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Die Entstehung, Aufrechterhaltung und Therapie chronischer Schmerzen im Kontext von Erwartungsverletzungen

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Abkürzungsverzeichnis

CS	*conditioned stimulus* (deutsch: konditionierter Stimulus)
IASP	*International Association of Pain Study*
ICD 11	*International Classification of Diseases 11*
KVT	Kognitive Verhaltenstherapie
RCT	*Randomized Controlled Trial* (deutsch: randomisiert kontrollierte Studie)
US	*unconditioned stimulus* (deutsch: unkonditionierter Stimulus)

1 Zusammenfassung und Abstract

1.1 Zusammenfassung

Erwartungen in Form von befürchteter Schädlichkeit von Bewegungen (*‚threat beliefs'*) wird bei der Entstehung und Aufrechterhaltung chronischer Schmerzen eine entscheidende Rolle zugeschrieben und können einen Ansatzpunkt zur Optimierung von Expositionstherapie darstellen. Der Einfluss von Erwartungen und Erwartungsveränderungen ist im Zusammenhang mit chronischen Schmerzen bislang nur unzureichend verstanden. Das Ziel der vorliegenden Dissertation war es daher den Einfluss von Erwartungen auf die Entstehung und Aufrechterhaltung von chronischen Schmerzstörungen und die Nutzbarmachung von Erwartungen in der psychologischen Schmerztherapie zu untersuchen.

Mit einer längsschnittlichen prospektiven Befragung von PatientInnen mit akuten Schmerzen ($N = 30$) wurde untersucht, ob selbstkonzeptrelevante Erwartungen die Entstehung chronischer Schmerzstörungen begünstigen (Studie I). Die Befürchtung, aufgrund der Schmerzen nicht den eigenen Ansprüchen gerecht zu werden (= Selbstverstrickung), sagte die Schmerzbeeinträchtigung drei Monate später über den Einfluss von Katastrophisierung und Schmerzangst hinaus vorher.

In einem experimentellen Paradigma mit längsschnittlicher Erweiterung (Studie II) wurde an ProbandInnen mit subklinischen Schmerzstörungen ($N = 73$) untersucht, ob induzierte schmerzbezogene Erwartungen durch wiederholte gegenteilige Erfahrung angepasst werden. ProbandInnen, die eine Schmerzsteigerung erwarteten, berichteten eine größere Erwartungsverletzung durch die sinkenden Hitzereize als ProbandInnen, die eine Schmerzreduktion erwarteten. Entgegen unserer Hypothese zeigte sich eine stärkere Erwartungsanpassung in der Gruppe, die eine Schmerzreduktion erwartete. Unabhängig von der experimentellen Bedingung korrelierte die Stärke der Erwartungsverletzung mit einer Erwartungsveränderung und einer Generalisierung der Lernerfahrung auf Selbstwirksamkeitserwartungen.

In einer dritten, ebenfalls experimentellen und längsschnittlichen Studie (III) mit gesunden weiblichen Probandinnen ($N = 116$) untersuchten wir, ob sich die Wirksamkeit und Ökonomie von Schmerzkonfrontationen durch eine therapeutische Anleitung zur Erwartungsüberprüfung im Vergleich zur therapeutischen Anleitung zur Habituation optimieren lassen. Während das Expositionskriterium in der Erwartungsüberprüfungsbedingung nach deutlich weniger Durchgängen erreicht wurde als in der Habituationsbedingung, unterschieden sich die beiden Bedingungen nicht bezüglich der Veränderung in schmerzbezogenen Zielgrößen (Schmerztoleranz und kognitiver Bewältigung), weder direkt im Anschluss noch eine Woche später.

Zusammenfassend liefern die Ergebnisse des vorliegenden Dissertationsprojekts Hinweise dafür, dass Erwartungen in Form von Befürchtungen eine relevante Rolle bei der Entstehung und Aufrechterhaltung chronischer Schmerzstörungen durch Beeinflussung der Schmerzwahrnehmung und Persistenz gegenüber gegenteiligen Erfahrungen spielen. Gleichzeitig scheint eine direkte Adressierung idiosynkratrischer Befürchtungen und die therapeutische Anleitung zur Befürchtungsüberprüfung expositionsbasierte Ansätze optimieren zu können. Daraus ergeben sich relevante Hinweise für Optimierung von Prävention und Intervention von chronischen Schmerzstörungen (z.B. durch Ansätze zur kognitiven Vorbereitung der Exposition).

1.2 Abstract

Expectations regarding the harmfulness of movements (threat beliefs) play a crucial role in the formation and maintenance of chronic pain and thus pose a starting point for optimizing exposure therapy. The role of expectations in the context of chronic pain and how changes in pain-related expectations are processed is not well understood yet. The aim of this dissertation was therefore to investigate the influence of expectations on the formation and maintenance of chronic pain conditions and the utilization of expectations in psychological treatment for chronic pain.

In a longitudinal prospective survey, the influence of expectations concerning one's self-concept in the development of chronic pain disorders was examined in patients with acute pain ($N = 30$). The expectation of not being able to meet one's own expectations due to the pain (= self-enmeshment with pain) predicted pain-related disability after three months over and above pain catastrophizing and pain-related fear.

In an experimental paradigm with a longitudinal follow-up, subjects with subclinical pain disorders ($N = 73$) were examined to study whether pain-related expectations were adjusted when disconfirming experiences are made repeatedly. Participants who expected increasing pain reported a greater expectation violation due to decreasing heat stimulus than participants who expected decreasing pain. Contrary to our hypothesis, a stronger expectation adjustment was found in the group with induced lower initial expectations. Regardless of the experimental condition, the extent of the expectation violation correlated with an expectation change and a generalization of the learning experience to a generalized pain-related self-efficacy.

In a third, also experimental and longitudinal study with healthy female subjects ($N = 116$), we investigated whether the efficacy and cost-effectiveness of pain exposure can be optimized by a therapeutic instruction based on expectation violation compared to a therapeutic instruction based on habituation. While the exposure criterion in the expectation violation condition was achieved after significantly fewer sessions than in the habituation condition, the two conditions did not differ with respect to change in pain-related outcome measures (pain tolerance and cognitive coping). The effect was stable over a one-week follow-up.

In sum, the results of the present dissertation provide evidence that expectations are relevant in the formation and maintenance of chronic pain conditions by influencing pain perception and persistence against disconfirming experiences. Directly addressing idiosyncratic threat beliefs and therapeutic guidance to test those beliefs seems to optimize exposure-based approaches. Relevant implications for prevention and intervention can be drawn (e.g., for the need of cognitive interventions prior to exposure).

2 Theoretischer Hintergrund

2.1 Relevanz chronischer Schmerzen

Während fast jeder im Laufe seines Lebens Rückenschmerzen erlebt (Balagué, Mannion, Pellisé, & Cedraschi, 2012), entwickelt sich bei ungefähr jedem fünften Betroffenen ein chronischer Verlauf (Henschke, Kamper, & Maher, 2015). Laut der kürzlich aktualisierten Definition der *International Association of Pain Study* (*IASP*) für die aktualisierte *International Classification of Diseases* (ICD 11; Nicholas et al., 2019; Treede et al., 2015; Treede et al., 2019) soll chronischer primärer Schmerz diagnostiziert werden, wenn Schmerz in mindestens einer anatomischen Region: (I) über einen Zeitraum von drei Monaten anhält bzw. wiederkehrt, (II) mit erheblichem emotionalem Leid (z.B. Angst, Ärger, Frustration, depressiver Stimmung) und/oder einer erheblichen funktionalen Beeinträchtigung (in täglichen Aktivitäten und sozialer Teilhabe) einhergeht und (III) die Symptome nicht besser durch eine andere Diagnose erklärt werden können.

Angaben zur Prävalenz chronischer Schmerzen schwanken aufgrund bislang unzureichender einheitlicher Klassifikationen zwischen 2% bis 50%, meistens liegen sie bei 20% (Breivik, Collett, Ventafridda, Cohen, & Gallacher, 2006; Reid & Harker, 2011; Steingrímsdóttir et al., 2017). Einheitlicher scheint der Befund, dass Frauen häufiger betroffen sind als Männer (Breivik et al., 2006; Friessem, Willweber-Strumpf, & Zenz, 2009; Henschke et al., 2015) und jeder zweite von chronischen Schmerzen Betroffene unter Rückenschmerzen leidet (Breivik et al., 2006). Akute Schmerzen im unteren Rücken treten mit steigendem Alter häufiger auf (Macfarlane, 2016), am häufigsten im frühen bis mittleren Erwachsenenalter (20-55 Jahre; Balagué et al., 2012).

