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Visualizing one's Best Possible Self increases positive future expectancies, but does not boost selective learning in fibromyalgia

Tabea Kloos [a], Fernando Blanco [b], Winfried Rief [a], Ann Meulders [c,d,*,1], Jenny Riecke [a,1]

[a] Clinical Psychology and Psychotherapy, Philipps-University Marburg, Marburg, Germany
[b] Department of Social Psychology, University of Granada, Granada, Spain
[c] Experimental Health Psychology, Maastricht University, Maastricht, the Netherlands
[d] Research Group Health Psychology, KU Leuven, Leuven, Belgium

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ABSTRACT

Compromised learning is considered to contribute importantly to the development and maintenance of chronic pain disability. More specifically, predictive learning is impaired in people with chronic pain. Therefore, learning mechanisms have been identified as treatment targets. A widely neglected, but relevant question is whether resilience factors can enhance selective learning. This online study combined a selective learning task with a positive psychology intervention in participants with fibromyalgia (FM). The Best Possible Self group (BPS) described and visualized a future in which everything had gone well, which is shown to increase optimism and positive affect, while the active control group described and visualized their Typical Day (TD). Subsequently, selective learning was tested within a contingency learning scenario task using a blocking procedure and pain expectancies as main outcome. We successfully manipulated positive future expectancies (a proxy for state optimism), but not positive affect within a single-session intervention. In contrast with our expectations, the positive psychology intervention did not increase selective learning in the BPS group compared to the TD group, but a small blocking effect was observed in the merged sample. However, because no healthy control group was included, no conclusions can be drawn as to whether the selective learning effect is reduced compared to a non-clinical population. To conclude, there was partial evidence for selective learning in people with fibromyalgia, but manipulated resilience factors did not modulate the selective learning effect.

1. Introduction

People affected by Fibromyalgia (FM) are characterized by musculoskeletal pain in a variety of body regions, as well as cognitive impairments, sleep disturbances, fatigue and mood disorders, and report to suffer from appalling low life quality (Arnold et al., 2008; Galvez-Sánchez et al., 2019). However, the chronic disease's cause is largely unknown (Galvez-Sánchez et al., 2019) and treatments show limited effectiveness (Kia & Choy, 2017).

Studies with experimental pain inductions have demonstrated impaired differential threat-safety learning, overgeneralization and reduced extinction of fear generalization in people affected by FM (Jenewein et al., 2013; Meulders et al., 2015, 2017). Recently, Meulders et al. (2018) reported evidence for reduced selective learning in participants with FM compared to healthy controls in a contingency learning scenario task without any experimental pain, but using verbal outcomes "pain" vs. "no pain" as outcomes. Selective learning can be described as the ability to direct the fear response to reliable predictors of pain and showing reduced fear to less good predictors. The most appropriate way to test selective learning is within contingency learning experiments using a blocking procedure (Houwer & Beckers, 2002; Kamin, 1969). In a typical blocking paradigm, after one cue has been learned to reliably predict pain, subsequently a new predictor of pain is introduced as a compound with the first predictor. Selective learning manifests as lower pain expectancies for the new predictor compared to the first learned predictor when tested alone. Reduced selectivity in associative learning or reduced blocking, would be evident from smaller differences in pain expectancy between the new predictor and the first

* Corresponding author. Experimental Health Psychology, Department of Clinical Psychological Science, Maastricht University, Universiteitssingel 40, 6229 ER Maastricht, the Netherlands.
E-mail address: ann.meulders@maastrichtuniversity.nl (A. Meulders).
[1] Joint senior authorship.

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learned predictor, whereas improved selective learning would be evident from larger differences between these two predictors. Reduced selectivity in associative learning or reduced blocking is relevant as it probably reflects one impaired learning mechanism in chronic pain patients, which contributes to excessive spreading of pain-related fear and avoidance, in turn giving rise to pain-related disability (Vlaeyen & Crombez, 2020; Vlaeyen & Linton, 2000, 2012).

Recently, fear-avoidance models that focused mainly on vulnerability factors were supplemented by resilience factors, i.e., positive affect and optimism that might help in exiting the vicious cycle (Basten-Günther et al., 2018; Boselie & Vlaeyen, 2017; Gatzounis et al., 2021; Hanssen et al., 2017; Meulders, 2020; Vlaeyen et al., 2016). There is preliminary experimental evidence in pain-free samples suggesting that increasing positive affect may alter at least two learning processes: extinction (inhibitory) learning and generalization. In a voluntary joystick movement paradigm, in which a joystick movement in one direction (CS+) was paired with the pain-US and another joystick movement (CS-) was not, Meulders, Meulders, and Vlaeyen (2014) showed that healthy individuals with low levels of trait positive affect failed to inhibit their fear to CS-, a joystick movement that was never paired with pain and that they learned to be a safe, once the extinction phase started. Using a similar fear of movement conditioning paradigm, Geschwind et al. (2015) showed that experimentally increasing positive affect protected against generalization of fear to novel safe movements. Interestingly, increased positive affect only reduced "excessive generalization" (i.e., fear generalized less to GSs similar to CS-), leaving the adaptive generalization effect intact (i.e., fear generalized less to GSs similar to CS+). In a robotic arm avoidance conditioning paradigm, Gatzounis and Meulders (2022) showed that experimentally increasing positive affect led to more generalization of safety learning from an extinguished movement (the only movement performed during response prevention with extinction) to other movements that were previously sometimes or never paired with pain. Taken together, these findings seem to suggest that positive affect may reduce uncertainty about ambiguous cues or ambiguous situations (e.g., changing contexts or contingencies), and thus may also improve selective learning. Empirical evidence suggests that positive affect may improve safety learning in non-clinical samples. Similar facilitating effects of positive affect on extinction learning have been reported in anxiety literature (Meulders, 2020; Zbozinek & Craske, 2017a, 2017b; Zbozinek et al., 2015). Besides, increasing situational optimism was associated with lower pain intensity ratings and better executive functioning in the face of experimental pain (Boselie et al., 2014, 2017; Hanssen et al., 2013).

State optimism and positive affect can effectively be enhanced by the Best Possible Self exercise (BPS) (Carrillo et al., 2019; Heekerens & Eid, 2020). However, few studies have investigated the BPS intervention in chronic pain populations (Boselie et al., 2018; Molinari et al., 2018; Peters et al., 2017). Yet, Molinari et al. (2018) provided evidence for the effectiveness of the BPS intervention in people affected by FM with significant increases in positive affect and elevated positive future expectancies (as a proxy for state optimism). Nevertheless, to our knowledge, no study has investigated the buffering effects of resilience factors in countering learning impairments in chronic pain populations. Within our study, we aimed to implement the BPS exercise as a single-session online intervention for people affected by FM and to subsequently investigate whether enhanced state positive affect and positive future expectancies boost selective learning in chronic pain patients. Therefore, the previously used blocking procedure was replicated to test selective learning in people affected by FM (Meulders et al., 2018). We hypothesized that the BPS group would show (1) larger increases in state positive affect and positive future expectation (as a proxy for state optimism), and (2) increased selective learning, compared to the active control group.

2. Materials and methods

2.1. Participants

A total of 249 people affected by FM were randomized to participate in either the BPS group or the active control typical day (TD) group. After dropouts and exclusion criteria, the final sample for analyses consisted of 158 people with FM. Of $n = 121$ participants that were randomized into the BPS group and of $n = 128$ participants allocated to the TD group, $n=73$ were analyzed in the BPS group and $n = 85$ in the TD group. For a detailed overview see Fig. 1, for demographic characteristics and pain duration see Table 1. Initially, we aimed for 164 participants, which was decided by conducting a priori power analyses after assuming a small effect ($f = 0.10$) on the within-between interaction (Power 0.8, $\alpha = 0.05$). However, we stopped our recruitment earlier based on the restricted time frame for patient inclusion (from the 8th of April 2021 until the 2nd of August 2021). A posteriori sensitivity analyses revealed that the final sample of 158 participants allowed to detect small effects ($f = 0.1$ or larger) in the 2x2 within-between interaction with a power of 0.80. All power analyses were conducted in G*Power (Faul et al., 2007). Prior to participation, participants confirmed via self-report that they had a doctor-based diagnosis of fibromyalgia. Participants were excluded if they had diagnosed dyslexia or other cognitive deficits, which were independent of their pain condition (e.g., stroke or brain deficits).

