling required delivery to move beyond centralised innovation support and become manageable by local teams across different organisational contexts, raising practical questions related to workflow integration, training, resource allocation and institutional readiness (Morgan et al. 2025; Elser et al. 2024).

1.3 Experiential familiarisation and readiness appraisal

Formative evaluation in implementation research typically relies on stakeholder perceptions collected before deployment (Damschroder et al. 2009). For immersive technologies, this approach may be limited when professionals lack prior XR experience, as judgements about usability or workflow impact may reflect expectation rather than direct interaction. This has been described as the experience gap (Ferrer Costa and Armayones Ruiz 2026).

A pragmatic response is to introduce brief experiential familiarisation before eliciting stakeholder assessments. Building on this principle, MCDA-XR was developed as a structured pre-implementation appraisal combining stakeholder-rated strategic importance and organisational readiness across multiple criteria after hands-on exposure (Ferrer Costa et al. 2025a). As REDOCVR expanded beyond initial feasibility testing, 2 implementation pathways emerged: internal expansion through iterative adaptation within the original organisational context, and external scale-out supported by experiential familiarisation and structured readiness appraisal.

1.4 Aim of this study

This study examines how REDOCVR moved from pilot implementation toward routine service delivery through professional-driven optimisation and multicentre scale-out. In this article, routine service delivery refers to REDOCVR groups delivered as usual clinical activity within existing primary care chronic pain programmes, led by local clinical teams and no longer limited to

formal research assessments. It does not imply that all aspects of funding, governance or technical maintenance had become fully independent of institutional innovation support.

Building on previous feasibility work (Ferrer Costa et al. 2025b), the study focuses on the 2024–2026 implementation phase, during which accumulated real-world use led to software redesign and refinement of the delivery model. The analysis addresses three interconnected processes: iterative optimisation based on professional feedback, internal expansion across multiple centres within the originating organisation and external scale-out supported by experiential familiarisation and structured readiness appraisal.

Clinical and medication-related outcomes were included only as contextual indicators of programme continuity, not as primary effectiveness measures.

2 Methods

2.1 Study design and setting

This study was designed as a real-world multicentre implementation case study of REDOCVR during its transition toward routine primary care use. The objective was to examine how repeated delivery within everyday clinical groups generated professional feedback, workflow learning and redesign needs, rather than to evaluate the comparative effectiveness of XR as a stand-alone intervention.

The implementation case spans February 2024 to May 2026 and was conducted within Badalona Serveis Assistencials (BSA), an integrated public healthcare organisation in Catalonia, Spain, together with collaborating external primary care settings. REDOCVR was delivered as part of routine clinical activity, using existing group rooms, local multidisciplinary teams and commercially available standalone head-mounted displays.

2.2 REDOCVR intervention and implementation trajectory

REDOCVR is an XR-supported adaptation of existing multidisciplinary psychoeducational chronic pain groups delivered in primary care by psychologists and physiotherapists. The chronic pain group programme exists independently of XR, and immersive content was introduced as a professional support layer rather than as an autonomous treatment. XR modules were used selectively to reinforce therapeutic objectives already addressed by clinicians, including attentional focus, acceptance of pain, self-compassion, breathing exercises, and movement-based activation.

The co-design, feasibility, and initial optimisation stages of REDOCVR, corresponding to Phases 1 and 2 in 2023–2024, have been reported previously (Ferrer Costa et al. 2025b). That publication describes the hybrid type 2 phased implementation design, the 8-session intervention structure, the original implementation procedures, and the feasibility, usability, satisfaction, tolerability, and exploratory clinical outcome measures used in the research protocol. The present analysis extends the implementation case to the period from February 2024 to May 2026 and focuses specifically on accumulated real-world use, professional reflection, redesign planning, and transition toward routine service delivery.

2.3 Professional discussion groups

In January 2026, two semi-structured professional discussion groups were conducted to examine accumulated REDOCVR experience and identify priorities for routine use. One group included five physiotherapists responsible for movement-based sessions, while the other included five primary care psychologists responsible for mindfulness, emotional regulation and acceptance-based components. All participants had delivered REDOCVR during 2024 and 2025.