Viele Betroffene berichten Schmerzverschlimmerung im Zusammenhang mit alltäglichen Aktivitäten und Beeinträchtigungen durch die Schmerzen in allen Lebensbereichen. Jeder zweite bis vierte Betroffene berichtet Schwierigkeiten einer regelmäßigen Arbeit nachzugehen, sexuelle Beziehungen zu führen und/oder Auto zu fahren (Breivik et al., 2006). Das globale Ausmaß des durch chronische Schmerzen verursachten Leids wird durch die Einschätzung als Störung mit den größten Einschränkungen gemessen durch *‚years lived with disability‘* deutlich (Buchbinder et al., 2013; Hoy et al., 2012; Murray et al., 2012; Wu et al., 2020).

Aus der hohen Prävalenz und den einschneidenden Beeinträchtigungen ergeben sich ein hoher motivationaler Antrieb zur Schmerzlinderung auf Seiten der Betroffenen (Navratilova & Porreca, 2014) und folglich immense gesellschaftliche und wirtschaftliche Kosten durch Inanspruchnahme des Gesundheitssystems (Friessem et al., 2009; Reid & Harker, 2011) und

Arbeitsausfälle (50 Milliarden Euro jährlich, ca. 2% des Bruttoinlandprodukts; Wenig, Schmidt, Kohlmann, & Schweikert, 2009). Die wirtschaftlichen Kosten, die im Zusammenhang mit chronischen Schmerzen entstehen, übersteigen die Kosten anderer weit verbreiteter Krankheiten wie Herzkrankheiten, Krebs und Diabetes in den USA (Gaskin & Richard, 2012).

2.2 Erklärungsmodelle chronischer Schmerzen

Betrachtet man, wie unterschiedlich Menschen auf denselben nozizeptiven Reiz reagieren, wird deutlich, dass Schmerzempfinden ein komplexes individuelles Geschehen ist und dies in Erklärungsmodellen zu chronischen Schmerzen abgebildet werden sollte. Die Dauer oder Stärke der Schmerzen allein erklärt weder, wer eine chronische Schmerzstörung entwickelt, noch die enorme Beeinträchtigung, die viele Betroffene erleben (Gatchel, Peng, Peters, Fuchs, & Turk, 2007). Um sich von zu kurz greifenden Störungsmodellen zu distanzieren, die suggerieren, dass Schmerz nur mit erkennbarer medizinischer Ursache auftreten kann, werden seit den 1990er-Jahren in Störungsmodellen neben rein physiologischen Aspekten auch psychologische und behaviorale Mechanismen berücksichtigt (Verhaak, Kerssens, Dekker, Sorbi, & Bensing, 1998). In modernen biopsychosozialen Modellen wird die Beeinträchtigung durch den Schmerz als dynamische multifaktorielle Interaktion zwischen physiologischen, medizinischen, psychologischen und sozialen Faktoren betrachtete (Edwards, Dworkin, Sullivan, Turk, & Wasan, 2016).

Im Rahmen der kognitiven Verhaltenstherapie wird chronischer Schmerz als eine dysfunktionale Anpassung an veränderte situative Gegebenheiten verstanden (Meulders, 2020). Im Folgenden soll das ‚Fear-Avoidance Model' vorgestellt werden, das eine Erklärung für die paradoxen Konsequenzen von Schonverhalten liefert: Während Schonung für die Heilung mancher akuter Schmerzursachen förderlich sein kann, sie bei länger andauernden Schmerzzuständen das Leid gravierend verschärfen (Linton, Flink, & Vlaeyen, 2018).

2.2.1 ‚Fear-Avoidance Model'

Das einflussreichste kognitiv-behaviorale Erklärungsmodell – das ‚Fear-Avoidance Model' (deutsch: Angst-Vermeidungsmodell) wurde 2000 von Johan Vlaeyen und Steven Linton zur Anregung von Praxis und Forschung entwickelt (Vlaeyen & Linton, 2000) und seitdem mehrmals auf Grundlage neuer Erkenntnisse überarbeitet (Vlaeyen, Crombez, & Linton, 2016; Vlaeyen & Linton, 2012). Wie in Abbildung 1 dargestellt, wird in zwei gegenläufigen Prozessen beschrieben, wie die Bewertung von Schmerzen darüber entscheidet, ob Betroffene eine beeinträchtigende Schmerzstörung entwickeln oder nach kurzer Zeit ihr vorheriges Funktionsniveau zurückgewinnen: Werden Schmerzen nicht als bedrohlich wahrgenommen, wird die Person sich entsprechend des Heilungszustand wieder zunehmend mit Bewegungen konfrontieren. Nach einer kurzen Zeit verminderter Aktivität im Sinne der Schonung wird sie ihre täglichen Aktivitäten wiederaufnehmen und vollständig genesen, sobald die Schmerzursache – falls vorhanden – verheilt ist.

Werden Schmerzen infolge von Bewegungen dagegen als bedrohlich („da geht etwas kaputt“) und/oder unaushaltbar bewertet, kommt es laut ‚Fear-Avoidance Model‘ zu Vermeidung oder drastischen Einschränkung von Bewegungen und Aktivitäten, indem diese zum Beispiel nur noch unter ängstlicher Wachsamkeit für Veränderungen (= Hypervigilanz) ausgeführt werden. Ausgeprägtes Vermeidungsverhalten verhindert, dass korrigierende Erfahrungen gemacht werden können. Vermeidungsverhalten führt auf zwei Wegen zu Beeinträchtigungen: Zum einen führt sie zu einer körperlichen Dekonditionierung, die zu einem durch eine niedrigere Schmerzschwelle gekennzeichneten ‚*Disuse*‘-Syndrom führen kann (Verbunt et al., 2003). Zweitens führt die Vermeidung zur Unfähigkeit, wertorientierte Aktivitäten zu verfolgen, und geht mit einer Abnahme der positiven Verstärkung und dem Verlust sozialer Teilhabe einher. Zusammenfassend lässt sich sagen, dass die Konfrontation mit gefürchteten Bewegungen nach einer kurzen Ruhephase, in der – falls vorhanden – physiologische Schäden heilen können, als ein adaptives Verhalten angesehen wird, da es der Person schließlich ermöglicht, den Teufelskreis zu durchbrechen und sich in Richtung Angstreduktion und Erholung zu bewegen.

Im aktualisierten ’Fear-Avoidance Model‘ (Abbildung 2; Vlaeyen & Linton, 2012) haben die Autoren auf Grundlage neuer Forschungsergebnisse motivationale Aspekte berücksichtigt: Die beiden gegenläufigen Kreisläufe werden als Priorisierung von Schmerzreduktion versus Priorisierung geschätzten Lebenszielen benannt. Interpretiert eine Person Schmerzerfahrungen als bedrohlich, priorisiert sie Schmerzreduktion und vermeidet in der Folge alle Aktivitäten, die sie mit Schmerzen assoziiert. Dieser Pfad führt in eine Sackgasse aus ‚*Disuse*‘-Syndrom, Depressivität und Beeinträchtigung und setzt einen sich selbst aufrechterhaltenden Prozess in Gange. Interpretiert sie dagegen die Schmerzen als nicht bedrohlich, wird sie wertorientierte Ziele verfolgen und sich dabei mit Bewegungen und Tätigkeiten konfrontieren.

Das Modell stütz sich auf Mechanismen der klassischen Konditionierung (d.h. Assoziationslernen) zur Erklärung der schmerzbezogenen Angst und Schädlichkeitserwartungen und der operanten Konditionierung (d.h. Lernen durch Konsequenzen) zur Erklärung des Vermeidungsverhaltens. Das Vermeidungsverhalten wird durch ausbleibende befürchtete Schädigung negativ verstärkt und generalisiert so letztendlich auf viele Situationen und Bewegungen. Die Pfade des Modells wurden in experimentellen und prospektiven Studien auf ihre Gültigkeit geprüft (Pfingsten et al., 2001; Trost, France, & Thomas, 2011; Wideman, Adams, & Sullivan, 2009) und die klinische Relevanz der Vorhersagen des Modells getestet (Bailey, Carleton, Vlaeyen, & Asmundson, 2010; De Jong, Vlaeyen, Onghena, Goossens, et al., 2005; Hasenbring & Verbunt, 2010; Pincus, Smeets, Simmonds, & Sullivan, 2010).