Recruitment took place via social media platforms like Instagram and Facebook, but also through FM associations, self-help groups as well as via flyers in medical offices and clinics. To increase the incentive to participate in the study, gift vouchers (4 x 50 Euro) were raffled among participants. Participants did not receive a guaranteed monetary compensation besides the gift vouchers. We obtained ethical approval by the local ethics committee of the Philipps-University of Marburg (file reference: 2020–70k). All methods were performed in accordance with the relevant guidelines and regulations. Informed consent was obtained from all participants. We preregistered the study at ClinicalTrials.gov (Clinical trial registration number: NCT04889300, date of first registration: 17/05/2021, unique protocol ID: BRF0421).

2.2. Experimental setting

The whole study was conducted online via two platforms: a survey platform (QuestBack EFS Survey, Unipark) and an experimental platform (programmed via JavaScript, presented in HTML and CSS in a web browser). Participants were only permitted to participate using a desktop computer or laptop with audio output (participation via mobile phone or tablet was not allowed). In order to keep participants engaged and to recreate a controlled laboratory situation, we included several videos in which the experimenter guides the participant throughout the experiment.

2.3. Procedure

An overview of the study procedure is depicted in Fig. 2.

After receiving the general study information and giving informed consent, participants completed the online experiment. The duration of study participation was approximately 52 ($SD = 29$) minutes. Our design included two experimental groups: participants either received the TD intervention (active control group) or the BPS intervention, in which state positive affect and positive future expectations were induced. The experiment consisted of six consecutive experimental phases: the prerating phase, the practice phase, the elemental acquisition phase, the reminder of acquisition phase, the compound acquisition phase, and the test phase, which are described below (also see Table 2). Selective learning was experimentally investigated by using the blocking procedure. In this procedure, one event (A+, i.e., the blocking stimulus) was first paired with pain, thus becoming a reliable predictor of pain

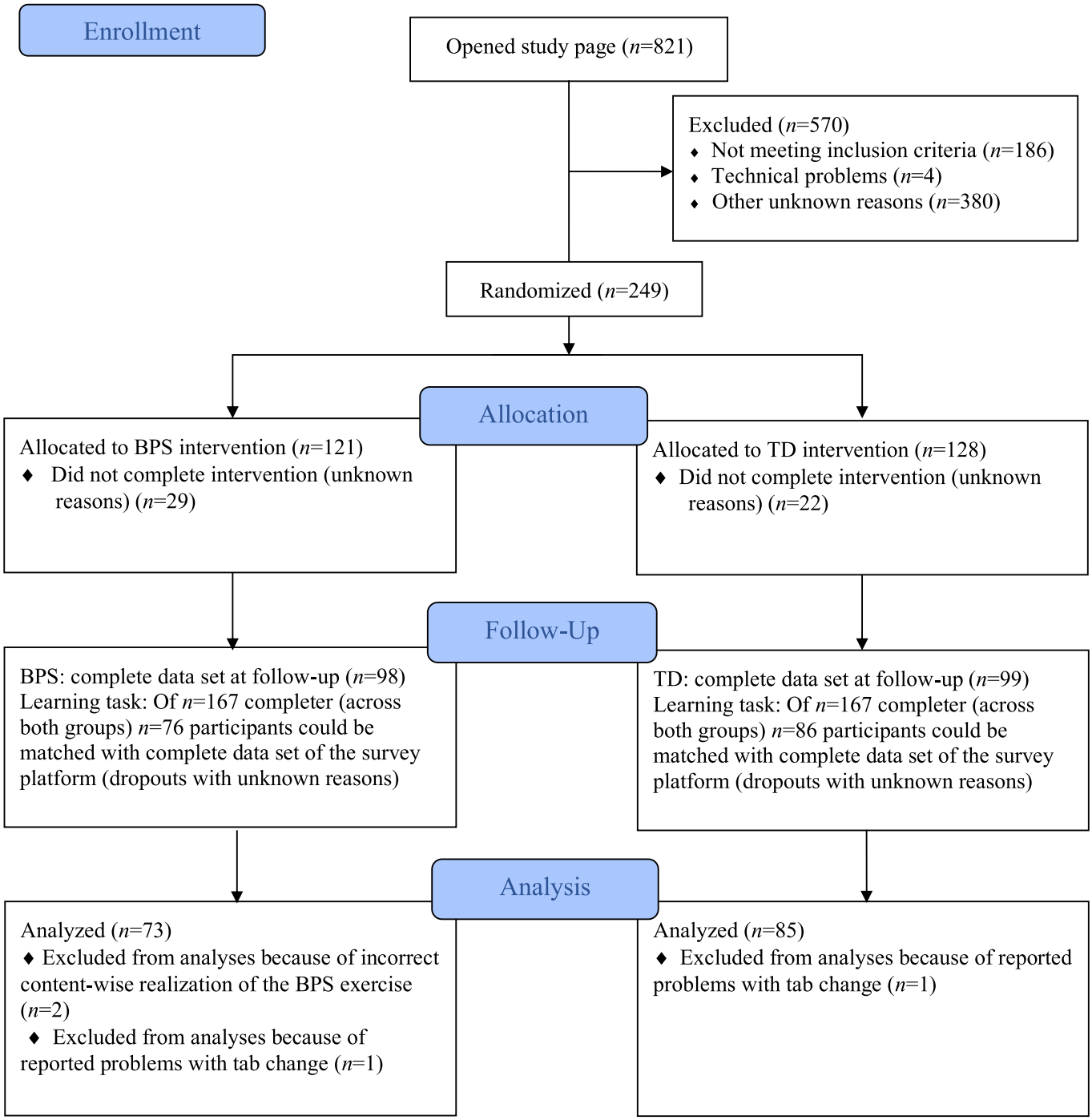

Fig. 1. Consort chart of participant flow through the study. BPS = Best Possible Self group; TD = Typical Day group.

(elemental acquisition phase). Later, another event (X), i.e., the blocked stimulus, was displayed together with the first event A (AX+) (compound acquisition phase). The combination of both events was also followed by pain. In the test phase, we assessed the extent to which participants expect pain for the blocked stimulus alone (X). In case of "blocked", i.e., reduced pain expectation for X, we can assume adaptive, selective learning.

Before and after the manipulation participants filled out several questionnaires to measure changes in these resilience factors. At the end of the experiment participants filled out several follow-up and post-experimental questionnaires.

2.4. Stimulus Material

Stimulus Material was used from the previous study by Meulders et al. (2018). Different situations that patients consider as typical triggers for pain episodes were used. Sentences were formulated in third person under the cover story of Kim's diary, in which Kim represents a fictitious pain patient (the name "Kim" is gender neutral in German). The situations (i.e. "The weather was bad today", "Kim has vacuumed", "Kim slept badly", "Kim was stressed", "Kim had a partnership dispute", "Kim has walked the dog") served as conditioned stimuli (CSs) in the contingency learning task. They were followed by the outcome information, or unconditioned stimulus (US), which was represented by the sentences "Kim experiences pain" or "Kim experiences no pain", as if

Table 1
Demographic characteristics for the Best Possible Self and Typical Day group separately.