Sessions were facilitated by the principal investigator using predefined guides adapted to each professional profile. Discussions addressed perceived clinical value, therapeutic fit, patient profiles, workflow barriers, technical usability and requirements for routine implementation. Because the sessions combined experiential reflection, content refinement and redesign planning, they were treated as formative professional evaluation rather than formal theory-generating qualitative focus groups.

Discussions were audio-recorded with informed consent, transcribed using Whisper and Gemini, and checked against the original audio by the principal investigator. Findings were organised in a

pragmatic coding matrix comparing psychology and physiotherapy perspectives, with additional codes added inductively when relevant implementation issues emerged. The full coding framework and cross-professional thematic matrix are provided in Supplementary Material S1.

2.4 Software redesign planning

The outputs of the professional discussion group analysis were translated into a software redesign workplan for a unified REDOCVR application. This workplan was treated as a methodological output of the implementation process, documenting how accumulated professional experience was converted into technical and organisational redesign requirements. These requirements addressed navigation, content access, recentring, interaction design, setup burden and professional autonomy during group delivery. Because the redesign implied development work, maintenance responsibilities and institutional resource allocation, it was considered part of the implementation requirements for sustaining XR in routine care. The redesign was not evaluated as an implemented intervention in this study.

2.5 Participants and analytical samples

Participants were adults enrolled in chronic pain group programmes at participating primary care centres through the usual clinical referral pathway. The cohort mainly included patients with chronic non-cancer pain, often associated with central sensitisation, emotional distress, kinesiophobia or insufficient response to previous treatments. Detailed recruitment procedures and eligibility criteria for the REDOCVR research phases have been described previously (Ferrer Costa et al. 2025b).

For implementation reach, all activated REDOCVR groups between February 2024 and May 2026 were considered, including research groups and routine service groups. Clinical, feasibility, usability, and medication-related analyses were restricted to research protocol groups with completed assessments by the end of 2025. Groups initiated in 2026 contributed only to implementation reach and adoption trajectory analyses because they were ongoing or delivered as routine service without formal research assessments. This completed research cohort included the 36 participants reported previously for Phases 1–2 (Ferrer Costa et al. 2025b), together with participants from subsequently completed research groups up to the end of 2025.

2.6 Protocols, data sources and external scale-out

REDOCVR was conducted under two interrelated protocols approved by the CEIm IDIAP Jordi Gol and registered at ClinicalTrials.gov (NCT06361706 and NCT06964360). REDOCVR refers to the base XR-supported chronic pain group programme, while REDOCVR-AC refers to the complementary protocol incorporating family physician-supervised medication review and tapering in selected groups. For completed research groups, the same domains, questionnaires, administration procedures and scoring approach used in the Phase 1–2 study were maintained. Full methodological details are therefore not repeated.

Data sources included operational records, group activation data, feasibility and usability questionnaires, clinical assessments, medication follow-up data, professional discussion group transcripts and external readiness appraisal outputs. Patient-reported and professional questionnaire results were transformed to a 0–100 metric for comparability, with higher values indicating more favourable ratings. Item-level results are provided in Supplementary Material S2.

External scale-out incorporated experiential familiarisation before professional appraisal. Valls was treated as a formative familiarisation case, while CAP Lloret served as an external Phase 3 readiness appraisal case. MCDA-XR was used as an exploratory implementation-planning tool, not as a predictive algorithm, combining strategic importance ratings on a 1–5 scale with organisational readiness ratings on a 1–3 scale across ten XR adoption criteria.

2.7 Analysis

The analysis extended the previously reported REDOCVR Phases 1 and 2 study (Ferrer Costa et al. 2025b) by examining accumulated real-world use, professional feedback and redesign planning from an implementation perspective. It

was descriptive and focused on service adaptation rather than effectiveness testing.

Operational data were summarised by centre, group status, implementation stage and participant reach. Quantitative outcomes from completed research groups were treated as continuity indicators. Patient-reported feasibility, usability and professional workflow indicators were transformed to a 0–100 metric, with higher scores indicating more favourable ratings; negatively worded items were reverse-coded before transformation.

Pre-post changes in contextual clinical indicators (WEMWBS-7, HADS-A, HADS-D, CSI and exploratory EQ-5D-5L total score) were analysed using paired-samples t-tests with paired-sample Cohen's d effect sizes. Individual EQ-5D-5L ordinal dimensions were analysed using Wilcoxon signed-rank tests. Analyses were exploratory and were not adjusted for multiple testing.