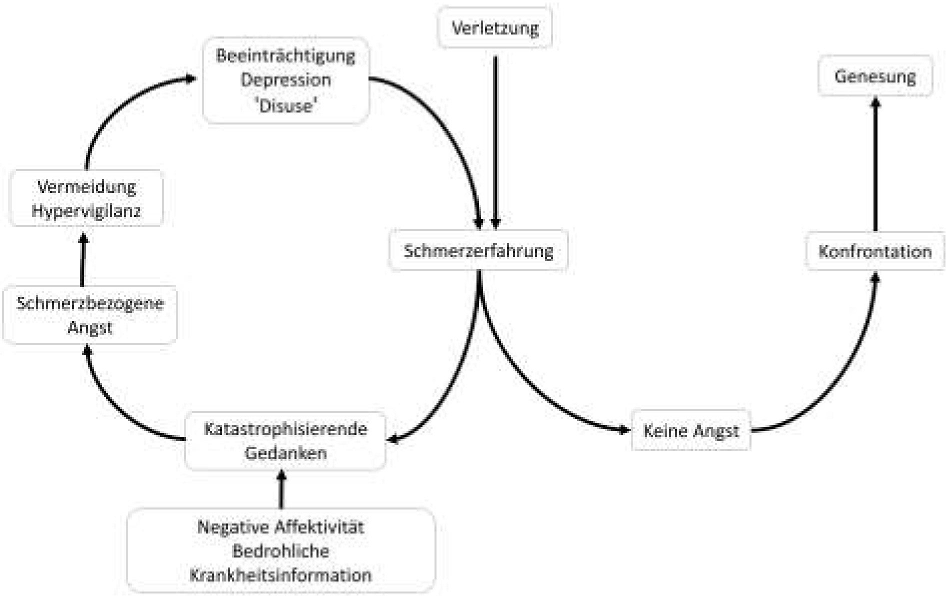

Abbildung 1. Das ‚Fear-Avoidance Model' (nach Vlaeyen & Linton, 2000).

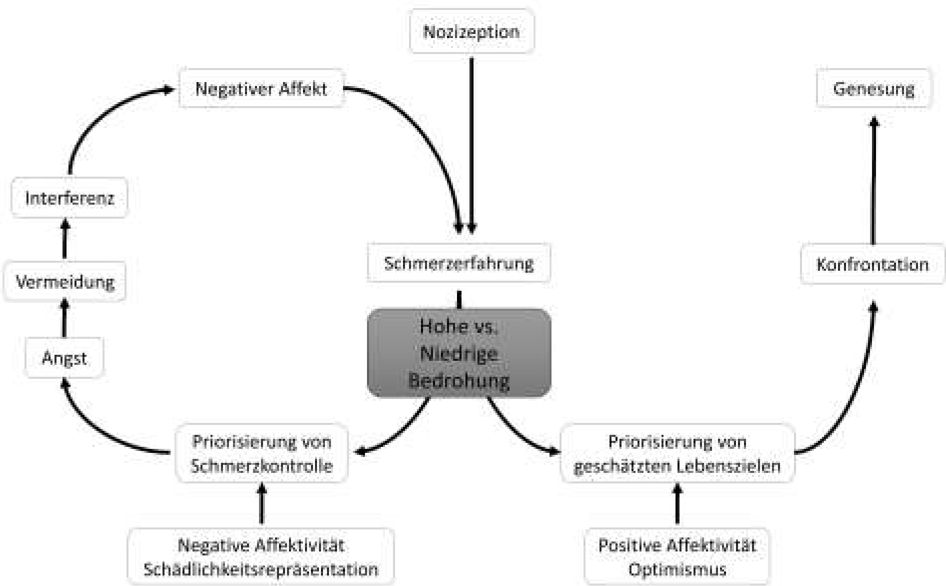

Abbildung 2. Das aktualisierte ‚Fear-Avoidance Model' (nach Vlaeyen & Linton, 2012).

2.3 Psychologische Behandlungsansätze chronischer Schmerzen

Behandlungsansätze, die sich aus der kognitiven Verhaltenstherapie (KVT) ableiten, basieren auf Lernprinzipien zur Verhaltensänderung. Ziel von psychologischer Schmerztherapie ist die Verringerung von durch den Schmerz erlebte Beeinträchtigung, Interferenz sowie Angst und des daraus resultierenden Vermeidungsverhaltens. Erlernen effektiver Bewältigungsstrategien sollte sich in einer erhöhten Selbstwirksamkeitserwartung niederschlagen (van Tulder et al., 2000). Schmerzreduktion dagegen ist kein primäres Ziel, kann allerdings in Folge der Dekonditionierung eintreten (Bailey et al., 2010; Vlaeyen et al., 2018). Laut internationaler Richtlinien sind psychologische Behandlungen pharmakologischen vorzuziehen (Qaseem, Wilt, McLean, & Forciea, 2017).

2.3.1 Wirksamkeit der Exposition *in vivo*

Expositionstherapie *in vivo* mit Reaktionsverhinderung (Vlaeyen, De Jong, Geilen, Heuts, & Van Breukelen, 2001; Vlaeyen et al., 2002) setzt direkt an den im ‘Fear-Avoidance Model‘ beschrieben Prozessen an und ist das therapeutische Pendant zur Extinktion: Durch die Konfrontation mit zuvor vermiedenen Bewegungen sollen Befürchtungen direkt überprüft werden und anhand neuer Erfahrung korrigiert werden (Vlaeyen & Crombez, 2020). Nach erfolgreicher Exposition können wertgeschätzte Tätigkeiten wieder aufgenommen werden, wodurch das Funktionsniveau und die Lebensqualität verbessert wird (Linton et al., 2018).

Bei Rückenschmerzpatienten mit erhöhter Ängstlichkeit zeigen Einzelfallstudien wiederholt eine Wirksamkeit der Expositionstherapie (Boersma et al., 2004; De Jong, Vlaeyen, Onghena, Cuypers, et al., 2005; Simons et al., 2020; Schemer, Schroeder, Ørnbøl, & Glombiewski, 2019; Vlaeyen et al., 2001). In randomisiert kontrollierten Studien (RCTs) zeigt die Expositionstherapie sich im Vergleich zu graduiertem Aktivitätenaufbau oder „klassischer“ KVT bezüglich der Reduktion von Bewegungsangst und Schädlichkeitserwartungen sowie der Zunahme von Selbstwirksamkeit überlegen (Leeuw et al., 2008; Linton et al., 2008; Woods & Asmundson, 2008). In einer älteren systematischen Übersichtsarbeit wurde keine Überlegenheit der Expositionstherapie festgestellt (Macedo, Smeets, Maher, Latimer, & McAuley, 2010), während neue systematische Übersichtsarbeiten mit metaanalytischen Befunden auf eine moderate Überlegenheit der Exposition gegenüber Physiotherapie und graduiertem Aktivitätenaufbau hinweisen (Garland & Jones, 2019; López-De-Uralde-Villanueva et al., 2016).

In einem neueren RCT konnten Glombiewski und Kollegen (2018) eine Überlegenheit von Exposition (bereits durch fünf Sitzungen) gegenüber KVT bezüglich einer größeren

Reduktion der Beeinträchtigung durch Schmerzen nachweisen. Exposition scheint daher ein ökonomischer und wirksamer Behandlungsansatz vor allem für ängstliche Schmerz-patientInnen (‚*tailored treatment*') mit großen Effektstärken (bei sorgfältiger Durchführung; Glombiewski et al., 2018) zu sein. Allerdings zeigten sich hohe Abbrecherquoten in den Expositionsbedingungen, was für eine geringe Akzeptanz des Verfahrens spricht (Glombiewski et al., 2018).

2.3.2 Wirkmechanismen der Exposition *in vivo*

Welche Mechanismen für die Reduktion psychopathologischer Symptome durch Exposition verantwortlich sind, ist bis heute nicht vollständig geklärt (de Kleine, Hendriks, Becker, Broekman, & van Minnen, 2017). Ergebnisse aus (tier-)experimentellen Studien (Ricker & Bouton, 1996; Todd, Vurbic, & Bouton, 2014) legen nahe, dass inhibitorisches Lernen statt – wie früher angenommen – einer Überschreibung des Furchtnetzwerks (z.B. Foa & Kozak, 1986; Foa, Huppert, & Cahill, 2006) entscheidend für erfolgreiche Extinktion ist (Craske, Hermans, & Vervliet, 2018). Übereinstimmend dazu zeigen klinische Beobachtungen und erste experimentelle Befunde, dass nicht ein Angstabfall (im Sinne der Habituation), sondern eine Neubewertung (Reduktion der Bedrohlichkeitseinschätzung) mit Therapieeffekten im Sinne einer Symptomreduktion zusammenhängt (Bluett, Zoellner, & Feeny, 2014; Craske, Liao, & Vervliet, 2012; Deacon et al., 2013; Schemer, Körfer, & Glombiewski, 2019).