Variables	BPS		TD	
	n	%	*n*	%
Sex (Female)	71	97.3	82	96.5
Age[a]	43.22	10.35	46.16	12.56
Highest education level				
Lower secondary education	4	5.48	2	2.35
Intermediate secondary education	7	9.59	14	16.47
Higher secondary education	10	13.70	20	23.53
Completed apprenticeship	37	50.68	33	38.82
Bachelor's degree	8	10.96	9	10.59
Master's degree (or diploma or state exam)	7	9.59	7	8.24
Occupation				
Full-time working	18	24.66	25	29.41
Part-time working	13	17.81	23	27.06
Unemployed	6	8.22	7	8.24
Retired	12	16.44	11	12.94
Incapacitated	19	26.03	17	20.00
In training	6	8.22	5	5.89
Other	23	31.51	20	23.53
Family Status				
Single	11	15.07	10	11.76
In a stable relationship	14	19.18	21	24.71
Married	42	57.53	44	51.76
Divorced	5	6.85	8	9.41
Widowed	1	1.37	2	2.35
Pain duration				
1–2 years	4	5.48	3	3.52
2–5 years	11	15.07	24	28.24
>5 years	58	79.45	58	68.24

Note. BPS = Best Possible Self group; TD = Typical Day group.
[a] Values are presented as means (± standard deviation).

they were part of a fictitious diary. Two situations (corresponding to stimuli C and D) were used in the practice phase, whereas the other four situations (i.e., stimuli A, B, X, and Z) were used during the experimental phases of the learning experiment. Which situations served as which stimuli was counterbalanced across participants.

2.5. Experimental phases

Pre-rating phase. Before the beginning of the blocking procedure, participants were asked to rate how much they themselves would expect pain in the situations which were later used as stimuli in the learning experiment (i.e., "To what extent do you expect that this situation would cause you pain?" for vacuuming, bad weather, sleeping badly, being stressed). Example sentences were "You had vacuumed" or "The weather was bad today". These a priori beliefs were assessed in order to control if participants regard CSs as precedents for pain irrespective of their subsequent pairings with the outcome.

Practice phase. In this phase participants were instructed about the learning task in detail. The task was introduced to the participants as "Kim's diary" in which Kim, a fictitious pain patient, documented every day whether pain occurred after certain situations and in which they (the participants) should predict in which situations Kim would experience pain. Participants were instructed to imagine to be Kim's physician trying to find out which situations cause Kim pain. Subsequently, participants were familiarized with the use of the scale while rating two situations, which were exclusively used in this phase (i.e., "Kim had a partnership dispute" and "Kim has walked the dog"). For each of these sentences representing various activities/situations, participants were asked to indicate how much they would expect them to cause Kim pain. The sentences were presented on the screen until the response was confirmed. Then, the outcome "Pain" or "No pain" replaced the scale and stayed onscreen for 3s. Further, an information box appeared on the left button of the screen to guarantee the understanding of the situation-outcome relation (i.e. "Kim reports in her diary that walking the dog did not lead to pain"). The screen was cleared for 0.5s before a new trial started. This phase consisted of two trials.

Elemental acquisition phase. During this phase, participants encountered two different situations (stimuli A and Z, e.g., "Kim has vacuumed" and "Kim was stressed"), which were counterbalanced and presented six times each. A was always followed by the "Pain" outcome, while stimulus Z was consistently paired with the "No Pain" outcome. The order of the stimuli was randomized.

Reminder of acquisition phase. Following the intervention and the positive affect and positive future expectancies questionnaires, participants were reminded of the elemental acquisition phase. The goal of this reminder phase is to ensure, that after the interruption of the intervention, all participants remember the association between A and the outcome that was trained in the elemental acquisition phase. This phase was identical to the previous learning phase, but the stimuli were only presented once each in a randomized order.

Compound acquisition phase. In this phase, Z still consistently led to the "No Pain" outcome. Additionally, a novel stimulus B was introduced and always followed by "Pain". Also, the blocked stimulus X consistently accompanied the stimulus A. After the successful acquisition of contingencies, X should become redundant as A already predicts the outcome reliably, i.e. there should be no surprise when the outcome follows AX, which would lead to impaired learning of the X-outcome association (Rescorla & Wagner, 1972). This phase comprised 18 trials: 6 Z-trials, 6 B+, and 6 AX + trials, which were presented in a random order.

Test phase. During this central test phase, the stimuli Z, B and X were only presented once in a randomized order. In contrast to the previous phases, the situations were not followed by the "Pain" or "No Pain" outcome, but rather by a text stating that Kim's diary would not say whether Kim had pain or not. This method was used with the purpose to avoid influencing the answers to subsequent test trials. For all phases of the learning task, pain expectancy was used as outcome measure (see Main Outcome Measure: Pain expectancy).

2.6. Manipulation of positive affect and positive future expectancies

After the elemental acquisition phase, the manipulation took place (see Fig. 1). Half of the participants were randomly allocated to the BPS group, and the other half was allocated to the control TD group. State positive affect and positive future expectancies were induced through the Best Possible Self (BPS) intervention. In this BPS intervention, participants were asked to imagine a future in which everything went well and in which all their wishes were fulfilled despite the pain they are currently experiencing. They were asked to think about this for 1 min, then write about it for 15 min and, subsequently imagine it for another 5 min as vividly as possible. This procedure is known to reliably increase positive affect and positive future expectations (Carrillo et al., 2019). Positive future expectancies are regarded as a measure for state optimism. In the control group, participants were asked to describe and visualize a typical day (TD) despite possible changes due to the COVID-19 pandemic using the same procedure. Based on previous research, we adapted the BPS instructions for a pain population (Flink et al., 2015; Peters et al., 2017). Specifically, we emphasized that participants should imagine their Best Possible Self despite the pain they were currently experiencing. Further, we adapted the TD instructions in order to take possible changes in participants' daily lives due to COVID-19 into account as during the recruitment period (between 8th of April 2021 and 2nd of August 2021) participants might have been affected by lockdown measures. All instructions were provided both verbally (within the video guidance) and in written form. Detailed instructions (translated from German) can be found in the supplementary material.

