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Acceptance and Commitment Therapy in Chronic Low Back Pain and Comorbid Depression: A Single-Case Study with Idiographic Network Analysis

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Abstract
This study analyzed the efficacy of acceptance and commitment therapy (ACT) in six individuals with chronic low back pain plus depressive symptoms using an idiographic approach within a randomized controlled trial. Daily ecological momentary assessments (EMA) and full assessments at baseline, posttreatment, and follow-up were collected. Outcomes included pain interference, pain intensity, and depressed mood, and the process variable was psychological inflexibility. Analyses involved visual inspection, non-overlap of all pairs, Tau, Tau-U, and idiographic network analysis. Moderate improvements were observed in pain interference (5/6), depressed mood (5/6), and psychological inflexibility (3/6), with limited change in pain intensity (1/6). Most participants (4/6) reported an overall relevant improvement. Idiographic networks showed considerable variability across participants, with psychological inflexibility and depressed mood playing a central role. Findings suggest ACT may help reduce pain interference and depressed mood, highlighting the need for personalized approaches and the continued use of single-case methods combined with EMA.

Keywords Chronic pain · Acceptance and commitment therapy · Single-case analysis · Network analysis · Idiographic approach · Ecological momentary assessment

Introduction

Chronic pain affects millions of individuals worldwide and is one of the leading causes of disability, significantly impairing quality of life (James et al., 2018). To address this burden, increasing attention has been directed toward psychological

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processes and functional outcomes relevant to adaptation to chronic pain (Fang & Ding, 2022). Among these, psychological flexibility—with pain acceptance as a core dimension—has emerged as a key process, while pain interference represents an important functional outcome; together, these constructs are primary clinical targets in chronic pain interventions (McCracken et al., 2022). Within this framework, psychological flexibility denotes the ability to face unwanted experiences openly and act according to personal values (McCracken, 2024); pain acceptance reflects the willingness to experience pain without attempting to control or avoid it, while engaging in meaningful activities (Chen et al., 2025); and pain interference describes the extent to which pain disrupts functioning (Karayannis et al., 2017).

Cognitive behavioral therapy (CBT) is widely recognized as the gold-standard psychological intervention for chronic pain (Day & Thorn, 2022). Extensive research has demonstrated CBT's effectiveness across various chronic pain populations (Williams et al., 2020), showing significant benefits in improving the quality of life (Ma et al., 2023), functional capacity (Yang et al., 2022), pain acceptance (Trindade et al., 2021), and psychological flexibility (Hughes et al., 2017), while also reducing pain intensity (Rosser et al., 2023), pain interference (Veehof et al., 2016), anxiety (Gandy et al., 2022), and depression (Lai et al., 2023).

Acceptance and commitment therapy (ACT) is a CBT-based approach that has gained increasing attention for its effectiveness in chronic pain management (McCracken et al., 2022). This therapy emphasizes contextual, experiential change strategies that foster flexible, value-driven behaviors (S. G. Hofmann & Hayes, 2018). ACT promotes holistic well-being by guiding individuals toward meaningful actions while considering the function and context of psychological experiences (McCracken, 2023). Empirical evidence supports its effectiveness in chronic pain populations (Lai et al., 2023). A recent umbrella review synthesizing meta-analytic findings concludes that ACT significantly reduces depressive and anxiety symptoms, decreases pain catastrophizing, and enhances pain acceptance and psychological flexibility (Martinez-Calderon et al., 2024).

Despite promising evidence, most ACT studies on chronic pain have adopted a nomothetic analytic approach, based on pooled data and average effects. This type of analysis limits the understanding of its clinical impact and its mechanisms of change from an idiographic approach (Ciarrochi et al., 2024). In this context, the emerging paradigm of process-based therapies (Ong et al., 2025) has begun to impact chronic pain research by highlighting the need for more personalized approaches. A high level of between-person variability in treatment response has been increasingly recognized, underscoring the importance of methodological approaches that account for individual differences (McCracken, 2023). Consequently, idiographic longitudinal analyses seem to be needed to tailor psychological therapies to particular people (Moskow et al., 2023; Scholten & Glombiewski, 2025).

One approach is to investigate the progress of participants during randomized controlled trials (RCTs) by examining a subset of individuals using a single-case experimental design (SCED) approach (Kratochwill et al., 2014) alongside idiographic network analysis of longitudinal assessments. SCEDs have long had an important role in evidence-based therapy (Tanious & Onghena, 2021), and idiographic networks are emerging as a key tool for understanding personalized

therapeutic mechanisms and can provide insights into which intervention components drive meaningful change (Burger et al., 2024; Ong et al., 2025). By including these two approaches in well-crafted RCTs, a new empirically grounded route to personalization opens up.

The IMPACT study evaluated the efficacy and cost-effectiveness of adding a videoconference group-based ACT or Behavioral Activation Treatment for Depression (BATD) to treatment-as-usual (TAU) for individuals with chronic low back pain (CLBP) plus clinically relevant depressive symptoms (Sanabria-Mazo et al., 2023a, b, 2024a, b). It provides a good foundation to examine this new methodological extension of RCTs. At the normative level, both therapies significantly improved pain interference, pain catastrophizing, behavioral activation, and psychological flexibility at posttreatment and follow-up, compared to TAU, with 65% of ACT and 45% of BATD participants showing clinically meaningful improvements (Sanabria-Mazo et al., 2023a, b). Both therapies were cost-effective, although not differentially so (Sanabria-Mazo et al., 2024a, b). There was, however, substantial heterogeneity in the relationships between outcomes, such as pain intensity and depressed mood, and the process variables (Sanabria-Mazo et al., 2024b).

The present study examined the progress of a small subset of participants ($n=6$) using both visual and statistical examination of the SCED data and individual network analysis that explored how core psychological variables (pain intensity, pain interference, depressed mood, and psychological inflexibility) interacted for each individual in the study. Building on previous findings, it was hypothesized that remotely delivered ACT would yield significant improvements in pain interference, pain intensity, and depressed mood, as well as a reduction in psychological inflexibility compared to a no-treatment baseline period. It was also anticipated that idiographic network analysis would reveal high variability across individuals for the processes of change relevant to these outcomes.

Method

Study Design

A single-case study was embedded within a 12-month, multicenter, single-blind RCT (NCT04140838), which included three study arms: ACT, BATD, and TAU. The analysis comprised four distinct phases, baseline (phase A), treatment (phase B), posttreatment (phase C), and 12-month follow-up (phase D), with daily ecological momentary assessments (EMA) collected during phases A, B, and C and full-length assessments during phases A, C, and D. This study adheres to The Single-Case Reporting guideline In BEhavioural interventions (SCRIBE; Tate et al., 2016). The RCT was approved by the Ethics Committee of the Fundació Sant Joan de Déu (PIC-178-19) and the Hospital del Mar (2019/8866/I). Recruitment and study procedures were carried out between October 2020 and July 2021. All participants provided written informed consent before their inclusion in the study. Detailed methodological information is available elsewhere (Sanabria-Mazo et al., 2020, 2023a, b; Sanabria-Mazo, Giné-Vázquez, et al., 2024b).

Participants

Participants were recruited from the Pain Unit of the Parc Sanitari Sant Joan de Déu (Sant Boi de Llobregat, Spain) and Hospital del Mar (Barcelona, Spain). A total of 234 participants were recruited in the original RCT between September 2020 and May 2021 (Sanabria-Mazo et al., 2023a, b). Inclusion criteria include (1) adults aged 18 to 70 years and (2) a diagnosis of CLBP lasting more than 3 months (as documented in medical history), along with depressive symptoms defined as a score of ≥ 10 on the Patient Health Questionnaire-9 (Spitzer et al., 1999). Exclusion criteria were (1) cognitive impairment noted in medical history, (2) prior psychological therapy within the past 12 months, (3) severe psychiatric disorder or substance dependence/abuse, (4) radiculopathy, (5) involvement in litigation with the healthcare system, and (6) a scheduled surgical intervention or inability to attend group sessions.

For the present idiographic analysis, a subgroup of participants was selected from the original RCT who received ACT and provided EMA and standard full-length measures data. Of 23 potentially eligible participants (see Sanabria-Mazo, Giné-Vázquez, et al., 2024b), 17 were excluded for failing to provide at least 80% of EMA responses for each of the four variables analyzed (i.e., a minimum of 56 out of 70 responses per variable) or for not supplying posttreatment and follow-up data on standard full-length measures. The response criterion was established to ensure sufficient data density to capture consistent and reliable patterns in idiographic analyses. Therefore, the final sample comprised six participants.