Medication-related outcomes were analysed descriptively in participants with 5-month follow-up. Dose reduction was calculated for each medication entry as the percentage change in daily intake from baseline to follow-up and summarised by therapeutic category. No inferential between-group testing was performed because the reference cohort was non-randomised and medication entries were heterogeneous.

Professional discussion transcripts were analysed using a pragmatic thematic approach supported by a structured coding matrix. The coding framework followed the semi-structured guides, with inductive codes added when relevant. Psychology and physiotherapy findings were compared to identify convergent and profession-specific implementation requirements. No formal inter-rater reliability assessment was conducted given the formative purpose.

External implementation material was interpreted separately, with Valls treated as formative familiarisation and Lloret as structured readiness appraisal. MCDA-XR outputs were interpreted descriptively as implementation-planning indicators rather than predictive scores.

3 Results

3.1 Implementation Trajectory and Programme Reach

REDOCVR progressed from the feasibility and optimisation phases reported previously (Ferrer Costa et al. 2025b) to a Phase 3 implementation pathway spanning February 2024 to May 2026. This trajectory combined multicentre research expansion, external scale-out and early routine service delivery within BSA. The chronological sequence of group activation across centres is shown in Fig. 1.

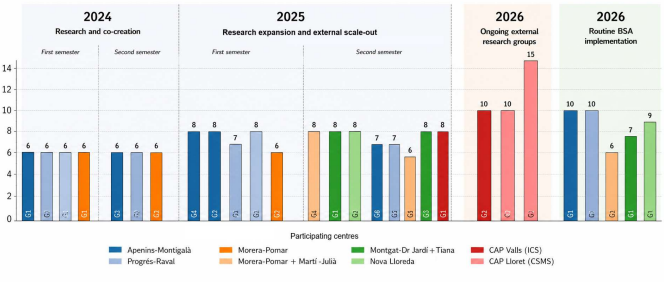


Fig. 1 REDOCVR group activation and participant reach across centres, 2024 to May 2026. Bars show participants included in each activated group by semester, centre and implementation stage. The 2024 groups correspond to Phases 1–2, the 2025 groups to Phase 3 research expansion and the first external CAP Valls group, and the 2026 sections to ongoing external scale-out groups and routine BSA service delivery. Ongoing and routine groups contributed to implementation reach but not to completed research outcome analyses. Colours indicate participating centres.

By the May 2026 cut-off, REDOCVR had reached 225 participants across two implementation layers: 174 enrolled under REDOCVR research protocols and 51 included in routine BSA service delivery. The research pathway included completed BSA implementation groups, the first completed external group at CAP Valls (ICS) and external MCDA-XR scale-out groups initiated in 2026 at CAP Valls and CAP Lloret. Routine BSA groups were activated in 2026 as usual care after the implementation pilot, did not include formal research assessments and were counted only as implementation reach. Together, these groups show the transition from initial feasibility work to internal expansion, external scale-out and early

routine integration within existing chronic pain group workflows.

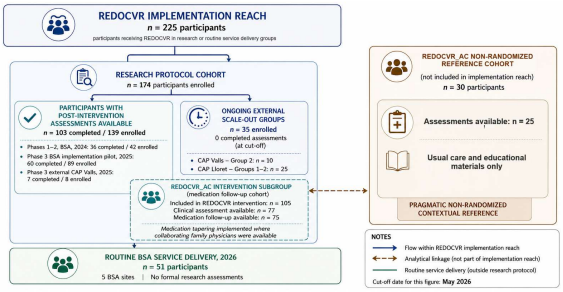


Fig. 2 REDOCVR participant flow and analytical samples, February 2024 to May 2026. Implementation reach included 225 participants: 174 under REDOCVR research protocols and 51 in routine BSA service delivery without formal research assessments. Outcome analyses were restricted to 103 participants with completed post-intervention assessments from 139 eligible research participants. REDOCVR-AC medication follow-up and the non-randomised reference cohort are shown separately as contextual analytical samples.