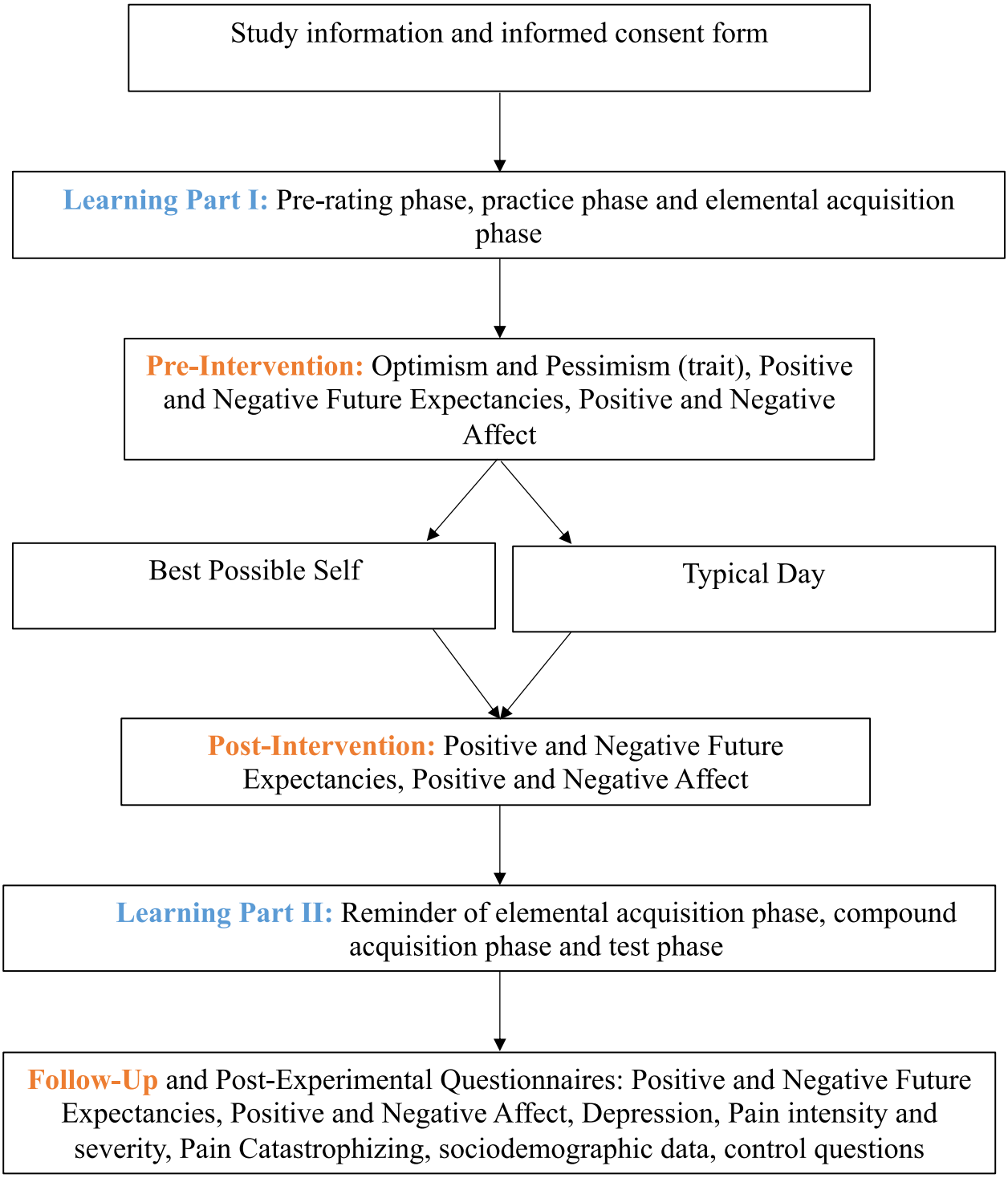

Fig. 2. Experimental procedure. Optimism and Pessimism (trait) were measured with the Life Orientation Test; Positive and negative future expectations (state optimism and pessimism) were measured with the Future Expectancies Scale; Positive and negative affect were assessed with the Positive and Negative Affect Schedule. At follow-up measurement additional questionnaires were introduced: Pain intensity and disability were measured with the Chronic Pain Grade Scale-Revised (which include the PEG-scale to measure pain severity); Depression was assessed with the Patient Health Questionnaire (PHQ-9); Pain Catastrophizing was measured with the Pain Catastrophizing Scale.

2.7. Outcome measures

2.7.1. Main Outcome Measure: Pain expectancy

Participants were asked to rate their pain expectancy for the depicted situations on a scale from 0 ("expect not at all") to 100 ("expect very much"). Participants could use their mouse to navigate across the scale and click to select a response, which was then displayed as integer numbers below the scale.

2.7.2. Secondary outcome measures: Affect and future expectancies

The Positive and Negative Affect Schedule (PANAS) (Krohne et al., 1996; Watson et al., 1988) was used to measure positive affect and negative affect. The PANAS comprises 20 adjectives measuring mood dimensions of positive and negative affect, which build two

Table 2
Experimental design – learning phases.

Pre-rating	Practice	Elemental acquisition	Reminder of acquisition	Compound acquisition	Test phase
A*	C+	6A+	A+	6B+	X
B*	D-	6Z-	Z-	6AX+	B
X*				6Z-	Z
Z*					

Note – A, B, X, and Z were operationalized by the following sentences: "Kim has vacuumed", "The weather was bad today", "Kim slept badly" and "Kim was stressed". The sentences were counterbalanced across participants. "*" refers of second ("You") instead of third person ("Kim") usage. In the pre-rating phase and in the test phase no outcomes were presented. Two more sentences "Kim had a partnership dispute" and "Kim has walked the dog" (C and D) were used in the practice phase. Stimuli were presented in a randomized order during each phase. "+" and "-" mean that after the stimuli "Pain" and "No Pain" (respectively) were presented. In the unreinforced test phase, no outcomes were presented but the sentence "The diary does not say whether Kim experienced pain or not".

corresponding subscales. Participants were requested to indicate how they felt in the moment when giving their ratings on a scale from 1 ("very slightly or not at all") to 5 ("extremely"). The PANAS has been shown to be a reliable and valid measurement instrument (Crawford & Henry, 2004).

The Future Expectancies Scale (FEX) (Hanssen et al., 2013; Peters et al., 2016) was used to assess positive and negative future expectancies. Statements encompassed five different areas (personal, social, work, health and, general) and participants were required to rate their future expectancies on a 1 ("not at all likely to occur") to 7 ("extremely likely to occur") Likert scale. In total, the FEX entails 20 items, which can be divided into statements regarding positive (FEX-Pos) and negative (FEX-Neg) events, which then form two corresponding subscales. The FEX was used to measure state optimism.

2.8. Modifications to the original experiment

Some minor modifications were done to the previous experiment. Stimuli and outcomes were presented on a white screen in size 20.5 and black bold Open Sans font type within a blue frame. At the top of the screen "Day x of Kim's diary" was written in order to contextualize the learning experiment in the cover story and to keep participants engaged. The day counter increased with each presented stimulus starting from the acquisition phase. Moreover, we changed the stimulus "Kim had a marital dispute" to "Kim had a partnership dispute". Furthermore, the scale was adapted to ratings from 0 to 100 instead of from 0 to 10 and participants were asked about the strength of their expectations (expect not at all/expect very much) instead of their certainty of pain to occur (certainly to pain/certainly pain).

2.9. Clinical and post-experimental questionnaires

We measured dispositional optimism (Life Orientation Test-Revised; LOT-R (Glaesmer et al., 2008; Scheier et al., 1994) *prior* to the intervention to verify if the BPS and the TD group differed in their levels of trait optimism (see Fig. 2). Further, we used a series of questionnaires *at the end of the experiment* with the purpose of characterizing our experimental sample. We measured depression (Patient Health Questionnaire; PHQ-9 (Gräfe et al., 2004; Kroenke et al., 2001), pain intensity and disability (Graded Chronic Pain Scale-Revised which also includes the PEG-scale to assess pain severity; GCPS-R (von Korff et al., 2020)), and pain catastrophizing (Pain catastrophizing scale; PCS (Meyer et al., 2008; Sullivan et al., 1995)) with validated questionnaires. Further, we included several post-experimental questions relating to the experiment to control for potential group differences and learning interferences. We measured attention and concentration, boredom, self-reported technical difficulties and self-reported task shortening. For an overview of participants' scores on clinical variables see Table 3 (for more clinical characteristics and control variables see Tables 1S–2S in the supplementary material).

2.10. Statistical analysis overview

To evaluate participants' a priori pain beliefs we conducted a 2 x 4 mixed ANOVA with Group (BPS/TD) and Stimulus (A, B, X, Z) as factors on the pain expectancy ratings in the pre-rating phase. Further, we ran independent *t*-tests to check for group differences (i.e., BPS vs. TD) in clinical and control variables as well as baseline affect and optimism/pessimism scores (trait and state). To test differential acquisition, we performed a 2 x 2 x 6 mixed ANOVA with Group (BPS/TD) as between-subjects factor, Stimulus (A+/Z-) and Trial (1–6) as within-subjects factors, and pain expectancy ratings in the acquisition phase. Similarly, we computed a 2 x 3 x 6 mixed ANOVA with Group (BPS/TD) as between-subjects factor, Stimulus (AX+/B+/Z-) and Trial (1–6) as within-subjects factors, and pain expectancy ratings in the compound acquisition phase as dependent variable.