Basierend auf Annahmen des Inhibitionslernens sollte eine Extinktion stattfinden, wenn Reize, die durch früheres Lernen (klassische Konditionierung) mit Schmerz bzw. Schädlichkeit assoziiert sind (konditionierte Stimuli = CS), wiederholt keinen Schmerz bzw. Schaden (unkonditionierte Stimuli = US) vorhersagen. In der Folge sollte neben der vorherigen CS-US Assoziation, eine neue CS-*no*US Assoziation entstehen (Bouton, 1993; Bouton & King, 1983). Mit zunehmender Erfahrung einer Präsentation des CS ohne US, sollte der CS seinen prädiktiven Wert verlieren und die konditionierte Vermeidungsreaktion und Angstreaktion sollte zurückgehen (den Hollander et al., 2010). Die relative Stärke der neuen inhibitorischen Assoziation entscheidet darüber, ob bei erneuter Konfrontation mit dem CS Angst und die konditionierte Reaktion (Vermeidung) ausgelöst wird (Craske et al., 2008; Culver, Vervliet, & Craske, 2015; Ploghaus et al., 2000). Ist die neue CS-*no*US Assoziation nicht stark genug, dann bleibt trotz wiederholter CS-*no*US Erfahrungen die alte CS-US Assoziation handlungsleitend (Meulders, 2020). Extinktionseffekte scheinen daher sehr kontextspezifisch und fragil zu sein und „Rückfälle" wie durch ‚*return of fear*' oder ‚*reinstatement*' erklärbar (Bouton, 2002, 2004; Bouton, Winterbauer, & Todd, 2012). Insbesondere ‚*reinstatement*' spielt bei PatientInnen mit chronischen Schmerzen eine große Rolle, da diese PatientInnen auch nach einer erfolgreichen Behandlung definitionsgemäß regelmäßig Schmerzepisoden ausgesetzt sein werden (Gramsch et al., 2014; Van Damme, Crombez, Hermans, Koster, & Eccleston, 2006). Daher empfiehlt es sich, Exposition zur Überprüfung von Schädlichkeitserwartungen, statt erwarteter Schmerzverstärkung zu nutzen (Vlaeyen & Crombez, 2020).

Im Rahmen von Expositionen und Verhaltensexperimenten kann direkt überprüft werden, ob eine bestimmte Bewegung in einer bestimmten Situation zu dem befürchteten Zustand führt (z.B. (Wieder-) Verletzung; Vlaeyen, den Hollander, de Jong, & Simons, 2018). Während vorherige Überschätzung der Gefahr und des ausgelösten Schmerzes einer bestimmten Bewegung/Situation durch Expositionsübungen korrigiert werden kann, scheint die Generalisierung auf andere Situationen und ähnliche Bewegungen unklar (Crombez et al., 2002; Goubert, Francken, Crombez, Vansteenwegen, & Lysens, 2002; Trost, France, & Thomas, 2008). Neuste Untersuchungen liefern Hinweise darauf, dass Generalisierung auf andere Situationen/Bewegungen nach erfolgreicher Expositionstherapie funktioniert (den Hollander, de Jong, Onghena, & Vlaeyen, 2020; Riecke, Rief, Vlaeyen, & Glombiewski, 2020; Trost et al., 2008). Riecke und Kollegen (2020) konnten differenzierter zeigen, dass nach erfolgreicher Exposition Schädlichkeitserwartungen, aber nicht Schmerzerwartungen auf neue Bewegungen generalisieren. Eine therapeutische Anleitung zur Überprüfung von Schädlichkeitserwartungen in der Exposition scheint vor diesem Hintergrund vorteilhaft (Riecke et al., 2020). In einer ersten experimentellen Untersuchung in Bezug auf Schmerzbewältigung konnte die Überlegenheit von therapeutischen Instruktionen zur Erwartungsüberprüfung im Vergleich zur Habituation nachgewiesen werden (Schemer, Körfer, et al., 2019).

2.4 Erwartungen in der Psychotherapie

Durch beeindruckende Ergebnisse aus der Placebo-Forschung und Verhaltensmedizin sind Erwartungen in den letzten Jahren in den Fokus der Aufmerksamkeit der klinisch-psychologischen Forschung getreten (Auer et al., 2016; Colloca, 2019; Corsi & Colloca, 2017; Laferton, Kube, Salzmann, Auer, & Shedden-Mora, 2017; Petrie & Rief, 2019; Rief et al., 2017). Ergebnisse aus der Placebo- und Nocebo-Forschung haben eindrucksvoll gezeigt, dass wir erleben, was wir erwarten (z.B. Tracey, 2010) oder, was uns nahegelegt wurde (z.B. van Laarhoven et al., 2011). Die Modulation der Wahrnehmung durch frühere Erwartungen ist bis zu einem gewissen Grad ein adaptiver und gesunder Prozess (McQueen, Cohen, John-Smith, & Rampes, 2013). Lernen aus Erfahrungen, um die Gegenwart zu verstehen und die Zukunft vorherzusagen ist nötig, um sich in einem sich ständig wechselnden Lebensraum sicher zu bewegen. Allerdings kann dies zu einer verzerrten Wahrnehmung und Bewertung neuer Erfahrungen führen: Eine priorisierte Wahrnehmung und Verarbeitung von Informationen, die unsere Erwartungen bestätigen, führen im Bereich von Schmerz zu einer sich selbst aufrechterhaltenden Verzerrung bei der Beurteilung des Schmerzerlebens (Atlas & Wager, 2012; Keltner et al., 2006; Koyama, McHaffie, Laurienti, & Coghill, 2005; Ongaro & Kaptchuk, 2019; Wiech, 2016; Wiech et al., 2014) und der Persistenz von dysfunktionalen Annahmen (Kube, Rozenkrantz, Rief, & Barsky, 2020; Pezzulo, Maisto, Barca, & Van den Bergh, 2019).

2.4.1 Die Veränderung bzw. Aufrechterhaltung (dysfunktionaler) Erwartungen

Um uns vor einer halluzinatorischen Wahrnehmung der Realität zu schützen, gibt es Mechanismen, die den Einfluss von Erwartung auf das Erleben durch einen Abgleich mit tatsächlichen Erfahrungen begrenzen (Crombez & Wiech, 2011). Erwartungen und die Realitätswahrnehmung beeinflussen sich gegenseitig: Erwartungen können die Wahrnehmung verzerren oder schärfen. Eine adaptive Anpassung sollte dadurch gelingen, dass Erwartungen an abweichende tatsächliche Erfahrungen mit der Realität iterativ angepasst werden.

Einen theoretischen Rahmen liefern Theorien des „prädiktiven Kodierens“ (engl. *‚predictive coding‘*; z.B. Büchel, Geuter, Sprenger, & Eippert, 2014; Hechler, Endres, & Thorwart, 2016; Huang & Rao, 2011): Diese konzeptualisieren das Gehirn als „Vorhersage-Maschine“, die sogenannte *‚priors‘* (d.h. Erwartungen über die Wirklichkeit) auf Grundlage von vorherigen Erfahrungen aus ähnlichen Situationen und Verarbeitung bestimmter Hinweisreize (z.B. Fernández, Pedreira, Boccia, & Kaczer, 2018) berechnet. Der Abgleich eines *‚priors‘* mit der Wirklichkeit erlaubt ein schnelles Entdecken von Abweichungen, sogenannten Erwartungsfehlern (engl. *‚prediction errors‘*; Rescorla & Wagner, 1972). Der Fokus auf Erwartungsfehlern ermöglicht es, vorherige Erwartungen – falls fehlerhaft – zu verändern oder zu ergänzen (Danek & Flanagin, 2019; Proulx, Sleegers, & Tritt, 2017; Wiech, 2016).

Rief und Kollegen (2015) beschreiben in einem theoretischen Rahmenmodell (Abbildung 2), wie Erfahrungen, die generalisierten (dys-)funktionalen Erwartungen widersprechen (d.h. erwartungsverletzende Erfahrungen), verarbeitet werden und welche Mechanismen, darüber entscheiden, ob generalisierte Erwartungen angepasst bzw. aufrechterhalten werden. Darin wird angenommen, dass auf Grundlage generalisierter Erwartungen, die multifaktoriell (durch vorherige Lernerfahrungen/Konditionierung, soziale Einflüsse sowie interindividuelle Unterschiede) beeinflusst sind, in bestimmten Situationen situationsspezifische Vorhersagen ausgebildet werden. Erfahrungen, die diese Vorhersagen bestätigen, sollten die generalisierte Erwartung stärken. Stimmen Erfahrungen allerdings nicht mit der Vorhersage überein, kommt es zu einer sogenannten Erwartungsverletzung (engl.: *‚expectation violation‘*; daher: ‚ViolEx‘). Im ‚ViolEx‘-Modell wird der Stärke des Vorhersagefehlers eine funktionale Rolle bei der Erwartungsaktualisierung zugeschrieben (Rescorla & Wagner, 1972), d.h. je größer die Erwartungsverletzung, desto wahrscheinlicher wird die Person ihre generalisierte Erwartung anpassen.