As shown in Fig. 2 and Table 1, outcome analyses were restricted to research participants with post-intervention assessments available at the cut-off. Of the 174 research participants, 35 belonged to external groups initiated in 2026 that were still ongoing. The remaining 139 participants had reached the assessment stage, of whom 103 completed post-intervention assessments. This completed research cohort included 36 participants previously reported for Phases 1 and 2 and 67 participants from subsequently completed groups through the end of 2025.

3.2 Professional-driven optimisation process

Following the 2024 and 2025 implementation groups, two semi-structured professional discussion groups were conducted in January 2026 to examine accumulated REDOCVR experience and define optimisation priorities for routine delivery. One group involved five physiotherapists and the other five psychologists. The coding framework and cross-professional thematic matrix are provided in Supplementary Material S1.

Professionals described XR as clinically useful when used as a selective complement to the existing group programme. Physiotherapists valued AR exercises for graded movement exposure, reduced kinesiophobia, physical activation and perceived safety through visual connection with the physical environment. Psychologists valued immersive content for reducing distractors, supporting attention and facilitating engagement with emotional regulation practices, particularly in patients with rumination, difficulty concentrating or initial resistance to mindfulness-based exercises.

Professionals also emphasised that XR should be matched to the therapeutic objective, patient profile and group dynamics. Workflow barriers were technical, logistical and organisational, including fragmented applications, difficulty locating content, unreliable menus, manual recentring, variable scene positioning, headset preparation, room constraints, group size, scheduling, staffing capacity and dependence on innovation-team support. These barriers did not undermine perceived clinical value, but limited professional autonomy and scalability.

The implementation requirements identified through the thematic matrix were translated into a software redesign workplan. Table 2 summarises the planned redesign features and the operational issues they were intended to resolve.

3.3 Session model refinement

In parallel with the software redesign, REDOCVR delivery was refined to improve feasibility within routine primary care. XR use was concentrated into four therapeutically selected sessions: two psychology-led sessions focused on emotional regulation and mindfulness, and two physiotherapy-led sessions focused on movement and body awareness.

This selective model aimed to preserve clinical value while reducing setup time, technical burden and workflow disruption. It reflected professional judgement that XR was most useful at specific therapeutic moments, rather than as a mandatory component of every session.

3.4 Feasibility, usability and professional workflow indicators

In the completed research assessment cohort (n = 103), patient-reported feasibility indicators

Table 1 Analytical cohorts and participant characteristics at the May 2026 cut-off

Indicator	REDOCVR research cohort[1]	REDOCVR-AC intervention subgroup[2]	REDOCVR-AC reference cohort[3]
Enrolled participants, n	139	105	30
Post-assessments, n	103	77	25
Medication follow-up, n	Not applicable	75	25
Completion rate, %	74.1	73.3	83.3
Completed groups, n	20	15	4
BSA centres, n	6	4	2
External centres, n	1	0	0
Age, mean ± SD	56.17 ± 10.42	55.51 ± 10.57	57.40 ± 10.33
Female sex, n (%)	97 (94.2)	71 (92.2)	23 (92.0)

[1] REDOCVR research cohort eligible for post-intervention assessment. [2] REDOCVR-AC intervention clinical subgroup. [3] REDOCVR-AC non-randomised reference cohort. *Note.* External research groups initiated in 2026 were excluded from outcome analyses because they were ongoing at the cut-off. REDOCVR-AC refers to the complementary medication tapering protocol implemented where collaborating family physicians were available. The non-randomised reference cohort is shown only as a contextual comparator.

Table 2 Planned REDOCVR application redesign features addressing operational barriers identified in professional discussion groups

Operational barrier	Software redesign feature
Fragmentation across multiple applications	Single mixed-reality main menu with two main blocks: exercises and emotional regulation
Difficulty locating content during sessions	Unified gym scene with exercise prefabs organised within an *ExerciseContainer*
Need for manual recentring	Automatic recentring of menus, exercises and emotional regulation scenes
Unreliable hand-attached menus	Wrist-button interface replacing the hand-attached poke menu
Setup time and logistical complexity	Simplified navigation, clearer content organisation and reduced interaction demands
Limited professional autonomy due to dependence on technical support	Reduced configuration steps, clearer module access and simplified session start-up

Note. The unified REDOCVR application redesign was planned from professional feedback and was not evaluated as an implemented intervention in this study.

remained favourable. Overall satisfaction was high (mean 81.70, SD 12.81), and content usability showed a similar profile (mean 82.32, SD 15.91). Headset comfort and tolerability scores were lower and more variable (mean 72.44, SD 22.30), as summarised in Table 3.