To test our first hypothesis that the BPS intervention would lead to increased state positive affect and elevated positive future expectancies, we run several 2 x 3 mixed ANOVAs with Group (BPS/TD) as between-subjects factor, Time (pre-intervention/post-intervention/follow-up) as within-subjects factor, and positive and negative affect as well as positive and negative future expectancies as outcome variables. Furthermore, we investigated the changes in these outcome variables within each group by using paired-samples t-tests. Additionally, to compare the extent of changes in the affect and future expectancies outcome parameters between groups, we computed difference scores (post-intervention minus pre-intervention) and compared these with simple one-way ANOVAs.

To test our main hypothesis that the intervention would modulate selective learning, we computed a 2 x 3 mixed ANOVA with Group (TD/BPS) as between-subjects factor, Stimulus as within-subjects factor, and pain expectancy in the test phase as dependent variable. Furthermore, to compare both groups in their blocking effect we computed difference scores with pain expectancies for B-X in the test phase and then computed between subjects *t*-tests.

Table 3
Clinical variables for the Best Possible Self and Typical Day group separately.

Variables [range]	BPS		TD			
	M	*SD*	*M*	*SD*	*t*	*p*
Pain intensity [a] [0; 10]	6.56	1.55	6.46	1.52	0.42	.675
Pain severity [0; 30]	20.44	4.66	20.42	4.31	0.02	.984
Depression [0; 27]	14.71	5.27	15.27	4.42	0.72	.470
Pain Catastrophizing [0; 52]	26.07	12.72	25.99	10.50	0.04	.965
Positive future expectancies [7; 70]	37.58	11.70	38.53	11.15	0.52	.601
Negative future expectancies [7; 70]	39.81	11.63	40.19	9.83	0.22	.824
Optimism (trait) [0; 12]	6.81	3.12	6.74	2.94	0.14	.890
Pessimism (trait) [0; 12]	5.64	2.94	5.75	2.53	0.25	.802
Positive affect [10; 50]	25.32	6.51	25.49	6.85	0.17	.867
Negative affect [10; 50]	21.30	9.75	20.86	8.05	0.31	.755

Note. BPS = Best Possible Self group; TD = Typical Day group; M = Mean; SD = Standard deviation; df = 156; [a] Mean pain intensity in last seven days, item from Graded Chronic Pain Scale-Revised; Pain severity was measured with the PEG-Scale = Questions 3–5 of the Graded Chronic Pain Scale-Revised; Depression, Patient Health Questionnaire (PHQ-9); Pain catastrophizing, Pain Catastrophizing Scale; Optimism and Pessimism (trait), Life Orientation Test; Positive and negative future expectancies (state optimism and pessimism), Future Expectancies Scale; Positive and negative affect, Positive and Negative Affect Schedule; Positive and negative future expectations as well as positive and negative affect presented here comprise pre-intervention scores.

When homogeneity of covariances was violated, we ran robust ANOVAs. Further, we applied the Greenhouse-Geisser procedure in case of violation of sphericity. To calculate our planned contrasts, we performed simple *t*-tests and controlled for multiple testing with Holm-Bonferroni corrections. If the homoscedasticity assumption was violated, we calculated Welch's t-tests. We used RStudio (RStudio Inc. Boston, MA, USA) to run all analyses.

3. Results

3.1. Hypothesis I: Does the BPS intervention change affect and future expectancies

Significant interactions for positive affect (see Fig. 3A), F (2, 312) = 3.93, $p < .05$, $\eta_p^2 = .02$, $\varepsilon = .89$, negative affect (see Fig. 3B), F (2, 312) = 3.37, $p < .05$, $\eta_p^2 = .02$, $\varepsilon = .77$, positive future expectancies (see Fig. 3C), F (2, 312) = 4.19, $p < .05$, $\eta_p^2 = .03$, $\varepsilon = .71$, and negative future

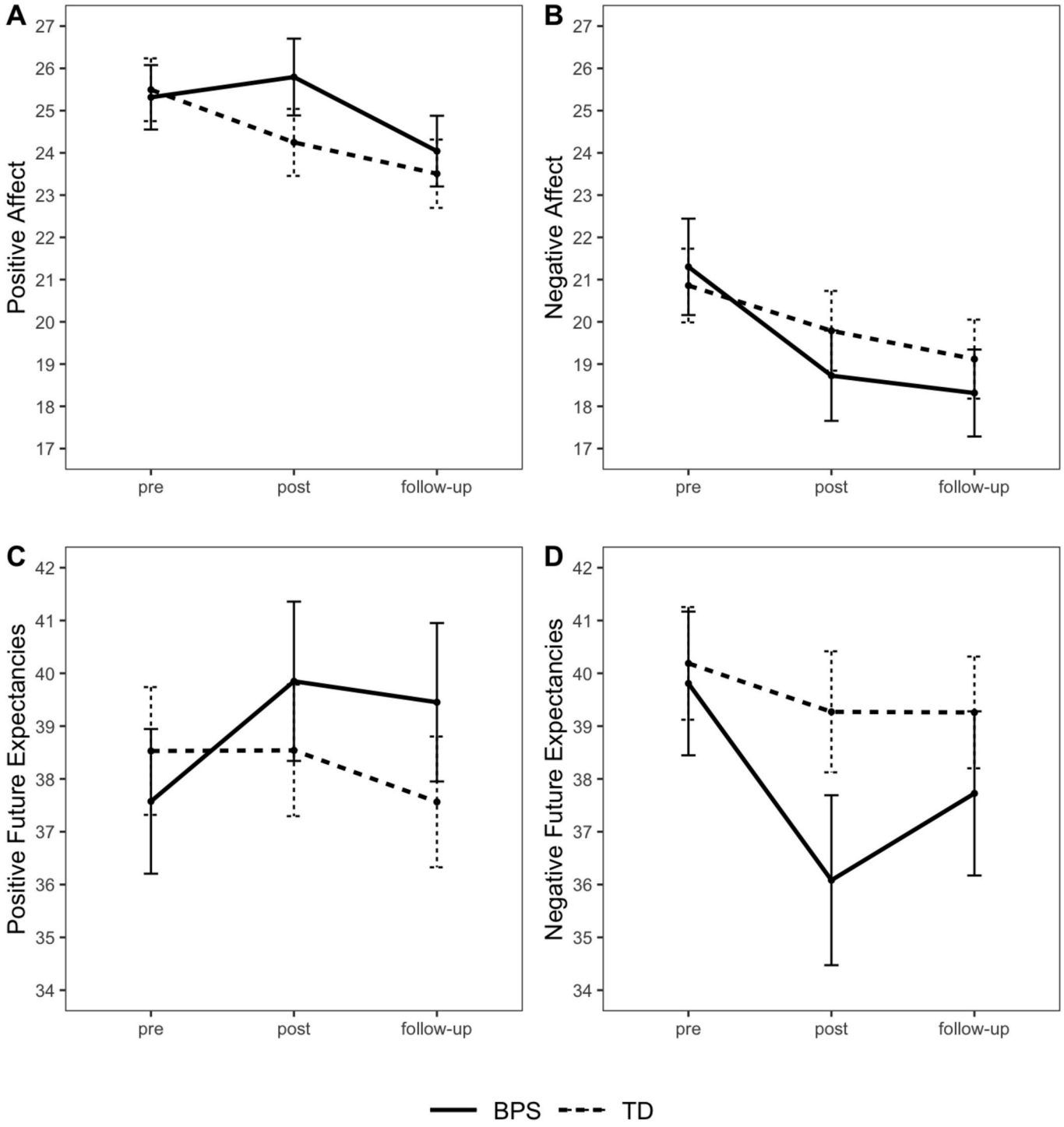

Fig. 3. Mean (A) Positive affect ratings (scale from 0 to 50), (B) Negative affect ratings (scale from 0 to 50), (C) Positive Future Expectancies ratings (scale from 0 to 70), (D) Negative Future Expectancies (Scale from 0 to 70) at pre-intervention, post-intervention and at follow-up for participants in the Best Possible Self (BPS) and in the Typical Day (TD) group separately. Error bars represent SEM's.

expectancies (see Fig. 3D), F (2, 312) = 3.51, $p < .05$, $\eta_p^2 = .02$, $\varepsilon = .84$, were found.