Abgeleitet aus klinischen Beobachtungen wird im Modell berücksichtigt, dass

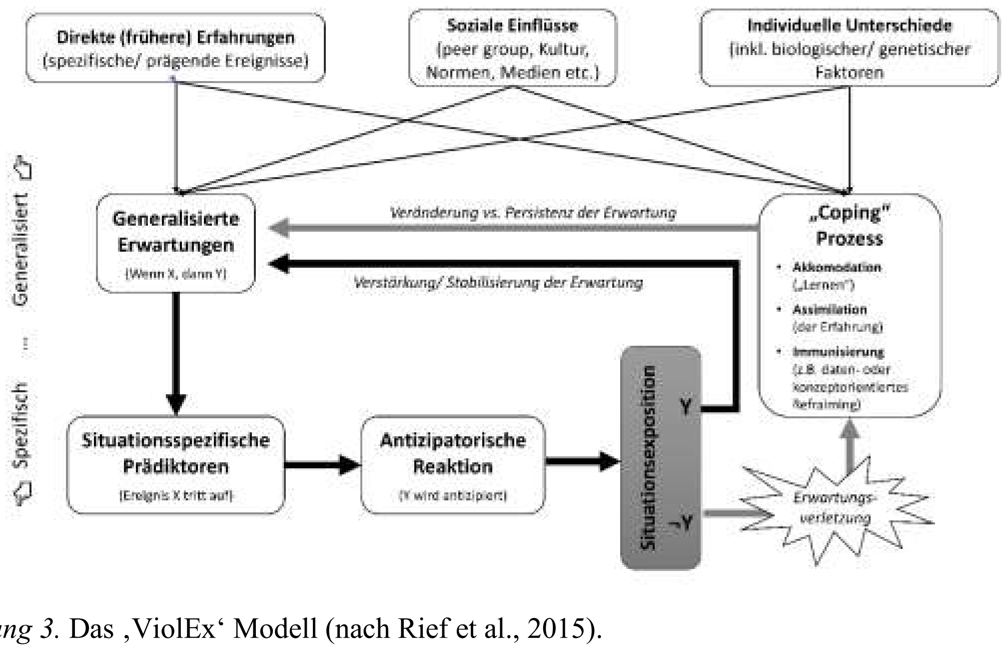

Abbildung 3. Das ‚ViolEx‘ Modell (nach Rief et al., 2015).

erwartungsverletzende Erfahrungen allerdings nicht unweigerlich zu einer Veränderung der generalisierten Erwartungen führen. "Kognitive Immunisierung" wird als eine implizite

Strategie vorgeschlagen, die dazu beiträgt, relevante Erwartungen gegen widersprüchliche Beweise „zu verteidigen“, um die Erwartungen aufrechtzuerhalten und nicht zu aktualisieren. Das Modell postuliert, dass kognitive Immunisierungsstrategien, die Gültigkeit oder Relevanz erwartungsverletzender Erfahrungen infrage stellen, was wiederum die Aktualisierung der Erwartungen behindert. Es wird angenommen, dass diese Mechanismen auf kognitiver Ebene die fehlende Generalisierung erwartungsverletzender Erfahrungen bei Expositionstherapie und die Persistenz dysfunktionaler Überzeugungen wie beispielsweise bei psychischen Störungen erklären. Die AutorInnen empfehlen, therapeutische Strategien zur Maximierung der Erwartungsverletzung einzusetzen, um PatientInnen auf die meist implizit ablaufenden Prozesse aufmerksam zu machen. Rief und Glombiewski (2016) schlagen auch vor, explizit in der Vorbereitung von Expositionstherapien und Verhaltensexperimenten zu besprechen, was eintreten müsste, damit PatientInnen ihre Erwartungen anpassen würden. Anschließend sollen therapeutische Übungen so gestaltet werden, dass auch die individuelle Befürchtung überprüft werden kann.

2.5 Die Rolle von Erwartungen bei chronischen Schmerzen

Erwartungen spielen eine wesentliche Rolle im Alltag von SchmerzpatientInnen (Peerdeman, van Laarhoven, Peters, & Evers, 2016) und in der klinischen Praxis (z.B. als wichtiger Prädiktor für Behandlungsergebnisse; Boersma & Linton, 2006; Cormier, Lavigne, Choinière, & Rainville, 2016). Daher erscheint es vielversprechend, den Einfluss von Erwartungen – auch über die im ‚Fear-Avoidance Model‘ beschriebenen ‚*threat beliefs*‘ hinaus – auf die Entstehung und Aufrechterhaltung von chronischen Schmerzen und in der Expositionstherapie zu untersuchen (Vlaeyen, 2015).

2.5.1 Rolle von Erwartungen in der Entstehung chronischer Schmerzen

Im ‘Fear-Avoidance Model‘ wird eine katastrophisierende Bewertung von Schmerzen und/oder Bewegung als Vorläufer der Angst und Initiator der Vermeidung beschrieben (Vlaeyen & Linton, 2000). Damit werden Befürchtungen eine zentrale Rolle in der Entstehung und Aufrechterhaltung von beeinträchtigenden Schmerzstörungen zugeschrieben (Swinkels-Meewisse et al., 2006). Katastrophisierung und schmerzbezogene Angst wurden wiederholt als Prädiktoren für Schmerzbeeinträchtigung gefunden (Boersma & Linton, 2006; Klenerman et al., 1995; Ramírez-Maestre, Esteve, Ruiz-Párraga, Gómez-Pérez, & López-Martínez, 2017).

Rief und Glombiewski (2016) leiten darüber hinaus aus ihrer psychotherapeutischen Erfahrung ab, dass verschiedene Kategorien von Erwartungen die Aufrechterhaltung psychischer Störungen und Therapie beeinflussen könnten. Sie schlagen folgende

Erwartungskategorien vor: Erwartungen in Bezug auf störungsspezifische Merkmale, in Bezug auf sich selbst, auf andere Menschen und an die Psychotherapie. Im ‚Fear-Avoidance Model' wird nach dieser Einteilung ausschließlich die Bewertung der Schmerzen im Sinne von beispielsweise Schädlichkeitserwartungen beschrieben, die sich als „Erwartungen in Bezug auf störungsspezifische Merkmale" auffassen lassen.

Im letzten Jahrzehnt wurde der Blick in der Schmerzforschung erweitert: Man nimmt an, dass Betroffene Schmerzen nicht nur für den Moment als bedrohlich und potentiell schädlich erleben, sondern Schmerzen darüber hinaus auch eine Bedrohung für die eigene narrative Identität – das Selbstkonzept – darstellen (Kindermans et al., 2010; Van Damme & Kindermans, 2015; Vlaeyen, Morley, & Crombez, 2016). Betroffene, die befürchten aufgrund der Schmerzen, relevante Lebensziele nicht zu erreichen (= Selbstverstrickung mit Schmerzen; Huijnen et al., 2011), werden sie vermutlich primär Strategien zur Schmerzreduktion verfolgen (Van Damme & Kindermans, 2015). Befürchtungen, die Schmerz als Bedrohung für das eigene Selbstkonzept und als Hindernis bei der Erreichung relevanter Lebensziele betrachten (Yu, Norton, Harrison, & McCracken, 2015), blieben bislang unberücksichtigt in der Forschung zur Entstehung von Schmerzstörungen.

2.5.2 Rolle von Erwartungen bei der Aufrechterhaltung chronischer Schmerzen

Die Befürchtung, Schmerzen und damit einhergehende Gefühlszustände nicht aushalten zu können, verstärkt die Vermeidung und bahnt den Weg für eine Generalisierung auf andere Bewegungen, Situationen und Kontexte (Linton et al., 2018). Wie im ‚Fear-Avoidance Model' beschrieben, verhindert exzessives Vermeidungsverhalten wiederum, dysfunktionale Kognitionen durch neue Erfahrungen zu überprüfen und gegebenenfalls zu korrigieren (Vlaeyen, 2015). Studien in der Forschergruppe von Geert Crombez konnten wiederholt erhöhte Schädlichkeitserwartungen und deren Korrektur durch Expositionsübungen bei RückenschmerzpatientInnen nachweisen (Crombez et al., 2002; Goubert et al., 2002). Allerdings gibt es Hinweise, dass Erwartungen trotz wiederholter gegenteiliger Erfahrung nicht angepasst werden und bestimmte Bewegungen/Haltungen als Schon- bzw. Sicherheitsverhalten negative verstärkt werden (Linton et al., 2018).