At item level, the highest satisfaction ratings were observed for support and guidance during VR sessions (mean 92.48, SD 14.78), visual and image quality (mean 89.81, SD 13.75), and ease of interaction (mean 88.35, SD 15.97). Lower ratings were observed for perceived improvement in concentration and pain management (mean 68.45, SD 24.99), intention to continue using VR (mean 74.03, SD 25.47), and adequacy of session duration (mean 75.24, SD 24.88).

Professional usability was moderate to favourable (mean SUS 68.75, SD 11.35). Professional workflow indicators showed greater variability, with ease of integration into daily care practice scoring 65.91 (SD 37.54) and reverse-coded learning effort scoring 59.09 (SD 30.15), where higher values indicate lower perceived learning burden. Full item-level results for patient-reported content usability, headset comfort and tolerability, satisfaction, and professional usability and workflow indicators are provided in Supplementary Material S2.

3.5 External familiarisation and MCDA-XR readiness appraisal

External scale-out followed a staged pathway from experiential familiarisation to structured readiness appraisal. CAP Dr Sarro, Valls, contributed to formative refinement of the external pathway, while CAP Lloret provided the first prospective MCDA-XR application during Phase 3.

Table 3 Feasibility, usability and workflow indicators

Domain	Indicator	Sample	Score, mean ± SD
Patient-reported feasibility	Overall satisfaction	$n = 103$	81.70 ± 12.81
Patient-reported feasibility	Content usability	$n = 103$	82.32 ± 15.91
Patient-reported feasibility	Headset comfort and tolerability	$n = 103$	72.44 ± 22.30
Professional usability	SUS total score	$n = 11$	68.75 ± 11.35
Professional workflow	Ease of integration into daily care practice	$n = 11$	65.91 ± 37.54
Professional workflow	Learning effort required[1]	$n = 11$	59.09 ± 30.15

[1] Reverse-coded item, with higher values indicating lower perceived learning burden. *Note.* Scores are reported on a 0–100 scale, with higher values indicating more favourable ratings. Full item-level results are provided in Supplementary Material S2.

At CAP Dr Sarro, three professionals participated in demonstration, direct testing and post-demonstration appraisal. XR was perceived as complementary to chronic pain group work, with training, technical support and logistics identified as relevant implementation conditions. This case was not treated as a formal MCDA-XR matrix application.

At CAP Lloret, MCDA-XR was prospectively applied after experiential familiarisation with eight XR-naïve professionals. The importance-readiness profile showed high perceived strategic value and organisational readiness across most criteria. Nine of the ten criteria were classified as ready for implementation, while resources and costs required monitoring during early deployment.

3.6 Clinical continuity indicators

Clinical and medication-related outcomes were interpreted as contextual indicators, not as primary effectiveness endpoints. Among the 103 participants with completed post-intervention assessments, patient-reported outcomes showed favourable pre-post changes in emotional well-being, anxiety, depression, central sensitisation and the exploratory EQ-5D-5L score, as summarised in Table 4.

Medication follow-up in the REDOCVR-AC cohort suggested a more consistent descriptive dose-reduction pattern than in the non-randomised reference group, particularly for analgesics, benzodiazepines and opioids, when physician-supervised tapering was available. These findings should not be interpreted as causal evidence of clinical or deprescribing effectiveness. Full clinical and medication-related indicators are provided in Supplementary Material S3.

4 Discussion

4.1 Principal finding

This study examined how an XR-enhanced chronic pain programme moved from pilot implementation toward routine service delivery. Real-world use showed that scalability was constrained mainly by workflow integration, device logistics and technical usability, rather than by clinical content or patient acceptance. These constraints mapped onto key implementation outcomes, including feasibility, acceptability and sustainability (Proctor et al. 2011), and informed both software redesign and a more selective delivery model.

Moving from pilot to practice required more than demonstrating feasibility. It required adaptive optimisation informed by professional experience, organisational learning and structured readiness appraisal when expanding to new settings.