As expected, participants in the BPS group showed an increase in positive future expectancies directly after the intervention compared to pre-intervention, t (72) = 2.18, $p = .016$, $d = .26$, while participants in the TD did not, t (84) = 0.02, $p = .986$. Comparing the change scores in positive future expectancies (post-pre intervention) between both groups, we found significantly higher increases in positive future expectancies in the BPS group than in the TD group, F (1, 156) = 7.32, $p <$ .01, $\eta_p^2 = 0.02$.

However, there was no significant increase of positive affect scores immediately after the intervention in the BPS group, t (72) = 0.96, $p =$ .170, but a decrease in positive affect for participants in the TD control group, t (84) = 3.07, $p < .01$, $d = 0.33$. Comparing both groups in their change scores from pre-to post-intervention, a significant difference emerged with higher changes in the TD group than in the BPS group, F *(1,156) = 7.32, p* < .01, $\eta_p^2 = 0.05$.

Furthermore, contrasts revealed a decrease in negative future expectancies for participants in the BPS group, t (72) = 3.64, $p < .001$, $d =$ .43, directly after the intervention, which was in contrast to participants in the TD with no decrease in negative future expectancies, t(84) = 1.33, $p = .188$. These results were underpinned by analyses comparing the change scores in negative future expectancies from pre-to post-intervention, with higher decreases in negative future expectancies in the BPS than in the TD group, *F(1,156) = 5.43, p < .05,* $\eta_p^2 = 0.03$.

Unexpectedly, participants had a significant decrease in negative affect directly after the intervention both in the BPS group, t (72) = 5.22, $p < .001$, $d = 0.61$, and in the TD group, t (84) = 2.32, $p < .05$, $d = 0.25$. Further analyses comparing the change scores in negative affect from pre-to post-intervention revealed that negative affect reduction was greater in the BPS than in the TD group, *F(1,156) = 7.32, p < .05,* $\eta_p^2 =$ 0.05.

To summarize, participants that underwent the BPS intervention had an increase in positive future expectancies (but not in positive affect) as well as a decrease in negative future expectancies and negative affect directly after the intervention. Participants that described their typical day displayed a decrease in positive and negative affect at post-intervention but did not change their future expectancies.

3.2. Hypothesis II: Does the BPS group show increased selective learning compared to the TD group

3.2.1. A priori pain beliefs

Analyses on participants' a priori beliefs highlighted that there was no interaction of Group and Stimulus Type, F (3, 468) = 1.61, $p = .185$, in the pre-rating phase, confirming that the two groups did not significantly differ in their a priori pain expectancies for the used stimuli. Furthermore, the analyses did not identify significant main effects for Group or Stimulus, both p's > .05.

3.2.2. Baseline differences

Before the intervention, there were no differences in any clinical or outcome variable (positive affect, positive future expectancies, negative future expectancies, and negative affect, all p's > 0.60) comparing participants of the TD with participants of the BPS. In the same vein, there were no trait differences in optimism and pessimism (assessed with the LOT-R) before the intervention, both p's > 0.80 (see Table 3). Therefore, we did not include any control variables in our analyses.

3.2.3. Manipulation checks

3.2.3.1. Elemental acquisition phase. As expected, the Stimulus x Trial

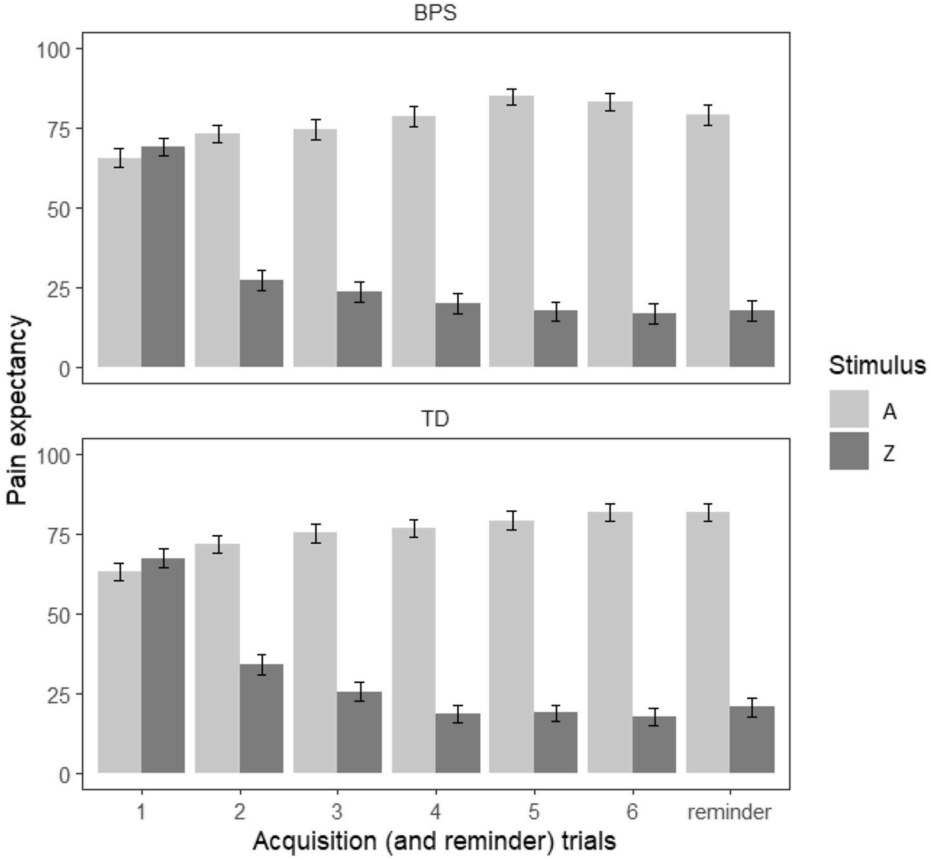

Fig. 4. Mean pain expectancy ratings for A+ and Z-during acquisition and reminder of acquisition phase for each trial and participants in the Best Possible Self (BPS) and in the Typical Day (TD) group separately. Error bars represent SEM's.

interaction was significant, F (5, 1560) = 145.98, $p < .001$, $\eta_p^2 = .32$, $\varepsilon = .82$, indicating that pain expectancy for A+ increased over time, while Z- decreased over the course of this phase (see Fig. 4). Furthermore, there was no modulation of this interaction by Group, suggesting that participants in the TD and the BPS group did not show a different acquisition pattern. On the first trial, participants did not differ in their A+ vs. Z- ratings neither in the BPS nor in the TD group. By contrast, on the last trial, participants in the BPS group, t (72) = 15.31 $p < .001$, $d = 1.91$ as well as participants in the TD group, t (84) = 14.81, $p < .001$, $d = 1.61$, displayed higher pain expectancy for A+ than they did for Z-. Taken together, these analyses confirm differential acquisition of pain expectancies during the elemental acquisition phase.

3.2.3.2. Compound acquisition phase. Analyses yielded a significant Stimulus x Trial interaction, F (10, 1560) = 21.27, $p < .001$, $\eta_p^2 = .11$, $\varepsilon = .65$, indicating that ratings evolved differently for the three stimuli over the course of this phase (see Fig. 5A). The interaction was not modulated by Group, F (10, 1560) = 0.79, $p = .589$, $\eta_p^2 = .005$, $\varepsilon = .65$. Planned contrasts revealed that, by the end of the compound acquisition phase (i.e. on the last trial), participants showed higher AX + ratings than Z-ratings in the BPS group, t (72) = 23.10, $p < .001$, $d = 2.70$, and in the TD group, t (84) = 21.04, $p < .001$, $d = 2.28$. Similarly, B+ ratings were higher than Z-ratings on the last trial, both in the BPS group, t (72) = 16.24, $p < .001$, $d = 1.90$, and in the TD group, t (84) = 16.84, $p < .001$, $d = 1.83$. These analyses corroborate differential acquisition of pain expectancies for the different stimuli in both groups during the compound acquisition phase.