2.5.3 Rolle von Erwartungen in der psychologischen expositionsbasierten Schmerztherapie

Da Kognitionen im ‚Fear-Avoidance Model' als entscheidend für den Eintritt in den Teufelskreis der Chronifizierung dargestellt werden, werden in Expositionstherapien gezielt solche Bewegungen durchgeführt, die aufgrund von Befürchtungen Angst auslösen. Während zuerst nicht genau spezifiziert wurde, wie in Expositionen mit Kognitionen umzugehen ist, wird in der neusten Version eines Praktikermanuals (Vlaeyen, den Hollander, et al., 2018, S. 188) vorgeschlagen, dass Befürchtungen (‚*threat beliefs*') konkret geprüft werden sollten. Dazu wird auf Philips (1987) verwiesen, die vorschlägt, dass eine explizite Benennung von Befürchtungen während der Exposition vorteilhaft sein könnte. Dies scheint mit neueren Vorschlägen zur Optimierung von Expositionen aus dem Angstbereich konkordant zu sein (Craske, Hermans, & Vervliet, 2018; Craske, Treanor, Conway, Zbozinek, & Vervliet, 2014). Vlaeyen und Kollegen (2018) beschreiben, dass PatientInnen durch Exposition mit zuvor aus Angst vermiedenen Bewegungen häufig lernen, dass eine spezifische Bewegung eine Ausnahme von der allgemeinen Regel „Bewegungen schaden meinem Rücken" darstellt und dies in der Folge als Sicherheitsverhalten eingesetzt werden kann, im Sinne von: „Nur wenn ich mich so bewege, wie mein Therapeut es mir gezeigt hat, kann nichts passieren.". Da folglich keine fundamentale Veränderung der Schmerz-/Schädlichkeitserwartung stattfindet, wird empfohlen, Expositionsübungen mit anderen Bewegungen und in anderen Situationen zu wiederholen (Crombez et al., 2002; den Hollander et al., 2020) und möglichst viel Variation in die Übungen einzubauen (Craske et al., 2018, 2008, 2014). Dadurch soll die neue Lernerfahrung einfacher auf neue Bewegungen/Situationen generalisieren (vgl. S. 10).

Auch ein direktes Adressieren dysfunktionaler Kognitionen scheint indiziert: eine Reduktion der Katastrophisierungsneigung scheint den Erfolg von physiotherapeutischen Behandlungen und KVT zu vermitteln (Smeets, Vlaeyen, Kester, & Knottnerus, 2006). Außerdem sprechen PatientInnen mit hoher Katastrophisierungsneigung schlechter auf psychologische Behandlungsansätzen an (Miró et al., 2018), profitieren weniger von Exposition (Flink, Boersma, & Linton, 2010) und brechen häufiger multimodale Therapieangebote ab (Oosterhaven, Wittink, Dekker, Kruitwagen, & Devillé, 2019). Vlaeyen und Kollegen (2018) schlagen in Anlehnung an Empfehlungen aus der Expositionsbehandlung für Angststörungen vor, dass man mit PatientInnen vor der Durchführung von Expositionen und Verhaltensexperimenten explizit ihre Befürchtungen bespricht und konkrete Übungen zur Überprüfung plant.

3 Darstellung des Dissertationsvorhabens

3.1 Relevanz und Herleitung der Fragestellungen

Eine genauere Erforschung weiterer Fragestellungen hinsichtlich der Rolle von Erwartungen und ihrer Persistenz bzw. Veränderung durch psychologische Schmerztherapie (Exposition) scheint indiziert und vielversprechend, um den expositionsbasierten therapeutischen Ansatz weiter zu optimieren. Das zentrale Ziel des Dissertationsvorhabens war daher, die Rolle von Erwartungen bei der Entstehung von Schmerzbeeinträchtigung und die Anpassung bzw. Beibehaltung von Befürchtungen nach wiederholter gegenteiliger (erwartungsverletzender) Erfahrung zu untersuchen. Außerdem sollte die Wirksamkeit und Nützlichkeit von therapeutischen Instruktionen zur Erwartungsprüfung evaluiert werden. Im Folgenden sollen Forschungslücken identifiziert werden, aus denen sich die Zielsetzungen dieses Dissertationsprojekts ableiten lassen.

Aus der Zusammenfassung des bisherigen Forschungstandes wird deutlich, dass Erwartungen eine zentrale Rolle bei der Entstehung und Aufrechterhaltung von Schmerzstörungen zukommt. Allerdings konzentriert sich die Forschung bezüglich der Entstehung fast ausschließlich auf katastrophisierende Schmerzbewertungen (Vlaeyen, Kole-Snijders, Rotteveel, Ruesink, & Heuts, 1995). Boersma & Linton (2006) konnten zeigen, dass negative Erwartungen die Schmerzbeeinträchtigung ein Jahr später vorhersagten. Obwohl in den letzten Jahren in der Schmerzforschung diskutiert wird, Schmerz auch als Bedrohung für das Selbst (im Sinne von Selbstdiskrepanzen und Selbstverstrickung) aufzufassen (Huijnen et al., 2011; Kindermans et al., 2011; Van Damme & Kindermans, 2015; Vlaeyen, Morley, et al., 2016), bleiben selbstkonzeptbezogene Erwartungen (wie z.B. Selbstverstrickung) in der Entstehung bislang unberücksichtigt.

Das ‚Fear-Avoidance Model' liefert keine Erklärung, wieso es trotz Konfrontation (z.B. durch Exposition *in vivo*) nicht immer zu einer Anpassung dysfunktionaler störungsspezifischer Erwartungen kommt (Crombez & Wiech, 2011; Wiech, 2016). Annahmen der Modelle zum *‚predictive coding'* zufolge sollten Erwartungen durch die Berechnung von Vorhersagefehlern an die Wirklichkeit angepasst werden. Im ‚ViolEx' Modell wird beschrieben, dass erwartungsverletzende Erfahrungen nicht unweigerlich zu einer Erwartungsveränderung führen (Rief et al., 2015). Kognitive Immunisierung wird als Mechanismus vorgeschlagen, der dazu führt, dass die erwartungsverletzende Erfahrung so abgeschwächt wird, dass es zu keiner Anpassung der Erwartung kommt. Bislang wurden diese theoretischen Annahmen noch nicht im Kontext von schmerzstörungsspezifischen Erwartungen erforscht.

Expositionstherapie hat sich als wirksame Therapieform für schmerzängstliche PatientInnen erwiesen (Vlaeyen & Crombez, 2020). Allerdings zeigen sich Probleme in der Akzeptanz des Verfahrens, was sich in höheren Abbrecherquoten niederschlägt (Glombiewski et al., 2018) und die Generalisierung scheint eingeschränkt (Riecke et al., 2020; Vlaeyen, 2015). Daher ist eine Verbesserung der Therapieform wünschenswert (Eccleston, Morley, & Williams, 2013). Das ‚Fear-Avoidance Model' erklärt, wie durch Vermeidung von Bewegungen, eine Korrektur von irrationalen Bewertungen (Katastrophisierung) und daraus resultierender Angst ausbleibt. Im Einklang damit empfehlen die neusten Manuale, Exposition *in vivo* so zu gestalten, dass idiosynkratischen Befürchtungen direkt überprüft werden können und dass die Generalisierung neuer Lernerfahrung auch auf andere – nicht direkt exponierte Bewegungen und Situationen – erleichtert wird (Vlaeyen, den Hollander, et al., 2018). Befunde zu Wirkmechanismen der Expositionstherapie und Generalisierung von Therapieerfolgen aus dem Bereich der Angststörungen legen nahe, dass die Berücksichtigung von Erwartungen Potential zur Optimierung bietet (Heinig et al., 2017). Außerdem soll durch eine maximale Widerlegung der Befürchtung das inhibitorische Lernen gesteigert und die Generalisierung erleichtert werden (Craske et al., 2008). Konkrete Vorteile einer direkten Erwartungsüberprüfung sind bei Schmerzexpositionen bislang kaum untersucht worden. In einer ersten experimentellen Arbeit hat sich eine therapeutische Anleitung zur Erwartungsüberprüfung gegenüber einer Anleitung zur Habituation bei gleicher Anzahl von Expositionsdurchgängen als überlegen bezüglich der Erhöhung der Schmerztoleranz erwiesen (Schemer, Körfer, et al., 2019).