Intervention

ACT was delivered in a remote, synchronous format, with groups of seven to 13 participants. The intervention comprised eight 1.5-h sessions over approximately 8 weeks. Three therapists, each assigned to two of the six groups, conducted the sessions. These therapists completed 3 h of training to ensure protocol fidelity and intervention consistency. In addition, throughout the intervention, the therapists received technical support from research assistants during each session. After the first session, participants received a document with a homework document designed to reinforce key therapy concepts. The ACT content adhered to the protocol by Vowles and Sorrell (2007). A session-by-session outline is available in Sanabria-Mazo et al. (2023a, b).

Procedure

Before the clinical interview, participants were informed about the study's objective and provided with confidentiality agreements. In addition to completing standard full-length measures, they installed the Pain Monitor app (Suso-Ribera

et al., 2018) on their phones and received detailed instructions for completing their daily measures.

Standard full-length measures data were collected at baseline (phase A), post-treatment (2 months after baseline; phase C), and follow-up (12 months after baseline; phase D). Daily measures were collected twice a day via EMA over a 70-day period: 7 days (week 1) for baseline (phase A), 56 days (weeks 2 to 9) for treatment (phase B), and 7 days (week 10) for posttreatment (phase C).

For the daily measures, push notifications reminded participants to complete items in the morning (between 8 a.m. and 10 a.m.) and in the evening (between 7 p.m. and 9 p.m.), with a 2-h response window. The item sequence remained consistent across all administrations, with an average time to complete each administration of under 2 min. An automated notification system monitored participant responses throughout the intervention, offering technical support as needed.

Diary Measures

The daily measures assessed in the IMPACT study consisted of 21 items. Of these, nine items were relevant to the objectives of this work and are analyzed here. The outcomes (pain interference, pain intensity, and depressed mood) and the process variable of psychological inflexibility collected daily through EMA are described in detail in Supplementary Table 1. These variables were selected based on their theoretical and empirical relevance in the literature on ACT and chronic pain. EMA data were assessed daily for 10 weeks using Pain Monitor: baseline (phase A), treatment (phase B), and posttreatment (phase C). The reliability of the EMA measures was assessed using the R_kf coefficient, with values ranging from 0.98 to 0.99 (see Supplementary Table 2).

Pain-Related Outcomes

Three single ad hoc items were used to measure pain interference, pain intensity, and depressed mood. Specifically, pain intensity was assessed with the item "*What intensity of pain are you feeling right now?*", pain interference with "*How much has the pain interfered with your activities today?*", and depressed mood with "*What intensity of depressed mood are you feeling right now?*". Pain interference was collected in the evening, while pain intensity and depressed mood were measured both in the morning and evening. The data for pain intensity and depressed mood were averaged to obtain a daily response per participant. If one of the two daily assessments was missing, the available value was used; if both were missing, the value for that day was recorded as missing. All items were rated on a 0–10 scale, with higher values indicating worse pain-related outcomes.

Process Variable

Six single items from the *Multidimensional Psychological Flexibility Inventory (MPFI)* (Rolffs et al., 2018) were used to measure psychological inflexibility based

on the Hexaflex model proposed by Hayes et al. (2011): (1) experiential avoidance, (2) lack of contact with the present moment, (3) self as content, (4) fusion, (5) lack of contact with values, and (6) inaction. Specifically, the item with the highest factor loading within each corresponding MPFI-12 dimension was selected. The total scores ranged from 0 to 24, with higher scores reflecting greater psychological inflexibility. For visualization purposes, the score range (from 0 to 24) was linearly transformed to a scale of 0 to 10.

Standard Full-Length Measures

During the initial interview, participants completed a questionnaire collecting sociodemographic information (gender, age, marital status, living arrangement, educational level, and employment status) and clinical characteristics (years since diagnosis and current episode of depression). The *Composite International Diagnostic Interview* (CIDI) (Wittchen, 1994) was used to diagnose a current episode of major depression.

The standard full-length measures assessed in the IMPACT study consisted of 17 questionnaires. Six of them were relevant to the objectives of this work and are analyzed here. Selected outcomes include pain interference, pain intensity, and depressed mood as clinical variables and psychological inflexibility as a process variable—all conceptually aligned with those assessed through EMA. These measures were collected at baseline, posttreatment, and 12-month follow-up, while subjective improvement variables (perceived change and treatment-related adverse effects) were assessed only after treatment. All these variables were recorded using the Research Electronic Data Capture (REDCap) software.

Pain-Related Outcomes

The *Brief Pain Inventory-Interference Scale* (BPI-IS) was used to measure pain interference (de Andrés Ares et al., 2015), the *Numerical Rating Scale (NRS)* for pain intensity, and the *Depression Anxiety Stress Scales-21 (DASS-21)* for depressive symptoms over the past week (Bados-López et al., 2005). The BPI-IS and NRS are reported on a scale of 0 to 10, and the DASS-21 for depression on a scale of 0 to 21, with higher values indicating worse pain-related outcomes. These questionnaires showed a Cronbach's alpha ranging from 0.70 to 0.92 in the RCT. More information about the characteristics of these questionnaires is available elsewhere (Sanabria-Mazo et al., 2023a, b).

Process Variable

The *Psychological Inflexibility in Pain Scale* (PIPS) was used to measure psychological inflexibility toward pain (Rodero et al., 2013). The PIPS is reported on a scale of 12 to 84, with higher scores indicating greater psychological inflexibility in pain. This questionnaire showed a Cronbach's alpha of 0.90 in the RCT. More information

about the characteristics of this questionnaire is available elsewhere (Sanabria-Mazo et al., 2023a, b).

Subjective Improvement

The *Patient Global Impression of Change* (PGIC) was used to measure the impression of change. The PGIC consists of a single item measuring the perception of global improvement. This questionnaire was answered on a scale from 1 ("much better") to 7 ("much worse"), with higher scores indicating a greater perception of worsening. In addition, an ad hoc measure of *Adverse Effects of Treatment* was used to check the presence of negative effects of ACT (Sanabria-Mazo et al., 2020). This item was as follows: *Have you experienced, during the psychological treatment, any unwanted symptom that you think might be directly or indirectly associated with the psychological intervention?*

Statistical Analyses

Analysis of Diary Measures

Daily data were utilized to generate visual representations and perform statistical analyses (Chisari et al., 2022). Visual representations of daily outcomes (pain interference, pain intensity, and depressed mood) and the process variable of psychological inflexibility were created to graphically represent data from baseline (A), treatment (B), and posttreatment (C) phases for each participant. This approach facilitated the calculation and visualization of mean levels and idiographic trends. Missing data in daily measures were imputed using the Last Observation Carried Forward (LOCF) method, where the most recent prior value was used to fill in gaps, although the limitations of this method were acknowledged.

Statistical analyses included the calculation of effect sizes using non-overlap of all pairs (NAP), Tau, and Tau-U, implemented through the "SCD-effect-sizes" tool (Pustejovsky et al., 2024). NAP, a non-parametric coefficient, compared each measurement point in phase A with those in phases B and C to determine overlap, resulting in a percentage of non-overlapping data. NAP values were interpreted as follows (Parker & Vannest, 2009): below 0.50 indicates no improvement, 0.50–0.65 suggests small improvement, 0.66–0.84 reflects moderate improvement, and 0.85–1 denotes large improvement.

Tau, another non-parametric rank correlation coefficient, was employed to evaluate the relationship between scores and phases (A vs. B and A vs. C). When a baseline trend toward improvement was detected, Tau-U, an extension of Tau, was applied to adjust for these trends, enhancing its reliability. Tau-U, an extension of Tau, was applied to adjust for undesirable baseline trends, enhancing its reliability. Tau values were interpreted based on the following criteria (Vannest & Ninci, 2015): below 0.15 indicates minimal or no change, 0.15–0.20 indicates small change, 0.21–0.60 represents moderate change, 0.61–0.80 suggests large change, and above

0.80 reflects very large change. Additionally, 95% confidence intervals (CIs) were calculated to assess the precision of effect sizes.