3.2.4. Test phase

Our main analyses did not identify an interaction of Group and Stimulus, F (2, 312) = 1.49, $p = .228$, $\varepsilon = .93$ (see Fig. 5B). The main effect of Group also failed to reach significance, F (1, 156) = .18, $p = .671$. However, there was a significant main effect of Stimulus, F (2, 312) = 365.96, $p < .001$, $\eta_p^2 = .70$, $\varepsilon = .94$. Pain expectancy for B was significantly higher than for Z, t (157) = 24.87, $p < .001$, $d = 1.99$. Similarly, pain expectancies for X were significantly higher than for Z in the test phase, t (157) = 19.40, $p < .001$, $d = 1.55$. A noteworthy result to emerge from the data is an overall blocking effect for the total sample, t (157) = 4.15, $p < .001$, $d = .33$, with higher B than X pain expectancy judgments in the test phase. Contrary to our hypothesis, participants of the BPS group did not differ from those in the TD group in their blocking effect magnitude (difference score B-X as dependent variable), t (156) = 1.92, $p = .057$. Despite the non-significant Stimulus x Group interaction and the lack of difference in blocking magnitude between the groups, we continued testing the difference between B and X within each group. Results revealed a significant blocking effect in the TD group, t (84) = 4.00, $p < .001$, $d = .43$, but not in the BPS group, t (72) = 1.64, $p = .106$, suggesting that, if anything, the TD group is driving the overall blocking effect in the entire sample.

3.3. Correlations between clinical and control variables and selective learning

Further exploratory analyses were computed to identify possible correlations between clinical and control variables and the magnitude of selective learning (B-X). Noteworthy, these analyses suggest that people affected by higher levels of pain severity (measured with the PEG-Scale) display less selective learning, $r_s = -.16$, $p < .05$. However, including pain severity as covariate in the ANOVA analyses of the test phase did not change the results. To test whether the intervention only worked for those with higher levels of pain severity, we dichotomized pain severity at the median (i.e., 21) and computed another 2 x 2 ANOVA with group (BPS/TD) and pain severity (< than the median/≥ than the median) as between-subjects factors and selective learning (B-X) as dependent variable. Yet, the interaction did not reach significance, F (1, 2564) = 2.94, $p = .088$. Also, the main effects of pain severity, F (1, 2428) = 2.79, $p = .097$, and group, F (1, 3279) = 3.765, $p = .054$, remained insignificant. An overview of other (non-significant) correlational analyses can be found in the supplementary material (see Table 3S).

4. Discussion

To our knowledge, this is the first study to investigate resilience factors and their effects on selective learning in a chronic pain population. Particularly, we aimed to experimentally enhance state positive affect and positive future expectancies (as a proxy for state optimism) by the application of the BPS exercise. We hypothesized that (1) we would be able to manipulate affect and future expectancies through the intervention increasing state positive affect and positive future expectancies in the BPS group compared to the active control group and that (2) participants that underwent the BPS intervention would show more selective learning than participants in the TD control group. Overall, our results offer compelling insights for implementing the widely used BPS intervention in an online format (video-guided, single-session) for participants with FM. The intervention led to interactions in all outcome variables (positive and negative affect as well as positive and negative future expectancies) comparing the BPS and the TD group, with

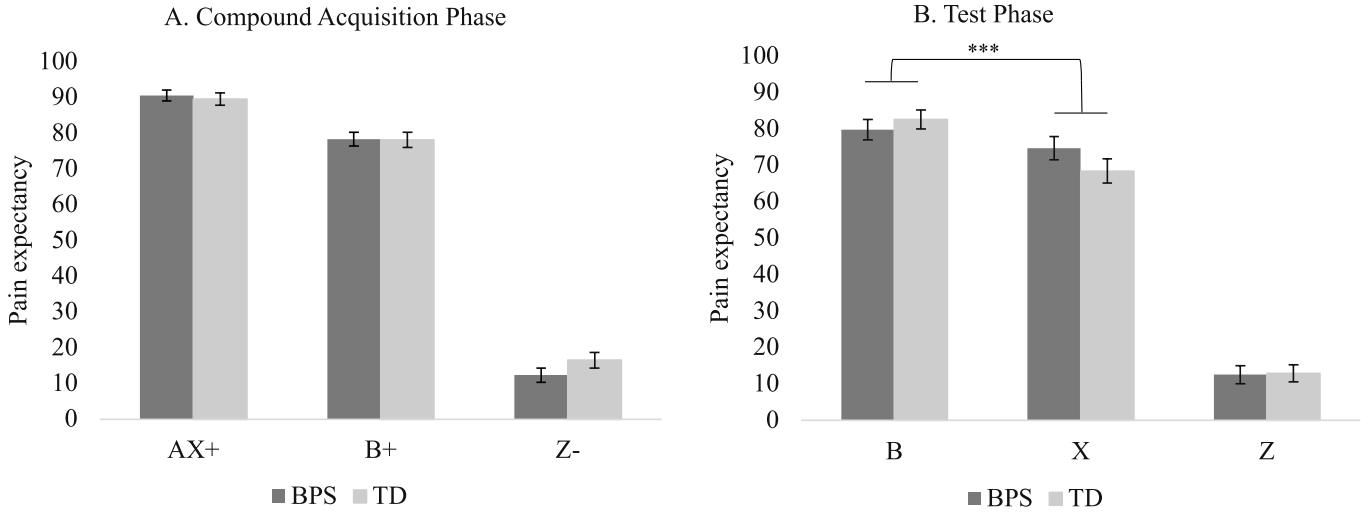

Fig. 5. Mean pain expectancy ratings (A) for AX+, B+ and Z-during the compound acquisition phase, (B) for B, X and Z at test for participants in the Best Possible Self (BPS) and in the Typical Day group (TD) separately. Error bars represent SEM's.

promising effects for the induction of positive future expectancies. Further, this study provided evidence for some degree of selective learning in people with FM as a small overall blocking effect was observed across the entire sample. However, increased state optimism did not boost selective learning.

As hypothesized, the intervention led to an increase in positive future expectancies in the BPS immediately after the intervention, compared to the TD group. Previous research in people affected by FM failed to produce this effect even in-person (Molinari et al., 2018). Possibly, the adaptation of the intervention for pain patients promoted the effect. Yet, the BPS intervention was not powerful enough to significantly increase positive affect. One explanation might be that people with chronic pain need stronger or longer interventions or additional in-person instructions to show enhancements in positive affect (Molinari et al., 2018; Peters et al., 2017). This might hold especially for fibromyalgia with distortions in positive (but not in negative) affect (Finan et al., 2009; Galvez-Sánchez et al., 2018). In general, the intervention becomes more effective when applied in person (Heekerens & Eid, 2020) and repetitively (Loveday et al., 2018). Further, participants who described their typical day indicated a reduction of positive affect after the intervention. Also, all participants displayed a decrease in negative affect after the intervention. Even though the typical day exercise is a widely used control condition (Boselie et al., 2017; Geschwind et al., 2015; Hanssen et al., 2013; Heekerens & Eid, 2020) our results indicate that it might not be neutral to control for affect induction in the context of pain and especially during the COVID-19 pandemic. Yet, negative future expectancies were reduced in the BPS, but not in the TD group.