4.2 From research-led feasibility to workflow-aligned adoption

The initial feasibility study reported high patient satisfaction, strong usability and favourable clinical outcomes (Ferrer Costa et al. 2025b). However, feasibility under research conditions with innovation team support did not guarantee scalability. As the programme expanded and professionals assumed greater operational responsibility, barriers emerged that had been less visible during the early phases: fragmentation across applications, unreliable interaction methods, manual recentring

Table 4 Contextual clinical outcome indicators

Indicator	Sample	Pre mean	Post mean	paired t-test p value
Emotional well-being, WEMWBS-7	$n = 103$	16.23	21.01	$< .001$
Anxiety, HADS-A	$n = 103$	13.13	11.07	$< .001$
Depression, HADS-D	$n = 103$	11.52	9.76	$< .001$
Central sensitisation, CSI	$n = 103$	64.83	60.86	$< .001$
EQ-5D-5L total exploratory score	$n = 103$	14.22	13.36	0.004

Note. Positive change indicates improvement for WEMWBS-7. Negative change indicates improvement for HADS-A, HADS-D, CSI and the EQ-5D-5L total exploratory score. Full indicators are provided in Supplementary Material S3.

and dependence on technical support. These challenges align with broader deployment difficulties described in clinical XR implementation, where technical interoperability and workflow integration often become primary constraints (Morgan et al. 2025).

This pattern is consistent with implementation research showing that early perceived value does not ensure adoption when technological and organisational demands exceed available capacity (Greenhalgh et al. 2017). The response involved both software redesign to reduce technical burden and session model refinement to concentrate XR where it was therapeutically relevant and organisationally feasible. As noted in the earlier study, session optimisation was already under consideration. Structured professional feedback helped consolidate the final model of four XR-supported sessions, rather than broader distribution across the programme (Ferrer Costa et al. 2025b).

The four-session model provided a practical response to the logistical burden of headset use in larger groups by concentrating XR where it added therapeutic value, reducing preparation time and making innovation-team support easier to plan.

4.3 Professional experience as an optimisation mechanism

Professional discussion groups translated accumulated field experience into actionable redesign requirements. Rather than applying generic usability frameworks prospectively, the process elicited insights from clinicians who had delivered REDOCVR under real-world conditions. Thematic analysis distinguished between limited clinical-content issues and workflow barriers that were central to feasibility, acceptability and adoption (Proctor et al. 2011).

This approach treated usability as a dynamic process shaped by repeated exposure, rather than as a static property assessed at a single timepoint, consistent with implementation frameworks that emphasise contextual determinants (Damschroder et al. 2009). The resulting requirements were grounded in group-based primary care practice, addressed recurrent gaps described in VR implementation literature (Elser et al. 2024; Kouijzer et al. 2023) and directly informed the planned unified architecture, automatic recentring and simplified interaction model.

4.4 Experiential familiarisation and readiness appraisal

External scale-out incorporated experiential familiarisation before readiness appraisal, building on the experience gap concept (Ferrer Costa and Armayones Ruiz 2026) and the MCDA-XR readiness framework (Ferrer Costa et al. 2025a). The Valls formative case and the CAP Lloret appraisal suggested that similar concerns emerged across settings: perceived value for patient engagement, alongside logistical and technical demands. In CAP Lloret, MCDA-XR indicated high perceived strategic value and organisational readiness across most criteria, while resources and costs required monitoring during early deployment.

The transition from hands-on exposure to MCDA-XR appraisal offers a practical response to a common weakness in XR adoption: asking stakeholders to assess technologies they have not meaningfully experienced. Brief exposure helped ground judgements about comfort, usability, spatial requirements and perceived disruption before

these were translated into implementation signals distinguishing strategic priorities, organisational readiness and gaps requiring action before scale-out. These findings suggest that some workflow challenges may be intrinsic to integrating XR into group-based primary care, although the external pathway remains exploratory and requires validation across more diverse organisational contexts.

4.5 Clinical continuity in context

Clinical and medication-related outcomes were treated as contextual indicators, not as effectiveness measures. The favourable clinical pattern observed in the expanded cohort was consistent with earlier phases (Ferrer Costa et al. 2025b), suggesting that scale-out did not visibly disrupt the expected clinical response. Medication follow-up also suggested that supervised tapering could be embedded in selected REDOCVR-AC groups when family physicians participated, supporting compatibility with pharmacological review and broader multidisciplinary workflows in primary care. These findings remain descriptive and cannot be attributed to REDOCVR alone.