Zusammenfassend lassen sich auf Basis der beschriebenen Forschungslücken drei weiterführende Forschungsfragen zur Relevanz von Erwartungen bei Schmerz im klinischen Kontext identifizieren, die bisher nicht oder nur unzureichend untersucht wurden: 1) Spielen selbstkonzeptrelevante Erwartungen eine Rolle in der Entstehung von chronischen Schmerzstörungen? 2) Wie werden erwartungsverletzende Schmerzbewältigungserfahrungen verarbeitet? 3) Können therapeutische Anleitungen zur Erwartungsüberprüfung die Wirksamkeit oder Ökonomie von Expositionen verbessern?

3.2 Fragestellungen des Dissertationsvorhabens

Um einen Beitrag zur Beantwortung der oben herausgestellten offenen Forschungsfragen zu leisten, wurden in diesem Dissertationsvorhaben drei Studien umgesetzt und die zu beantwortenden Fragestellungen folgendermaßen ausformuliert:

Studie I: Spielen negative selbstkonzeptrelevante Erwartungen (Selbstdiskrepanzen = vergrößerter Abstand zu vorgestelltem idealen Selbstbild und verringerter Abstand zu gefürchtetem Selbstbild und/oder Selbstverstrickung mit dem Schmerz = „der Schmerz hindert mich daran, so zu sein, wie ich sein möchte/macht mich zu dem, wie ich nicht sein möchte.“) eine Rolle bei der Schmerzchronifizierung? Wird die Schmerzbeeinträchtigung drei Monate nach Beginn eines akuten Schmerzes durch erlebte Selbstdiskrepanzen und/oder erwartete Verstrickung des Selbstkonzepts mit dem Schmerz vorhergesagt? Ist die Vorhersagekraft von Selbstdiskrepanzen und/oder Selbstverstrickung unabhängig von bekannten Risikofaktoren wie schmerzbezogener Angst und Katastrophisierung?

Studie II: Beeinflussen induzierte Erwartungen das Schmerzerleben experimenteller Hitzereize? Lassen sich induzierte Erwartungen durch wiederholte erwartungsverletzende Erfahrungen verändern? Werden Lernerfahrungen im Labor auf schmerzbezogene Selbstwirksamkeitserwartungen außerhalb des Labors generalisiert? Welche zugrundeliegenden Prozesse sind verantwortlich für die Persistenz von Erwartungen trotz erwartungsverletzender Erfahrungen?

Studie III: Zeigt sich eine therapeutische Anleitung zur Erwartungsüberprüfung überlegen gegenüber einer therapeutischen Anleitung zur Habituation bei Schmerzkonfrontationen für gesunde Probandinnen mit experimentell induzierter Ängstlichkeit? Unterscheiden die beiden therapeutischen Expositionsinstruktionen sich in Aspekten der Ökonomie (benötigte Expositionsdurchgänge zur Erreichung eines Expositionsziels)? Welchen Einfluss haben interindividuelle Unterschiede in schmerzbezogener Angst und Katastrophisierung auf die Anzahl benötigter Expositionsdurchgänge?

4 Zusammenfassung der Studien

4.1 Studie I: Prospektive Vorhersage von Schmerzbeeinträchtigung durch die Selbstverstrickung mit Schmerzen

Körfer, K., Riecke, J., Volberg, C., Glombiewski, J. A., & Kube, T. (under review). "Not until my pain is gone…": How the entanglement of self and pain predicts disability three months after acute pain. Manuscript submitted for publication to *Journal of Psychosomatic Research.*

Hintergrund: Akuter Schmerz ist der häufigste Grund für die Inanspruchnahme medizinischer Leistungen (Mäntyselkä et al., 2001). Jede/r sechste Patient/in, der/die aufgrund einer Verletzung die Notaufnahme aufsucht, berichtet nach drei Monaten noch immer Schmerzen und Beeinträchtigung (Holmes et al., 2010). Sobald Schmerz chronifiziert, spricht er deutlich schlechter auf bestehende Behandlungsansätze an (Borsook et al., 2019). Daher ist die Erkennung von Risikofaktoren für chronische Verläufe und frühzeitige Intervention von großer Relevanz (Katz & Seltzer, 2009). Bei vielen Menschen, die unter akuten Schmerzen nach einer Verletzung leiden, ist die Funktionsfähigkeit eingeschränkt und die Lebensqualität in Bezug auf soziale Teilhabe und alltägliche Aktivitäten vermindert. Folglich stellt Schmerz eine Bedrohung für die gesamte Person dar: Die Selbstverstrickungstheorie beschreibt, dass für viele Betroffene die Verwirklichung bedeutsamer Lebensziele durch den Schmerz behindert oder sogar unmöglich erscheint (Huijnen et al., 2011). Basierend auf der Erwartung, erst wenn der Schmerz aufhört, wieder so sein zu können, wie man idealerweise sein möchte, verfolgen PatientInnen verstärkt Strategien zur Schmerzreduktion (Van Damme & Kindermans, 2015). Ziel dieser Studie war es zu testen, ob eine erlebte Distanz zu einem angestrebten Zustand (d.h. Diskrepanz zwischen tatsächlichem vs. idealem Selbst) und die aversive Nähe zu einem vermiedenen Zustand (d.h. Diskrepanz zwischen tatsächlichem vs. gefürchtetem Selbst; Higgins, 1987) sowie die Wahrnehmung von Schmerz als Hindernis für die Erfüllung von wertorientierten Selbstbildern (d.h. Verstrickung des Selbstkonzepts mit den Schmerzen) eine Beeinträchtigung nach akuten Schmerzen vorhersagen und somit potentielle Risikofaktoren für eine Chronifizierung von Schmerzen darstellen können.

Methode: Dreißig Personen mit akuten Schmerzen wurden am Universitätsklinikum Marburg-Gießen, Standort Marburg rekrutiert (t1). ProbandInnen füllten Fragebögen zu zwei Messzeitpunkten im Abstand von drei Monaten aus (vollständige Stichprobe zu t2: $N = 25$, 72% männlich, Alter: $M = 50.04$; $SD = 17.6$). Selbstdiskrepanzen und Selbstverstrickung mit dem Schmerz wurden mit eigens dafür konstruierten Fragebögen erfasst: Zunächst wurden die ProbandInnen aufgefordert, ihr ideales und gefürchtetes Selbstbild in ihren drei wichtigsten

Lebensbereichen (Auswahl: Partnerschaft, Familie, Freunde/soziales Umfeld, Freizeit/Hobbys, Beruf/Arbeit/Ausbildung/Studium) zu beschreiben. Zur Erfassung der Selbstdiskrepanzen schätzten sie auf einer 11-stufigen Likert-Skala die Nähe bzw. Distanz zu den beschriebenen Selbstbildern ein. Selbstverstrickung wurde erfasst, indem ProbandInnen jeweils angaben, für wie wahrscheinlich sie es halten, ihr ideales Selbst zu erreichen bzw. ihr gefürchtetes Selbst zu vermeiden, unter der Bedingung, weiter Schmerzen bzw. keine Schmerzen mehr zu haben. Wir testeten in einer hierarchischen multiplen Regressionsanalyse, ob Selbstdiskrepanzen und Selbst-Schmerz-Verstrickungen die Schmerzbeeinträchtigung drei Monate später vorhersagten. Mithilfe von Bonferroni-korrigierten T-Tests für abhängige Stichproben wurde zudem die Veränderung in Selbstdiskrepanzen und -verstrickung von t1 zu t2 untersucht.

Ergebnisse: Über Katastrophisierung ($\beta = .76$, $p = .002$) und Schmerzangst ($\beta = -.60$, $p = .01$) hinaus sagte das Ausmaß der Verstrickung von Schmerz und dem idealen Selbst ($\beta = .43$, $p = .01$) Schmerzbeeinträchtigung drei Monate nach Schmerzbeginn ($R^2 = .53$, $\Delta R^2 = .17$, $p = .01$) vorher. Während die Selbstdiskrepanz zu dem gefürchteten Selbst zunahm $t(24) = 2.05$, $p = .05$, verringerte sich die Distanz zum idealen Selbst nicht, $t(24) = -.28$, $p = .78$. Die Selbstverstrickung nahm für das ideale Selbst zu, $t(24) = 3.04$, $p = .006$ und veränderte sich nicht für das gefürchtete Selbst, $t(24) = .14$, $p = .89$.