Within the scope of this study, we were also able to replicate the successful acquisition of differential pain expectancies in people affected by FM (Meulders et al., 2015, 2018). Further, and in contrast to previous research (Meulders et al., 2018), a small but significant blocking effect across the entire sample emerged from our data. Hence, these results demonstrated that FM patients show some degree of selective learning. Nevertheless, we cannot make a claim if it is reduced compared to a healthy population. In contrast to the preceding study, we mainly recruited through social media and therefore might have targeted a less disabled FM population. Yet, pain severity scores were rather high, suggesting that our sample suffered from moderate to severe pain on average. Further, around 90 % of the participants indicated high impact chronic pain (von Korff et al., 2020). Although, possibly other factors (that were not assessed) may influence disability. Correlational analyses offer compelling support that selective learning is associated with pain-related disability, with a negative correlation between pain severity and the magnitude of selective learning.

Crucially, we did not find support for our main hypothesis that selective learning would be increased in participants with increased positive affect and future expectancies. In contrast with our hypothesis, the overall blocking effect across groups, seems to be driven by the TD group, not the BPS group. One potential explanation is that the blocking effect might be context-dependent. Indeed, the elemental learning phase and the conditions under which the acquisition occurred may be relevant (e.g. emotional states and mood can function as a context (e.g. Lattal, 2007)). Contextual learning might affect cue competition (e.g. Boddez et al., 2011, in human learning; Miguez & Miller, 2022, in rats). From this perspective, the BPS might act as a context shift, which could explain the reduced blocking effect. However, to control for this potential context switch effect, we have included the reminder of acquisition phase in our design after the affect manipulation. There were no differences between the BPS and the TD groups comparing the pain expectancies for A+ during the last trial of acquisition compared to the reminder of acquisition trial, (Group x Trial interaction: $F(1, 156) = 0.79$, $p = .38$), suggesting that the affect intervention did not serve as a context switch and therefore probably does not explain the lack of blocking in the BPS group. Nevertheless, we cannot discard that a different timing of the intervention would have produced different results. Future research should further scrutinize the effects of the timing of the intervention.

Our findings are in line with those of Boselie et al. (2018), who failed to replicate the buffering effects of resilience factors in executive task performance observed in healthy samples in a chronic pain population. In the same vein, it is possible that resilience factors improve adaptive learning mechanisms in healthy samples in the face of pain (Geschwind et al., 2015), but that this cannot be easily extended to chronic pain or more extensive and longer interventions are needed. Due to the absence of positive affect changes, it cannot be ruled out that higher increases of positive affect might modulate selective learning. Because of the potential buffering role against deficient safety learning, overgeneralization, and relapse in chronic pain (Jenewein et al., 2013; Koenig et al., 2021; Meulders et al., 2015, 2017; Meulders, Harvie, et al., 2014; Riecke et al., 2020), future research should continue to investigate positive affect in chronic pain populations.

A few limitations should be discussed as well. First, a potential confound is that we had limited control over the test context and conditions (e.g., noise, technical problems, inattention), because we used an online procedure and patients participated from home. However, a similar online procedure was successfully used in a previous study (Meulders et al., 2018). Moreover, we intended to recreate the laboratory situation by implementing video guidance by a virtual experimenter and all patients confirmed that they had 1 h available to participate in the study without any interference or help. Another limitation is that affect changes also occurred in the control condition. Possibly, this was a result of 1) the reduced behavioral activity radius due to the COVID-19 pandemic which might have resulted in lower positive affect when describing and visualizing the typical day, and in contrast 2) behavioral activation through the intervention which might have led to lower negative affect (Molinari et al., 2018). Even though the description of a typical day is a common control condition, future studies might consider alternatives with e.g. description of places or early memories as a control group (Heekerens & Eid, 2020). Finally, the generalizability of our results is limited. We have not controlled for overshadowing and therefore, cannot rule out other non-associative processes. Possibly expectancy decreased when a cue was presented for the first time without the other cue because of uncertainty. Yet, with the current design we did not want to make strong claims about the nature of the non-selectivity in fibromyalgia patients, being associative blocking or another mechanism potentially leading to non-selectivity of conditioned pain expectancy judgements (e.g., uncertainty). From a clinical perspective, both may negatively affect pain-related outcomes and disability. Future studies could consider adding more/other control cues. For example, it could be interesting to test for A as well and/or add a combination of novel cues in the compound acquisition phase (CD+) and test them separately to control for overshadowing.

Furthermore, our sample comprised mostly female participants (which is common in studies with FM (Wolfe et al., 2018)) and medical FM diagnoses were self-reported. Further research needs to be carried out in other (more male-dominated) pain populations and in which medical diagnosis validation is considered to improve the external validity of our results for chronic pain populations in general. Nevertheless, people affected by FM are understudied and our study adds valuable findings to the scarce research body with a well-characterized sample.

Our findings may have clinically relevance. During the global COVID-19 pandemic, online treatment formats gained popularity and interest. Interventions used in online studies might serve as a blueprint for potential real-life micro-interventions. They bear the potential to extend the reach of therapeutics due to their low-threshold access and cost-effectiveness (Andersson & Titov, 2014; Baumel et al., 2020; Hedman et al., 2012). Thus, online studies might convey greater external validity despite potentially lower reliability. In our study, it is remarkable, that a single-session online intervention was able to improve positive future expectancies in people with FM. Furthermore, extending the BPS effectiveness for an older (than typical student) sample offers interesting insights as it has been highlighted that optimism in pain is

more beneficial with higher age (Basten-Günther et al., 2018). Increasing positive future expectations in patients could help to enhance their commitment to therapy by a more flexible goal pursuit and adjustment while prioritizing valued life goals (Boselie & Vlaeyen, 2017; Ramírez-Maestre et al., 2019). Further, it has been highlighted that positive affect in the treatment of anxiety disorders could help to improve exposure therapy and extinction learning (Zbozinek & Craske, 2017b). Due to similar underlying learning mechanisms, there is an intriguing chance that exposure-based therapies for chronic pain might also benefit from increasing resilience (Gatzounis et al., 2021). Moreover, previous research has indicated that improving positive affect was associated with a lower symptom burden in people affected by FM (McAllister et al., 2015).

In conclusion, this study widens our knowledge on the feasibility of the use of the BPS intervention in people affected by FM and thereby helps to gain a better understanding of the role of resilience factors in chronic pain conditions which is a promising, but neglected area in the field of pain (Basten-Günther et al., 2018; Casale et al., 2019; Flink et al., 2020; Goubert & Trompetter, 2017; Hanssen et al., 2017). We have managed to enhance resilience factors (i.e., positive future expectancies) in people affected by FM by a single-session online intervention. Yet, based on our study we recommend higher intervention dosage when positive affect is of interest. Further, successful acquisition of pain expectancies was replicated and our data suggested that people affected by fibromyalgia show some degree of selective learning as a blocking effect was demonstrated. However, the positive psychology intervention did not increase the magnitude of the blocking effect, which seems largely driven by the control group Nevertheless, we believe that more research is necessary to further unravel the potential beneficial effects of resilience factors on learning mechanisms in chronic pain. For instance, future studies could examine if exposure therapy can be improved by increasing resilience. On a wider level, chronic pain treatment might benefit from a comprehensive approach of combining both risk and resilience factors which should be subject to further investigation.

CRediT authorship contribution statement

Tabea Kloos: Writing – original draft, Visualization, Methodology, Investigation, Formal analysis, Data curation, Conceptualization. **Fernando Blanco:** Writing – review & editing, Software, Methodology, Formal analysis. **Winfried Rief:** Writing – review & editing, Methodology, Conceptualization. **Ann Meulders:** Writing – review & editing, Validation, Supervision, Methodology, Conceptualization. **Jenny Riecke:** Writing – review & editing, Validation, Supervision, Methodology, Conceptualization.

Disclosures

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Declaration of competing interest

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Appendix A. Supplementary data

Supplementary data to this article can be found online at https://doi.org/10.1016/j.brat.2025.104748.

The data that support the findings of this study are available on request from the corresponding author, AM. The data are not publicly available due to their containing information that could compromise the privacy of research participants.

Data availability

Data will be made available on request.

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