4.6 Limitations

The findings should be interpreted in light of several limitations. First, the study was conducted within a single healthcare organisation with established chronic pain groups and institutional innovation support, which may limit transferability to settings without comparable resources. External scale-out was restricted to two sites within the same regional health system.

Second, the professional discussion groups included all psychologists and physiotherapists directly involved in REDOCVR delivery during the study period, but they still represent a limited implementation cohort already familiar with the programme. Perspectives from external professionals and potential non-adopters were therefore less represented. The qualitative synthesis was conducted by the principal investigator without independent dual coding, consistent with its formative implementation purpose but limiting methodological depth.

Third, the software redesign was analysed as a planned operational response and was not evaluated as an implemented intervention. Fourth, the long-term maintenance model for XR was not formally assessed. Sustained use will require clear allocation of responsibilities between clinical services, the institutional innovation team and technical partners for device management, software updates, troubleshooting, asset replacement and content maintenance.

Finally, clinical and medication-related outcomes were descriptive, non-randomised and limited by short follow-up, which precludes causal interpretation and assessment of long-term sustainability. The predominantly female sample reflects chronic pain epidemiology but limits generalisability to male patients.

4.7 Implications and future directions

Feasibility under research conditions does not ensure scale-up, spread or sustainability, which require attention to organisational complexity and implementation outcomes beyond clinical response (Proctor et al. 2011; Greenhalgh et al. 2017). Expansion depends on professional autonomy, workflow alignment and technical simplification informed by accumulated experience, rather than on pre-implementation assessment alone.

Experiential familiarisation before readiness appraisal may improve the quality of stakeholder judgements for immersive technologies. Generic implementation frameworks may not fully capture technology-specific workflow demands. In this context, hands-on exposure can ground readiness assessments in direct experience, particularly for aspects such as headset comfort, spatial requirements, usability and perceived disruption.

The REDOCVR experience also suggests that sustained XR adoption requires an explicit institutional support model. Clinical teams are essential for delivery and therapeutic integration, but they should not carry the full burden of device management, software updates, troubleshooting and asset maintenance. In BSA, the innovation team acted as a bridging structure between clinical practice and technical implementation, supporting project management, hardware logistics, professional training and coordination with technical partners. This hybrid clinical and technical support may be a decisive factor for long-term adoption in hospitals and healthcare organisations,

particularly when XR projects move beyond isolated pilots and become part of routine service activity.

Future work should evaluate the implemented content redesign, examining whether the unified architecture resolves workflow barriers and supports professional autonomy. Longer-term follow-up is needed to assess clinical sustainability beyond early implementation. Expansion to settings without existing programmes or innovation support would clarify transferability. Controlled evaluation of MCDA-XR across diverse contexts would strengthen its validity as an implementation-planning tool.

5 Conclusion

This implementation case study examined the transition of an XR-enhanced chronic pain programme from pilot feasibility toward routine primary care delivery. Real-world use showed that scalability was constrained mainly by workflow integration, device logistics and technical usability, rather than by clinical content or patient acceptance. Professional feedback translated accumulated experience into software redesign requirements and a more selective session model, moving REDOCVR toward a more workable routine practice model.

External scale-out incorporated experiential familiarisation before readiness appraisal, addressing the experience gap that arises when professionals are asked to assess immersive technologies without prior exposure. Clinical and medication-related outcomes showed favourable patterns across the expanded cohort, but should be interpreted as contextual indicators rather than evidence of effectiveness.

Moving XR-supported interventions from pilot to practice requires professional autonomy, workflow alignment and technical simplification informed by real-world operational experience. Future work should evaluate the implemented unified REDOCVR application redesign, assess longer-term sustainability and test transferability to settings without existing innovation infrastructure.

Supplementary information. Supplementary Material S1 includes the professional coding framework and cross-professional thematic matrix. Supplementary Material S2 provides item-level feasibility, usability, tolerability, satisfaction and workflow results. Supplementary Material S3 provides contextual clinical and medication-related indicators, including effect sizes and medication follow-up data.