Analysis of the Standard Full-Length Measures

The percentage change in the full-length pain-related outcomes (pain interference, pain intensity, and depressive symptoms) and the process variable of psychological inflexibility were calculated for each participant from baseline (phase A) to post-treatment (phase C), as well as from baseline (phase A) to follow-up (phase D). A reduction exceeding 20% was considered clinically relevant, consistent with prior research identifying this threshold as indicative of a minimally important difference in chronic pain outcomes (Dworkin et al., 2008).

Network Analysis

Network analyses examined temporal relationships among variables in three consecutive phases (Ciarrochi et al., 2024). Initially, an Integrated Autoregressive Integrated Moving Average with Exogenous Variables (i-ARIMAX) model was used to examine the relationships between the process variable of psychological inflexibility and pain-related outcomes (pain interference, pain intensity, and depressed mood) across two time periods: the first half (35 days) of the time series (encompassing pre-treatment and part of treatment) and the second half (35 days) of the time series (encompassing the second half of treatment and posttreatment). In this phase, external regressors (XREG) were incorporated as the predictor for the dependent variables (pain-related outcomes). Subsequently, a Bayesian mixed-effects model was implemented using the *brms package* in R to evaluate the effects of the pain-related variables (pain interference, pain intensity, and depressed mood), time periods (first 35 days vs. last 35 days), and their interaction, including a random intercept for each participant.

Finally, a network analysis was conducted using the Group Iterative Multiple Model Estimation (GIMME) framework with the *rGIMME package* in R to explore both group-level and individual-level dynamics of the variables over time, incorporating autoregressive effects and standardizing the variables for comparability.

Results

Participant Characteristics

The study sample consisted of five women and one man, with a mean age of 58.5 years ($SD = 6.4$; range, 49–66 years) and a mean time since diagnosis of 9.5 years ($SD = 8.8$). Four participants (66.7%) were married and had completed secondary or university studies. Two participants (33.3%) were unemployed, while the rest were either retired or on sick leave. Four participants (66.7%) had a diagnosis of depression, attended all therapy sessions, and were considered

completers (i.e., attended six out of eight therapy sessions). Additionally, five participants (83.3%) were classified as responders (i.e., reported a one-point reduction or more in the pre-post BPI-IS total score). A summary of the participants' sociodemographic characteristics is provided in Table 1.

Completion Rate of Daily Measures and Standard Full-Length Measures

As per the inclusion criteria, participants were required to complete at least 80% of EMA assessments. Consequently, the sample selected for analysis demonstrated high response rates for daily measures. The imputation rates for missing daily measures were 10.9% for pain interference, 0% for pain intensity, 4.3% for depressed mood, and 14.5% for psychological inflexibility. Standard full-length measures were fully completed (100% response rate) across all participants throughout the study.

Visual and Statistical Analysis of Daily Measures

Figure 1 presents individual graphs for the six participants, displaying the plotted data for pain interference, pain intensity, depressed mood, and psychological inflexibility. Supplementary Figures 1 to 4 provide a more detailed visualization of each variable for every participant, including mean values and trends across the different phases.

Tables 2 and 3 show the NAP values, Tau, Tau-U values, and CIs around Tau for each participant's scores, comparing baseline–treatment (A–B) and baseline–posttreatment (A–C) phases.

Pain Interference

Baseline trends indicated improvement in *Participants 1* and *5*, while other participants exhibited fluctuating patterns. The majority showed a reduction in pain interference, with *Participants 2* and *6* showing significant improvements. *Participant 1* initially improved, but this improvement was not maintained and returned to baseline levels posttreatment. *Participants 3* and *5* exhibited slight improvements, while *Participant 4* experienced a slight worsening during treatment, which was not sustained posttreatment. Statistical analysis confirmed these trends. Significant improvements in NAP were observed for *Participants 1*, *2*, *3*, and *5*. In Tau, *Participants 1* and *2* demonstrated moderate and very large improvements, respectively; in contrast, *Participant 4* showed a large worsening. No significant changes were observed for the remaining participants. During posttreatment, *Participants 2*, *3*, *5*, and *6* demonstrated moderate to large improvements in NAP. For Tau, *Participants 2*, *5*, and *6* exhibited large to very large improvements, while no significant changes were observed in the other participants.

Table 1 Sociodemographic characteristics of the six participants

Participant	Gender	Age	Years of diagnosis	Depression diagnosis	Sessions attended	Marital status	Education level	Employment status	Completer	Responder
1	Female	54	2	Yes	5	Separated	Secondary studies	Unemployed	No	Yes
2	Female	60	5	Yes	8	Single	University	Paid employment	Yes	Yes
3	Female	66	25	Yes	8	Married	Primary studies	Retired	Yes	Yes
4	Male	49	17	Yes	7	Married	Primary studies	Unemployed	Yes	Yes
5	Female	64	5	No	8	Married	University	Sick leave	Yes	No
6	Female	58	3	No	8	Married	University	Paid employment	Yes	Yes

Completers were defined as those who attended at least six out of eight therapy sessions, and responders as those who showed a reduction of one point or more in the total BPI-IS (Brief Pain Inventory-Interference Scale) score from pre- to posttreatment

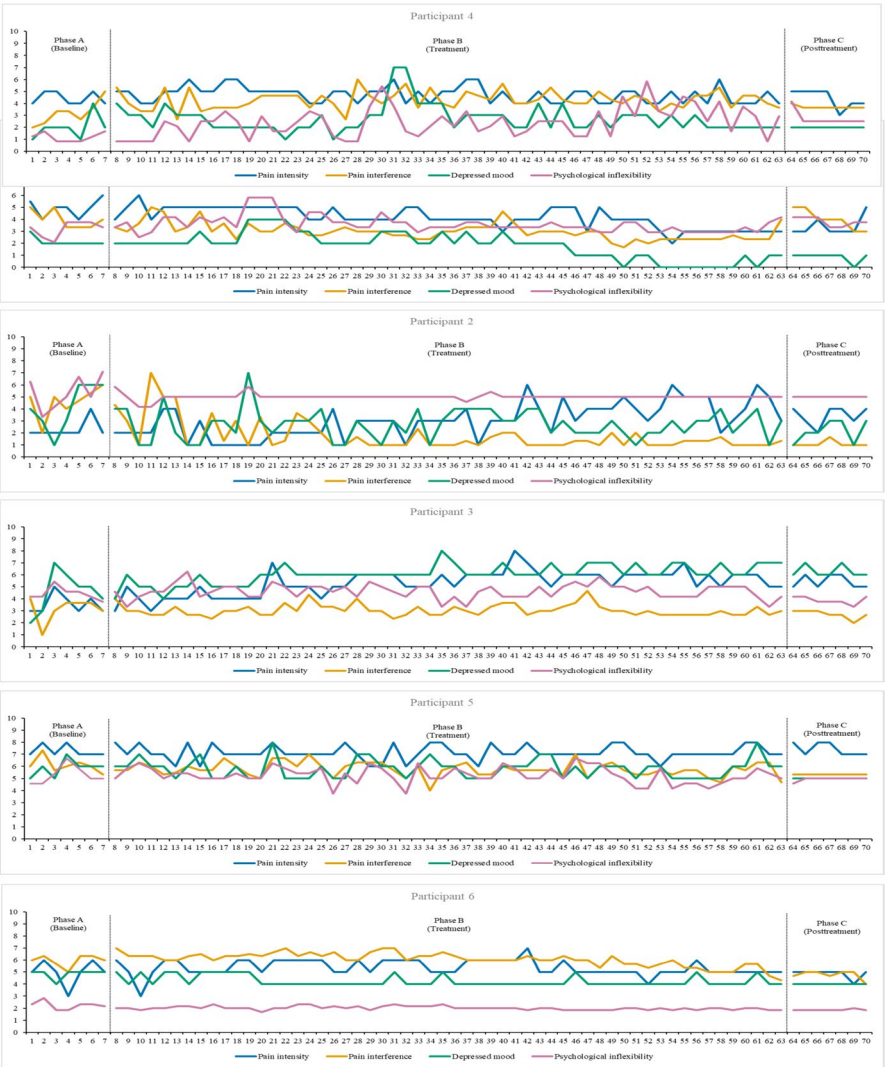

Fig. 1 Daily scores of outcomes (pain intensity, pain interference, and depressed mood) and process variable of psychological inflexibility across the 70 days: baseline (phase A), treatment (phase B), and posttreatment (phase C)

Pain Intensity

Participants 4 and *5* showed slight improvements at baseline. During treatment, most participants showed no significant changes in pain intensity, except for *Participant 3*, who experienced a worsening. In posttreatment, *Participant* 1 showed a decrease in pain intensity, while *Participants 2* and *3* showed an increase. No significant changes were observed in the remaining participants. Statistical analysis

Table 2 Tau, Tau-U, and NAP values of each participant's outcomes (pain intensity, pain interference, and depressed mood) and the process variable of psychological inflexibility from baseline (phase A) to treatment (phase B)

Participant	Pain interference			Pain intensity			Depressed mood			Psychological inflexibility		
	Tau	95% CI	NAP	Tau	95% CI	NAP	Tau	95% CI	NAP	Tau	95% CI	NAP
1	0.53 (0.51)	[0.07, 0.79]	0.76	0.50	[0.04, 0.77]	0.75	0.18 (0.16)	[−0.26, 0.55]	0.59	−0.17	[−0.54, 0.26]	0.41
2	0.86	[0.46, 0.96]	0.93	−0.34	[−0.67, 0.11]	0.33	0.45	[−0.01, 0.74]	0.72	0.15	[−0.29, 0.53]	0.57
3	0.31	[−0.15, 0.64]	0.65	−0.80	[−0.94, −0.39]	0.10	−0.56	[−0.81, −0.10]	0.22	−0.25 (−0.26)	[−0.60, 0.20]	0.38
4	−0.64	[−0.86, −0.19]	0.18	−0.23 (−0.24)	[−0.59, 0.21]	0.38	−0.42	[−0.72, 0.04]	0.29	−0.62	[−0.85, −0.18]	0.19
5	0.17 (0.15)	[−0.27, 0.54]	0.59	0.11 (0.10)	[−0.32, 0.49]	0.55	0.04	[−0.37, 0.44]	0.52	−0.05	[−0.45, 0.37]	0.48
6	−0.15	[−0.53, 0.29]	0.43	−0.19	[−0.56, 0.25]	0.40	0.61	[0.16, 0.84]	0.80	0.43 (0.42)	[−0.03, 0.72]	0.71

Scores in brackets represent Tau-U values; these were calculated due to baseline trend; below 0.15 = minimal or not change, 0.15–0.20 = small improvement, 0.21–0.60 = moderate improvement, 0.61–0.80 = large improvement, and above 0,80 = very large improvement; *CI*, confidence intervals; *NAP*, non-overlap of all pairs; below 0.50 = no improvement, 0.50–0.65 = small improvement, 0.66–0.84 = moderate improvement, and 0.85–1 = large improvement

Table 3 Tau, Tau-U, and NAP values of each participant's outcomes (pain intensity, pain interference, and depressed mood) and the process variable of psychological inflexibility from baseline (phase A) to posttreatment (phase C)

Participant	Pain interference			Pain intensity			Depressed mood			Psychological inflexibility		
	Tau	95% CI	NAP	Tau	95% CI	NAP	Tau	95% CI	NAP	Tau	95% CI	NAP
1	−0.10 (−0.27)	[−0.59, 0.45]	0.45	0.82	[0.21, 0.96]	0.91	1.00 (0.88)	[1.00, 1.00]	1.00	−0.55	[−0.85, 0.07]	0.22
2	0.98	[0.42, 1.00]	0.99	−0.67	[−0.91, −0.05]	0.16	0.63	[0.01, 0.89]	0.82	0.14	[−0.42, 0.62]	0.57
3	0.47	[−0.15, 0.81]	0.73	−0.92	[−0.99, −0.33]	0.04	−0.65	[−0.90, −0.03]	0.17	0.63 (0.53)	[0.01, 0.89]	0.82
4	−0.57	[−0.86, 0.05]	0.21	−0.06 (−0.10)	[−0.56, 0.48]	0.47	−0.14	[−0.62, 0.42]	0.43	−1.00	[−1.00, −1.00]	0.00
5	0.86 (0.67)	[0.26, 0.98]	0.93	−0.14 (−0.22)	[−0.62, 0.42]	0.43	0.71	[0.09, 0.93]	0.86	0.22	[−0.35, 0.67]	0.61
6	0.88	[0.28, 0.98]	0.94	0.22	[−0.35, 0.67]	0.61	0.86	[0.26, 0.98]	0.93	0.67 (0.61)	[0.05, 0.91]	0.84

Scores in brackets represent Tau-U values, which were calculated in cases where a baseline trend toward improvement was detected; below 0.15 = minimal or not change, 0.15–0.20 = small improvement, 0.21–0.60 = moderate improvement, 0.61–0.80 = large improvement, and above 0,80 = very large improvement; *CI*, confidence intervals; *NAP*, non-overlap of all pairs; below 0.50 = no improvement, 0.50–0.65 = small improvement, 0.66–0.84 = moderate improvement, and 0.85–1 = large improvement

supported these findings. During treatment, *Participants 1* and *4* showed small to moderate improvements, while no significant changes were observed in the remaining participants. In Tau, *Participant 1* experienced a moderate improvement in pain intensity, whereas *Participant 3* experienced a moderate worsening. In posttreatment, *Participant 1* showed a large improvement in NAP, and *Participant 5* showed a small improvement. In Tau, *Participant 1* showed a very large improvement, while *Participants 2* and 3 showed a large to very large worsening.

Depressed Mood

Participant 1 showed an early trend toward improvement, while the other participants showed more variable patterns. During treatment, *Participants 1*, *2*, *4*, and *6* showed a decrease in their mean scores, while *Participant 3* showed an increase, and *Participant 4* showed no change. In posttreatment, *Participants 1*, *2*, *5*, and *6* showed a decrease in depressed mood, *Participant 3* remained worsening, and *Participant 4* had still no changes. Statistical analysis showed similar results, with small to moderate improvements in NAP for *Participants 1*, *2*, *5*, and *6*. In Tau, *Participant 3* showed a moderate worsening, whereas *Participant 6* demonstrated a large improvement. In posttreatment, *Participants 1*, *2*, *5*, and *6* showed moderate to large improvements in NAP and large to very large improvements in Tau. In contrast, *Participant* 3 showed a large worsening in Tau.

Psychological Inflexibility

Baseline trends showed improvement for *Participants 3* and *6*. During treatment and follow-up, *Participants 2*, *3*, *5*, and *6* showed slight improvements in their mean scores, whereas *Participants 1* and *4* exhibited worsening. Statistical analysis revealed small to moderate improvements in NAP for *Participants 2* and *6* that remained at posttreatment, as well as an improvement in *Participants 3* and *5* only at posttreatment. In Tau, *Participant 4* showed a large to very large worsening in psychological inflexibility that remained posttreatment. In contrast, *Participants 3* and *6* demonstrated a moderate to large improvement in Tau posttreatment. No significant changes were observed in the remaining participants.

Statistical Analysis of the Standard Full-Length Measures

Table 4 presents the percentage of change in full-length variables, including pain-related outcomes (pain interference, pain intensity, and depressed mood), process variable of psychological inflexibility, adverse effects, and participants' global impression of change, from baseline to posttreatment (A–C) and baseline to follow-up (A–D).

Table 4 Percent change in the full-length pain-related (pain intensity, pain interference, and depressed mood) and process variable of psychological inflexibility from baseline (phase A) to posttreatment (phase C) and baseline (phase A) to follow-up (phase D)

Participant	Pain interference		Pain intensity		Depressed mood		Psychological inflexibility		Adverse effects	Global impression of change
	A–C	A–D	A–C	A–D	A–C	A–D	A–C	A–D		
1	43.8*	14.6	40.6*	−6.2	75*	62.5*	16.3*	−23.3	No	No change
2	65*	52.5*	12	0	33.3*	44.4*	14.5	27.5*	No	Quite better*
3	37.2*	34.9*	20*	31.8*	9.1	63.6*	−39†	−26.8	No	No change
4	42.1*	−28.9†	−11.4	−59.1†	75*	25*	24.6*	15.8	No	Quite better*
5	14.3	−35.7†	27.8*	10	−33.3†	−116.7†	28.1*	31.3*	No	Slightly better*
6	46.3*	40.7*	19.2	21.9*	87.5*	75*	9.1	10.6	Yes	Slightly better*

Phase A (A) = baseline; phase C (C) = posttreatment; phase D (D) = follow-up. *Clinically significant improvement, defined as a reduction exceeding 20% from baseline; †clinically significant worsening, defined as an increase exceeding 20% from baseline

Pain Interference

From baseline to posttreatment, clinically significant improvements in pain interference were observed in all participants except *Participant 5*, who did not show such changes. From baseline to follow-up, *Participants 2*, *3*, and *6* showed clinically significant improvements, while *Participants 4* and *5* experienced a relevant worsening. *Participant 1* showed no significant changes in pain interference between baseline and follow-up.