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Declarations

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- Competing interests
  JFC is employed by Badalona Serveis Assistencials, serves as principal investigator for REDOCVR implementation and contributed to REDOCVR conceptualisation, development and planned redesign. The authors declare no other competing interests.
- Ethics approval and consent to participate
  The study was approved by the IDIAP Jordi Gol Research Ethics Committee (24/047-P and 24/211-ACps), conducted in accordance with the Declaration of Helsinki and registered at ClinicalTrials.gov (NCT06361706 and NCT06964360). All participants provided written informed consent.
- Data availability
  Data are not publicly available due to GDPR-related restrictions, but may be requested from the corresponding author subject to institutional approval and data-sharing agreements.
- Code availability
  No custom analytical code was generated. Analyses used standard statistical and data management tools, including Numiqo.
- Use of AI tools

Whisper and Gemini supported transcription and transcript verification. All transcripts were checked against the original recordings by the principal investigator. Final figures, analyses, interpretations and manuscript content were produced and validated by the authors.

- Author contributions
  JFC: conceptualisation, methodology, formal analysis, investigation, data curation, original draft, visualisation, project administration, institutional coordination and funding acquisition. PB: conceptualisation, methodology, supervision, review and editing. XB: supervision, institutional coordination, review and editing. All authors read and approved the final manuscript.

References

Damschroder LJ, Aron DC, Keith RE, et al (2009) Fostering implementation of health services research findings into practice: a consolidated framework for advancing implementation science. Implement Sci 4:50. https://doi.org/10.1186/1748-5908-4-50

Elser A, Lange M, Kopkow C, et al (2024) Barriers and facilitators to the implementation of virtual reality interventions for people with chronic pain: scoping review. JMIR XR Spat Comput 1:e53129. https://doi.org/10.2196/53129

Ferrer Costa J, Armayones Ruiz M (2026) Enhancing the predictive value of formative evaluation in XR adoption: addressing the experience gap. JMIR Form Res 10:e93029. https://doi.org/10.2196/93029

Ferrer Costa J, Armayones Ruiz M, Bourdin-Kreitz P (2025a) Evidence-based strategic planning for XR: development and construction of the MCDA-XR governance framework. https://doi.org/10.2196/preprints.89801, preprint at https://preprints.jmir.org/preprint/89801

Ferrer Costa J, Fernandez Brusco A, Torrecillas Camacho C, et al (2025b) Integrating extended reality into primary care chronic pain programs via the REDOCVR intervention: real-world implementation feasibility and usability study. JMIR XR Spat Comput 2:e82858. https://doi.org/10.2196/82858

Greenhalgh T, Wherton J, Papoutsi C, et al (2017) Beyond adoption: a new framework for theorizing and evaluating nonadoption, abandonment, and challenges to the scale-up, spread, and sustainability of health and care technologies. J Med Internet Res 19(11):e367. https://doi.org/10.2196/jmir.8775

Iqbal AI, Aamir A, Hammad A, et al (2024) Immersive technologies in healthcare: an in-depth exploration of virtual reality and augmented reality in enhancing patient care, medical education, and training paradigms. J Prim Care Community Health 15:21501319241293311. https://doi.org/10.1177/21501319241293311

Kouijzer MMTE, Kip H, Bouman YHA, et al (2023) Implementation of virtual reality in healthcare: a scoping review on the implementation process of virtual reality in various healthcare settings. Implement Sci Commun 4:67. https://doi.org/10.1186/s43058-023-00442-2

Morgan JW, Patel RA, Campbell S (2025) Practical considerations of clinical XR (AR/VR) deployments. Front Virtual Real 6:1517402. https://doi.org/10.3389/frvir.2025.1517402

Proctor E, Silmere H, Raghavan R, et al (2011) Outcomes for implementation research: conceptual distinctions, measurement challenges, and research agenda. Adm Policy Ment Health 38(2):65–76. https://doi.org/10.1007/s10488-010-0319-7

Spiegel BMR, Rizzo A, Persky S, et al (2024) What is medical extended reality? A taxonomy defining the current breadth and depth of an evolving field. J Med Ext Real 1(1):4–12. https://doi.org/10.1089/jmxr.2023.0012

Zuo G, Wang R, Wan C, et al (2024) Unveiling the evolution of virtual reality in medicine: a bibliometric analysis of research hotspots and trends over the past 12 years. Healthcare 12(13):1266. https://doi.org/10.3390/healthcare12131266

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