Pain Intensity

From baseline to posttreatment, clinically significant improvements in pain intensity were observed in *Participants 1*, *3*, and *5*, while the remaining participants showed no remarkable changes. From baseline to follow-up, *Participants 3* and *6* demonstrated improvements beyond the 20% cutoff for clinically meaningful change, whereas *Participant 4* showed clinically significant worsening. No relevant changes were observed in the other participants during this period.

Depressive Symptoms

From baseline to posttreatment, clinically significant improvements in depressed mood were observed in *Participants 1*, *2*, *4*, and *6*, while *Participant 5* showed remarkable worsening, and *Participant 3* exhibited no significant changes. From baseline to follow-up, all participants except *Participant 5* demonstrated improvements. *Participant 5*, in contrast, experienced worsening during this period.

Psychological Inflexibility

From baseline to posttreatment, improvements above 20% in psychological inflexibility were observed in *Participants 1*, *4*, and *5*, while *Participant 3* showed significant worsening. No significant changes were observed in *Participants 2* and *6* during this period. Clinically significant improvements were noted in *Participants 2* and *5* from baseline to follow-up, while no remarkable changes were observed in the remaining participants.

Impression of Change

Participants 2, *4*, *5*, and *6* reported experiencing some improvements in the global impression of change after the intervention. Specifically, *Participants 2* and *4* rated to be "quite better," while *Participants 5* and *6* reported being "slightly better" after

the intervention. In contrast, *Participants 1* and *3* indicated "no change" in their global impression of change.

Network Analysis

Preliminary Analyses

Preliminary analyses using i-ARIMAX and Bayesian mixed-effects models at the group level indicated no significant temporal shifts in the relationship between psychological inflexibility and pain-related outcomes (pain interference, pain intensity, and depressed mood). Supplementary Figure 5 presents the examination of bivariate relationships between the process variable of psychological inflexibility and pain-related outcomes for each participant (assessed through i-ARIMAX), while Supplementary Table 3 displays the effects of the pain-related variables, time periods, and their interaction (as assessed through Bayesian mixed-effects models).

Given the absence of significant changes in these associations at the group level, a network analysis was conducted through the GIMME framework to explore the relationships among the variables across the entire time series. This approach allowed for the examination of within-person dynamics and the structural organization of the four explored variables. GIMME was employed to estimate both group-level and individual-level network effects. When running SGIMME, the modularity was 0, indicating that subgroup analysis was not suitable with only six participants. Supplementary Figure 6 shows the group-level network with the most consistent relationships and the strength of their associations.

Main Analysis

Group-level network analyses were insufficient due to the high variability in individual-level networks. As a result, idiographic network analyses were implemented to capture each participant's experience. In the network, solid lines represent contemporaneous (same-time) relationships, meaning that changes in one variable are associated with simultaneous changes in another; dashed lines represent lagged effects, showing how one variable influences another at a subsequent time point; and autoregressive effects (self-loops) suggest that each variable retains some degree of stability over time, indicating that the variables are not entirely dependent on each other but maintain their individual patterns across the study period. The thickness of the directed edges reflects the strength of the associations, providing a visual cue for the magnitude of the relationships between the variables.

Figures 2, 3, 4, 5, 6, and 7 illustrate the idiographic networks of the six participants over the 70 days analyzed in this study. In *Participant 1*, psychological inflexibility increased depressed mood, which in turn intensified pain intensity. However, pain interference showed no relevant connections. In *Participant 2*, depressed mood influenced pain interference, with psychological inflexibility also showing a moderate relationship with pain interference. No relevant connections were found for pain intensity. In *Participant 3*, psychological inflexibility and depressed

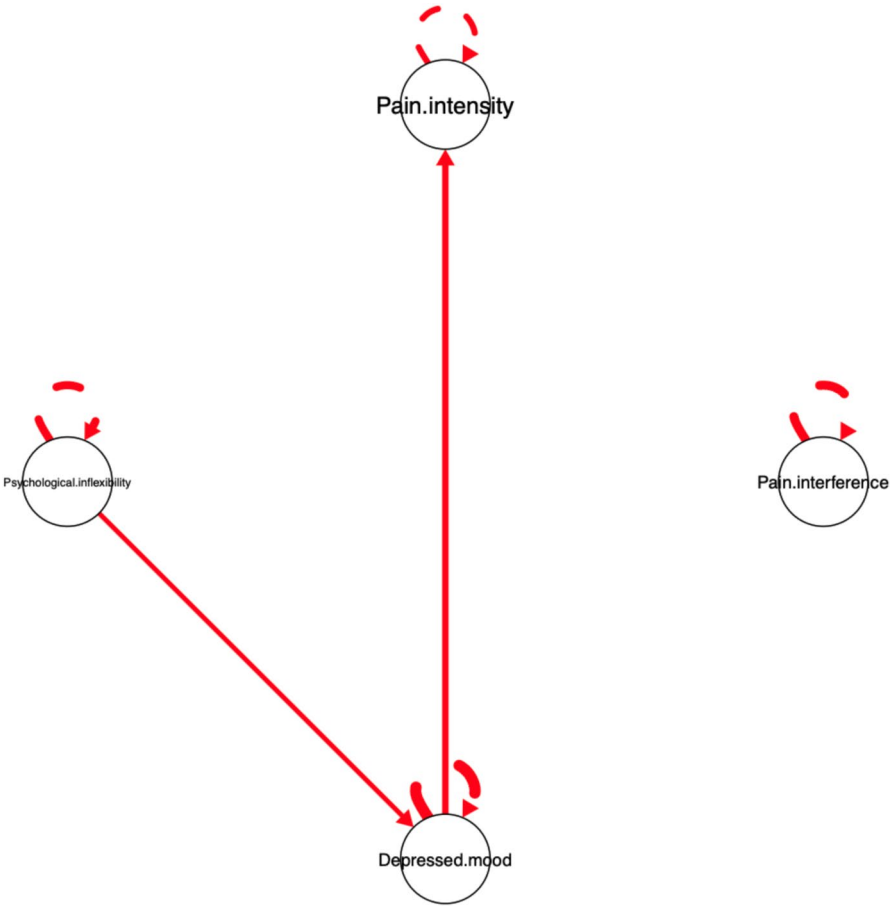

Fig. 2 Individual-level network estimated using Group Iterative Multiple Model Estimation (GIMME) framework for Participant 1. Note. Solid lines represent contemporaneous relationships between variables. Autoregressive effects (self-loops) reflect the stability of each variable over time. The thickness of the edges represents the strength of the associations

mood contributed to increased pain intensity, while pain interference led to greater depressed mood. In *Participant 4*, depressed mood increased pain interference, while psychological inflexibility and pain intensity had no relevant connections. In *Participant 5*, psychological inflexibility increased both depressed mood and pain interference, while pain intensity showed no relevant connections. In *Participant 6*, psychological inflexibility increased pain interference, which in turn heightened pain intensity. However, depressed mood showed no relevant connections. Autoregressive effects were observed in all variables across participants.

Across all participants, psychological inflexibility and depressed mood played a relevant role in the idiographic networks, although their effects varied among individuals. In most cases, psychological inflexibility was associated with an increase in

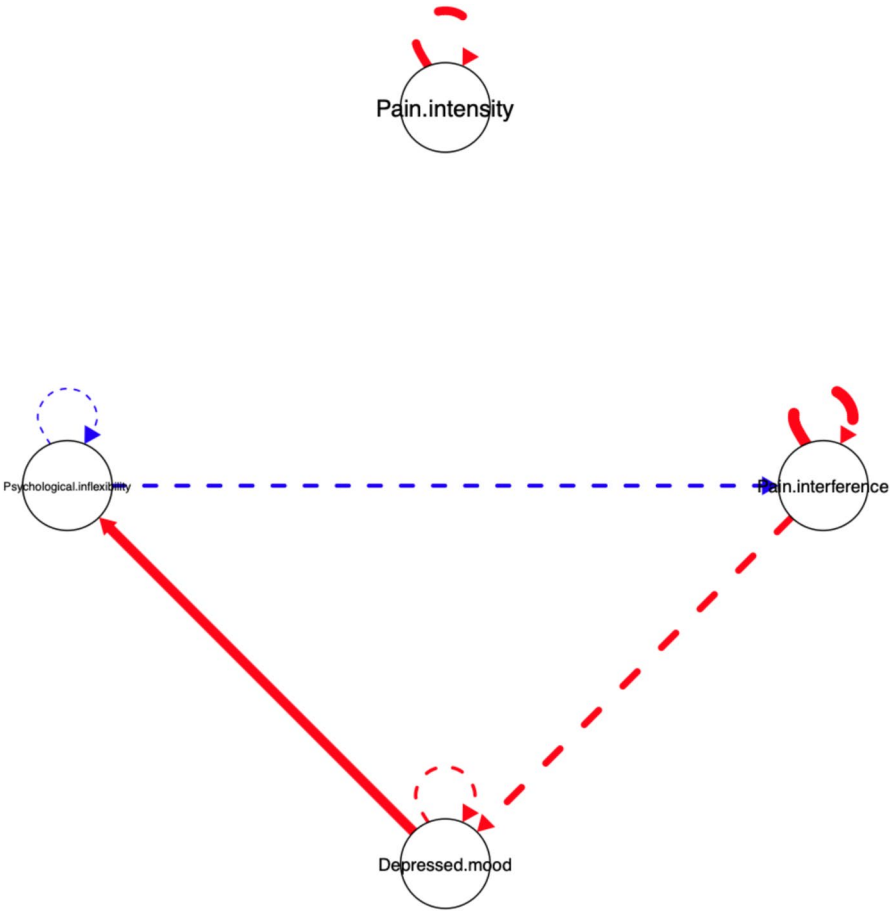

Fig. 3 Individual-level network estimated using Group Iterative Multiple Model Estimation (GIMME) framework for Participant 2. Note. Solid lines represent contemporaneous relationships between variables. Dashed lines represent lagged effects between variables. Autoregressive effects (self-loops) reflect the stability of each variable over time. The thickness of the edges represents the strength of the associations

depressed mood or pain interference, while depressed mood was linked to greater pain intensity or pain interference. However, the strength and direction of these relationships varied, and some participants showed no significant connections in certain cases. Additionally, pain interference and pain intensity did not always co-occur in the explored networks, suggesting distinct mechanisms may drive them. Autoregressive effects were consistent across all variables, reflecting stable patterns within each individual over the 70 days analyzed.

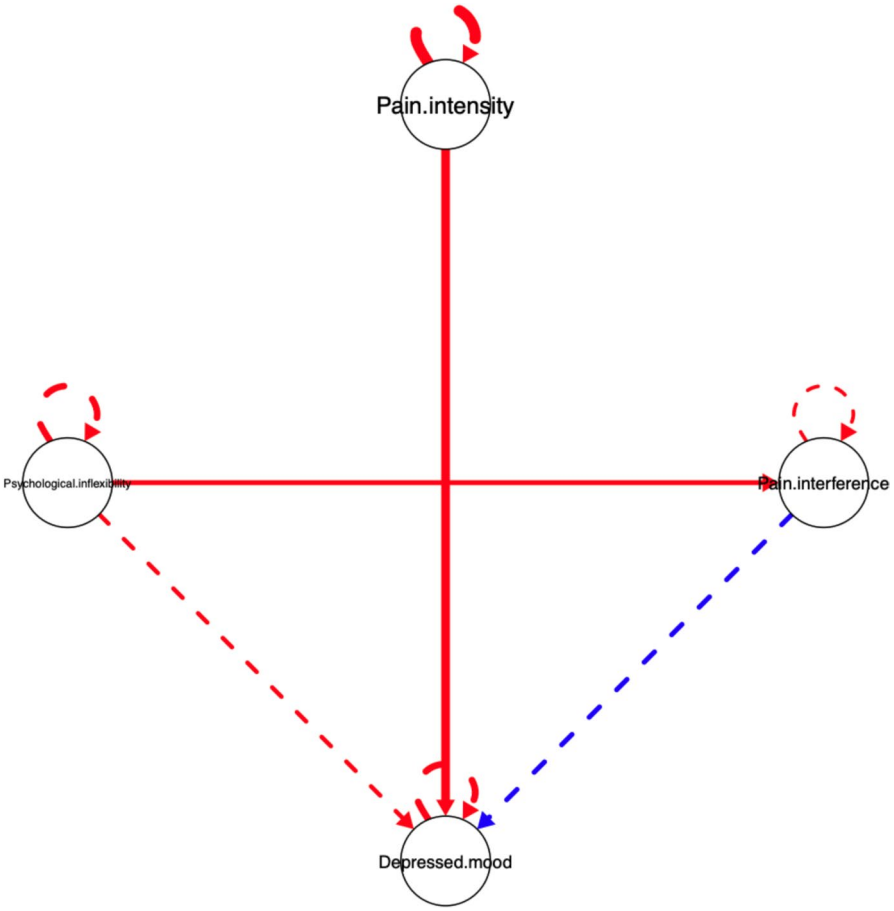

Fig. 4 Individual-level network estimated using Group Iterative Multiple Model Estimation (GIMME) framework for Participant 3. Note. Solid lines represent contemporaneous relationships between variables. Dashed lines represent lagged effects between variables. Autoregressive effects (self-loops) reflect the stability of each variable over time. The thickness of the edges represents the strength of the associations

Discussion

The present study utilized an idiographic approach to explore the clinical efficacy of remotely delivered, group-based ACT in individuals with CLBP plus depressive symptoms. By integrating EMA and SCED methodologies, this study captured individualized treatment trajectories over time, offering insights into the effectiveness of the ACT's impact beyond conventional group-level analyses. These findings contribute to a growing body of research emphasizing the need for personalized, process-based approaches to chronic pain management (Hayes et al., 2023; McCracken, 2023).

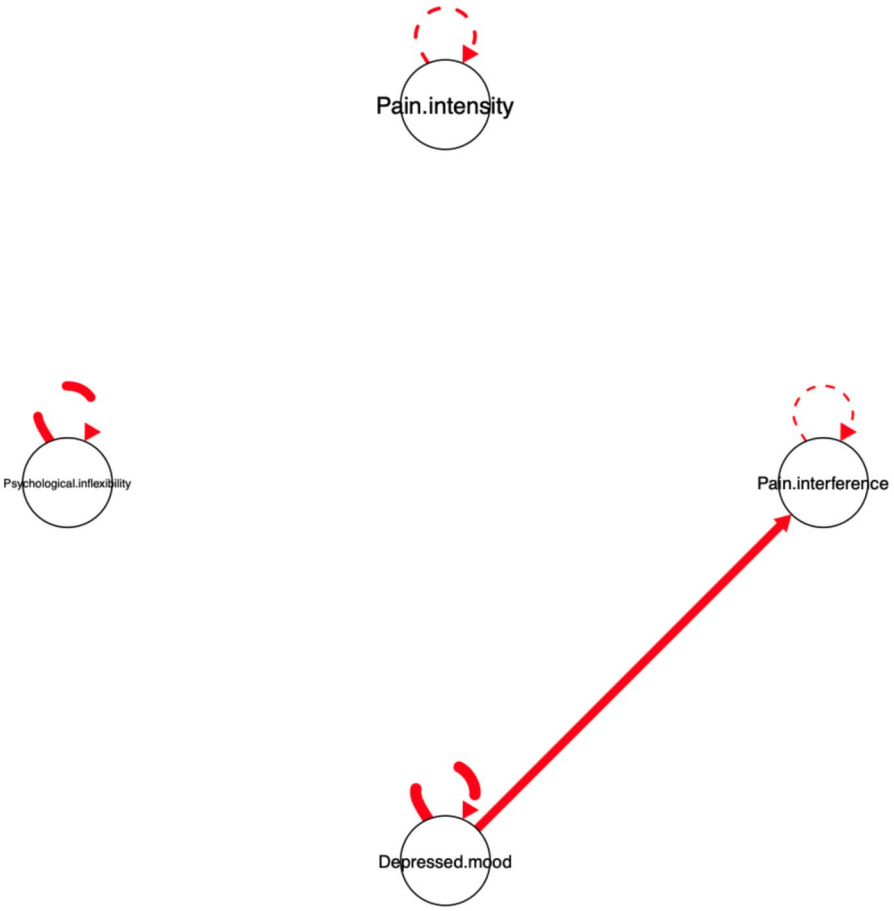

Fig. 5 Individual-level network estimated using Group Iterative Multiple Model Estimation (GIMME) framework for Participant 4. Note. Solid lines represent contemporaneous relationships between variables. Autoregressive effects (self-loops) reflect the stability of each variable over time. The thickness of the edges represents the strength of the associations

The comparison of baseline and treatment phases revealed that five participants exhibited at least one small positive effect of the intervention, with three participants demonstrating multiple small or larger effects, including at least one significant effect. Posttreatment analyses indicated stronger results, with five of six participants exhibiting moderate or larger effects reaching statistical significance. The most pronounced improvements were observed in pain interference, with three participants experiencing large effects, and depressed mood, with four participants demonstrating large effects. These findings align with previous research supporting ACT's efficacy in reducing emotional distress and improving pain-related functioning (Lai et al., 2023).

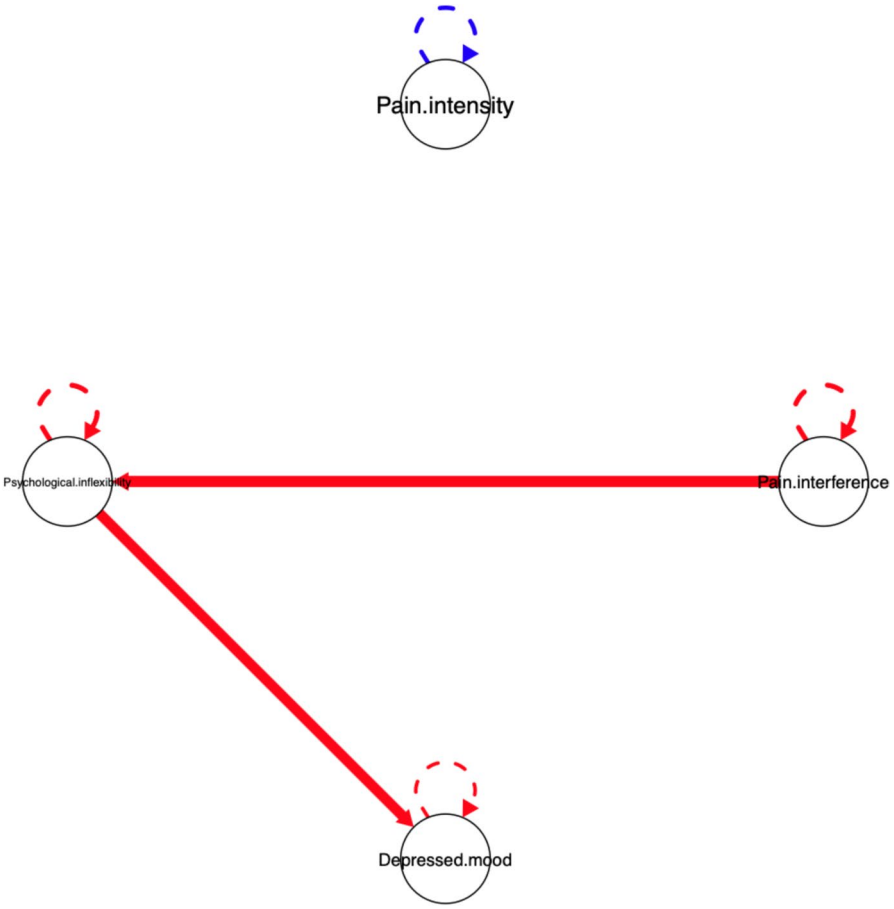

Fig. 6 Individual-level network estimated using Group Iterative Multiple Model Estimation (GIMME) framework for Participant 5. Note. Solid lines represent contemporaneous relationships between variables. Autoregressive effects (self-loops) reflect the stability of each variable over time. The thickness of the edges represents the strength of the associations

A recurring theme across all analyses was substantial interindividual variability in treatment responses. This highlights the importance of evaluating treatment effects at the individual level to gain a comprehensive understanding of the nuanced effects of the treatment (Ong et al., 2025). Relying solely on group-level changes may overestimate treatment efficacy, as substantial improvements in certain participants may not be representative of the broader sample. Similarly, poor responses—as observed in *Participant 4*—could have obscured meaningful improvements when analyzed at the group level.

Full-length measures administered before, immediately after, and at follow-up provide a complimentary perspective on the results. Overall, these measures show significant improvements, although slightly less than half of the possible outcomes

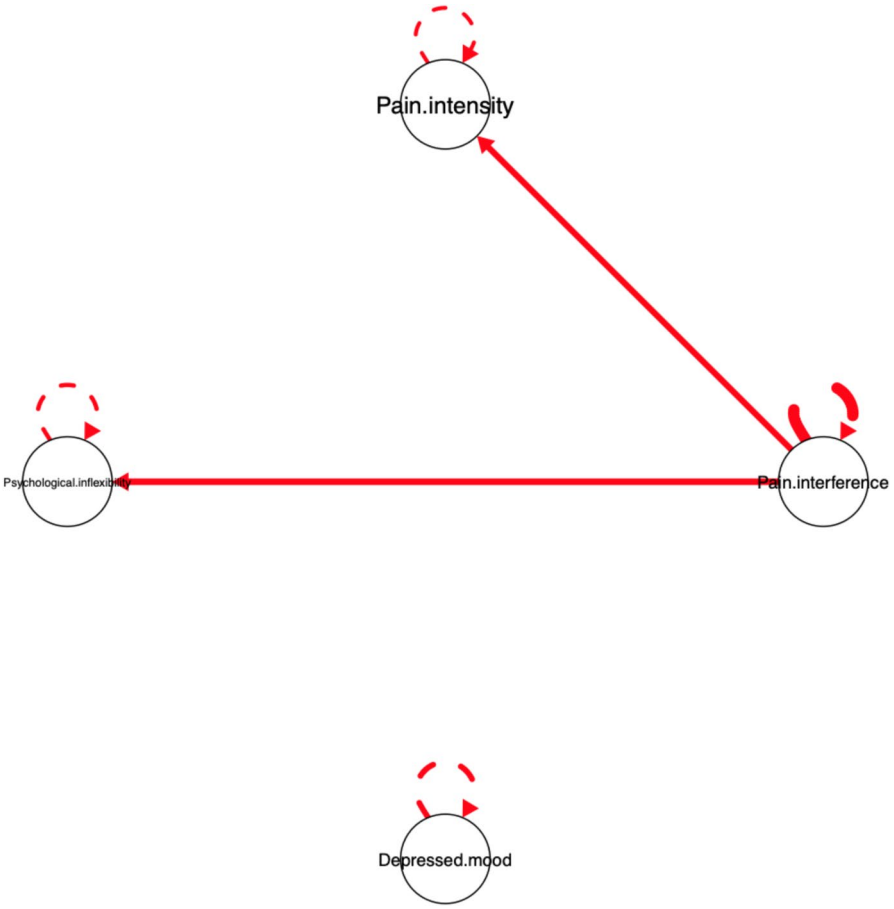

Fig. 7 Individual-level network estimated using Group Iterative Multiple Model Estimation (GIMME) framework for Participant 6. Note. Solid lines represent contemporaneous relationships between variables. Autoregressive effects (self-loops) reflect the stability of each variable over time. The thickness of the edges represents the strength of the associations

show either no change or significant worsening. Notably, this occurred in six out of 48 instances (12.5%) across six people, four measures, and two time points. While full-length measures sometimes align with daily data, this is not consistently the case. Instead, a recurring pattern of substantial individual variability emerges, affecting which measures change, at what time points, and to what extent.

There is increasing interest in understanding therapeutic change and identifying core processes of change (Moskow et al., 2023). The availability of intensive longitudinal data before, during, and after treatment offers unique opportunities for examining these mechanisms. In this study, network analyses were conducted to explore intraindividual relationships between key variables. One methodological concern in network analysis is the assumption of stationarity, which requires stable

relationships between variables over time. Initial analyses suggested that network structures remained stable over time, reducing concerns regarding stationarity.

Further analysis of individual networks indicated that aggregating data into a single summary network was not advisable due to high interindividual variability. Instead, distinct network structures emerged for each participant, despite all networks being based on the same four variables over a 70-day period. These differences emerged across multiple dimensions, including the strength and number of connections, the nature and direction of relationships, temporal patterns (lagged or contemporaneous), and even the degree of autocorrelation. Generally, within the networks across people, depression was the variable (node) that was most interconnected, psychological inflexibility and pain interference next, and pain intensity the least.

These findings align with previous literature indicating that depression plays a central role in chronic pain experiences (Linton & Bergbom, 2011). The prominence of psychological inflexibility within the network further supports existing research that highlights its role in maintaining pain-related distress and disability (McCracken & Vowles, 2014). The observed individual differences in network structures highlight the need for personalized treatment approaches, a perspective increasingly emphasized in contemporary pain management research (Lavefjord & Sundström, 2025). Moreover, the difference in the interconnectedness between pain intensity and pain interference is consistent with prior findings suggesting that pain-related disability is more strongly influenced by other pain-related outcomes (McCracken & Zhao-O'Brien, 2010).

The present results suggest that interventions targeting psychological flexibility and depression may have a more significant impact on pain-related outcomes than approaches focusing solely on pain intensity reduction. However, treatment plans should be adapted to account for interindividual differences in how these factors influence symptom trajectories over time.

Theoretical and Methodological Implications

From a theoretical perspective, these findings support an idiographic, process-based approach to treatment development for CLBP and related conditions. The results challenge conventional frameworks that categorize chronic pain as a fixed syndrome with uniform treatment pathways. They also raise critical questions about whether specific treatment protocols necessarily induce uniform process changes that correspond directly to outcome improvements. In this study, the processes of change were assessed using a single summary score for psychological inflexibility. Nonetheless, a broad range of effects was observed across individuals, both in the impact on the assessed process and in the variability of the relationships between changes in this process and treatment outcomes. These variations are too consistent and meaningful to be considered unreliable, highlighting the complexity of individual treatment responses.

From a methodological perspective, future research should refine adaptive treatment strategies and further develop innovative assessment methods to optimize

long-term outcomes for individuals with chronic pain. Such refinement should involve dynamic, person-centered designs that allow real-time monitoring and tailoring of interventions based on individual response patterns, rather than relying solely on group-based averages (Ciarrochi, 2021; S. G. Hofmann et al., 2020). These findings underscore the complexity of chronic pain treatment and emphasize the importance of individualized, process-based approaches. Incorporating more accurate idiographic assessments over time may provide a clearer picture of how psychological flexibility evolves during treatment and influences therapeutic outcomes. By refining methodologies and further integrating idiographic analyses, future research can enhance the precision and effectiveness of psychological interventions for chronic pain (Vlaeyen & Milde, 2025).

Clinical Implications

The findings reported in this study underscore the burgeoning need for a paradigm shift. It is necessary to move from a "one size fits all approach" to "tailored psychological interventions" in chronic pain. But rather than being paralyzed by the observed high heterogeneity between individuals—what some may simply interpret as "everyone is different"—the authors propose that the rich idiographic patterns revealed here are a resource for treatment planification, not a limitation. As reported in recent research (Sundström et al., 2025), ergodicity assumptions often fail in chronic pain populations, meaning group-level findings cannot be reliably generalized to individuals. Their idiographic approach offers a compelling alternative, revealing person-specific dynamics that can be directly leveraged for treatment tailoring.

For instance, this data shows that psychological inflexibility and depressed mood play differential roles across individuals, implying that for some individuals, enhancing acceptance strategies may yield greater benefit, while others may require more targeted mood interventions. These person-specific insights are not anecdotal—they are supported by dense time-series data and validated through network analysis. This aligns with the emerging consensus that personalization, informed by intensive EMA, is key to enhancing the effectiveness of psychological therapies (Scholten & Glombiewski, 2025; Scholten et al., 2025a, b). Moving forward, the authors encourage systematic linking of idiographic findings to individualized therapeutic targets—transforming variability from a challenge into a roadmap for adaptive treatment planning.

Limitations and Strengths

A strength of single-case design methods is the ability to replicate findings across individuals. However, in this study, this replication is partial or substantially incomplete most of the time. First, while positive outcomes for pain interference and particularly for depression can be considered substantially replicated, the results for pain intensity and psychological inflexibility do not demonstrate the same consistency. Second, although a sample of six participants can be sufficient to demonstrate

treatment efficacy, the incomplete replication rate suggests that this number may be relatively small. Third, the small sample size also limits the generalizability of the idiographic network analyses. While these analyses provide detailed insights at the individual level, the findings should be interpreted cautiously when considering larger populations. Fourth, a further limitation concerns the high exclusion rate due to insufficient EMA compliance, as 17 out of the 23 participants did not meet the 80% response criterion. This may have introduced self-selection bias, since participants who remained in the study could differ systematically from those excluded (e.g., in terms of motivation, engagement, or tolerance to study burden). Fifth, another limitation includes the ad hoc nature of the items used in the daily diary; however, achieving a fully satisfactory validation approach for idiographic measures remains an unresolved challenge in the field. Sixth, it would have been better to assess and analyze additional processes of change to provide a more detailed examination of these. Finally, the intervention itself followed a standardized protocol with minimal tailoring, which may have constrained its ability to activate the most relevant therapeutic processes for each participant. Moving forward, personalized intervention strategies that dynamically adjust to individual needs may offer a more precise way to optimize treatment outcomes (V. E. Hofmann et al., 2024).

Despite these limitations, the present study has several notable strengths. First, its foundational design, which emphasizes single-case assessments conducted intensively over time, allows each participant to serve as their own control or comparison. The study began with a one-person analysis, followed by five planned replications, reinforcing its methodological rigor. Second, the dual focus on both outcomes and processes of change represents a significant strength. This type of focus should be repeated in the future. Finally, the network approaches analyses should be seen as a strength and as a nudge to help others begin to think about how to incorporate similar analyses in future studies (Sahdra et al., 2024).

Conclusion

This study highlights the potential benefits of virtually delivered, group-based ACT for individuals with CLBP plus depressive symptoms, particularly in reducing pain interference and depressed mood. While some participants also demonstrated improvements in psychological flexibility, changes in pain intensity were infrequent. The findings underscore the importance of integrating intensive longitudinal methods with traditional full-length assessments, revealing complementary but distinct patterns of change. Moreover, the substantial individual variability observed in both treatment outcomes and process changes reinforces the necessity of idiographic approaches in chronic pain research. As has been recently pointed out (Scholten et al., 2025a, b), aggregated group-level data may obscure meaningful individual differences, emphasizing the need for personalized interventions.

Supplementary Information The online version contains supplementary material available at https://doi.org/10.1007/s41811-025-00268-x.

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Author Contribution Juan P. Sanabria-Mazo, Ana Gallego, and Juan V. Luciano conceived and designed the study. Juan P. Sanabria-Mazo wrote the first draft of the manuscript. Juan P. Sanabria-Mazo, Carla Rodríguez-Freire, Ana Gallego, and Joseph Ciarrochi analyzed the data. Carlos Suso-Ribera, Azucena García-Palacios, Steven C. Hayes, Stefan G. Hofmann, Joseph Ciarrochi, Lance M. McCracken, and Juan V. Luciano assisted in the final drafting and editing of the manuscript. All the authors had the opportunity to contribute to interpreting the results and revising the manuscript for intellectual content.

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Data Availability The data supporting this study's findings are available from the corresponding author upon reasonable request.

Declarations

Ethics Approval and Consent to Participate The study involved human participants and was conducted following ethical standards. Ethical approval was obtained from the Ethics Committee of the Fundació Sant Joan de Déu (reference: PIC-178-19) and the Hospital del Mar (reference: 2019/8866/I). All participants provided written informed consent before their inclusion in the study. None of the participants received any financial incentive.

Clinical Trial Registration This study was registered at ClinicalTrials.gov (https://www.clinicaltrials.gov) with the trial registration number NCT04140838. Registration date: October 28, 2019.

Conflict of Interest The authors declare no competing interests.

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