Diskussion: Die Ergebnisse deuten darauf hin, dass eine hohe Verstrickung des Selbst mit den Schmerzen ein möglicher neuer Kandidat für einen psychologischen Risikofaktor der Schmerzchronifizierung sein könnte: ProbandInnen, die erwarteten, aufgrund von Schmerzen nicht so sein zu können, wie sie gerne wären, berichteten stärkere Beeinträchtigung drei Monate später. Sofern die Ergebnisse in größeren Stichproben repliziert werden können, bestünde eine klinische Implikation darin, durch ein sparsames Screening zur Schmerz-Selbst-Verstrickung RisikopatientInnen frühzeitig zu identifizieren und niedrigschwellige psychologische Interventionen anzubieten.

4.2 Studie II: Wie Erwartungsverletzung die Generalisierung von Schmerzbewältigungserfahrungen verbessert – Ein Erfahrungslernparadigma

Körfer, K., Riecke, J., Glombiewski, J. A., & Kube, T. (submitted). How expectancy violations facilitate learning to cope with pain - An experimental experiential learning approach. Manuscript submitted for publication to *PAIN*.

Hintergrund: Die Erwartung schmerzhafter Empfindungen ist ein Kernmerkmal chronischer Schmerzzustände, und eine wichtige klinische Frage ist, ob solche Erwartungen angepasst werden, wenn widersprüchliche Erfahrungen (z.B. weniger Schmerzen als erwartet) gemacht werden. Die Theorie des ‚*predictive codings*' postuliert, dass aus früheren Erfahrungen Vorhersagen gebildet werden mit denen neue sensorische Information verglichen wird (Ongaro & Kaptchuk, 2019; Pezzulo et al., 2019; Van den Bergh, Witthöft, Petersen, & Brown, 2017; Wiech, 2016). Wenn die neue Information nicht mit der Vorhersage übereinstimmt, wird ein Vorhersagefehler (engl.: ‚*prediction error*') berechnet, der zur Aktualisierung der Erwartung verwendet werden kann. Experimentelle Forschung konnte zeigen, dass sich Schmerzerwartung und -wahrnehmung reziprok beeinflussen und es dadurch zu einem sich selbst aufrechterhaltenden Prozess kommt (Jepma, Koban, van Doorn, Jones, & Wager, 2018). Im ‚ViolEx'-Modell wird postuliert, dass je nachdem, wie das Individuum die erwartungsverletzende Erfahrung bewertet, eine Erwartungsaktualisierung manchmal trotz gegenteiliger Evidenz ausbleiben kann (Rief et al., 2015). Es gibt jedoch kaum Forschung, die diese Annahmen bei klinisch relevanten oder subklinischen Schmerzzuständen überprüft. Ziel dieser Studie war experimentell zu untersuchen, wie Menschen, die häufig subklinische Schmerzen empfinden, auf erwartungsverletzende Erfahrungen reagieren und was vorhersagt, ob sie ihre generalisierte Selbstwirksamkeitserwartung anpassen. Basierend auf der Annahme, dass Erwartungsanpassung in Abhängigkeit von erwartungsverletzenden Erfahrungen stattfindet, erwarteten wir stärkere Erwartungsanpassung und Generalisierung auf Selbstwirksamkeitserwartungen in der Erwartungsverletzungsbedingung im Vergleich zur Erwartungsbestätigungsbedingung. Eine mangelnde Erwartungsanpassung und Generalisierung trotz erwartungsverletzender Erfahrung sollte sich durch post-hoc Bewertungen (im Sinne der kognitiven Immunisierung) abbilden lassen.

Methode: In einem neu entwickelten experimentellen Paradigma applizierten wir schmerzhafte Hitzereize mit von Durchgang zu Durchgang sinkenden Temperaturen, die die zuvor induzierten Erwartungen der ProbandInnen entweder bestätigten (Erwartungs-bestätigungsgruppe; Bestätigung der Erwartung sinkender Schmerz-empfindlichkeit; n = 33) oder nicht bestätigten (Erwartungsverletzungsgruppe; Verletzung der Erwartung steigender Schmerzempfindlichkeit; n = 40). In drei Durchgängen wurden die erwartete und wahrgenommene Schmerzintensität und -aversion wiederholt erfasst, um Erwartungsverletzungen (Diskrepanz zwischen erwarteter und erlebter Schmerzintensität und -aversion) und Erwartungsanpassung zu bestimmen. Nach den drei Durchgängen wurden die ProbandInnen in einem Interview aufgefordert, ihre Erfahrungen vor dem Hintergrund ihrer vorherigen Erwartungen zu reflektieren, um kognitive Immunisierungsprozesse zu erfassen. Zudem wurden Veränderungen der Schmerztoleranz und der schmerzbezogenen Selbstwirksamkeit von der Prä- zur Postmessung und zum Follow-Up (1 Woche später = Generalisierung der Erfahrungen) ausgewertet.

Ergebnisse: Wie angenommen berichteten ProbandInnen in der Erwartungsverletzungsbedingung größere Erwartungsverletzungen durch den sinkenden Hitzereize, Pillai-Spur = 0,11, $F(2, 68)$ = 4,09, p = .021, partielles η^2 = .11. Trotz geringerer Erwartungsverletzungen passten ProbandInnen in der Erwartungsbestätigungsbedingung ihre vorhergesagte Schmerzintensität stärker an die sinkenden Hitzereize an, $F(1, 69)$ = 5,61, p = .021, partielles η^2 = .08. Deskriptiv gesehen war der Anstieg in der Schmerztoleranz und der Selbstwirksamkeitserwartung in der Erwartungsverletzungsbedingung größer. Eine hierarchische Regressionsanalyse zeigte, dass – unabhängig von der Bedingung – höhere Erwartungsverletzung und Zunahme in der Schmerztoleranz die Generalisierung der schmerzbezogenen Selbstwirksamkeit vom Experiment vorhersagte.

Diskussion: Das Paradigma scheint geeignet zur experimentellen Induktion von Schmerzerwartungen. Die Ergebnisse deuten darauf hin, dass das Erleben von weniger Schmerzen als erwartet nicht notwendigerweise eine Aktualisierung der Schmerzerwartungen nach sich ziehen muss. Die Annahme des ‚ViolEx'-Modells, dass kognitive Immunisierung dafür verantwortlich ist, konnten wir nicht nachweisen. Allerdings sollte in zukünftigen Studien ein geeignetes Messinstrument zur Erfassung von kognitiver Immunisierung entwickelt werden. Zusammenfassend deuten unsere Ergebnisse darauf hin, dass Erwartungsverletzungen die Generalisierung von Selbstwirksamkeitserwartungen erleichtern können, da nicht die vorherige Erwartung selbst, sondern das Ausmaß der Erwartungsverletzung mit einer Erhöhung der Schmerztoleranz und der schmerzbezogenen Selbstwirksamkeit assoziiert war. Eine stärkere therapeutische Fokussierung von erwartungsverletzenden Erfahrungen (wie z.B. im Rahmen von Expositionstherapien) erscheint daher vielversprechend.

4.3 Studie III: Experimentelle Untersuchung der Dosis-Wirkungs-Beziehung von Expositionen bei Schmerzen

Körfer, K., Schemer, L., Kube, T., & Glombiewski, J. A. (accepted with changes). An Experimental Analogue Study on the "Dose-Response Relationship" for Exposures to Pain: The more, the better? Manuscript submitted for publication to *Journal of Pain Research*.

Hintergrund: Expositionstherapie, die in der Behandlung von Angststörungen als „Goldstandard" angesehen wird, ist auch für schmerzängstliche PatientInnen ein wirksames Verfahren (Glombiewski et al., 2018). Im Vergleich zu traditioneller KVT leidet das Verfahren unter geringerer Akzeptanz, die sich in höheren Abbrecherquoten niederschlägt (Glombiewski et al., 2018). Daher ist eine Verbesserung des Verfahrens wünschenswert (Vlaeyen & Crombez, 2020). Basierend auf der Annahme, dass Inhibitionslernen (und nicht Habituation) der Wirksamkeit zugrunde liegt, wurden therapeutische Strategien zur Verbesserung der Expositionseffekte vorgeschlagen (Craske et al., 2014). In einer ersten experimentellen Untersuchung zeigte sich eine Überlegenheit der Überprüfung von konkreten Befürchtungen (d.h. Erwartungsverletzungsinstruktion) im Vergleich zur Fokussierung eines Angstabfalls (d.h. Habituationsinstruktion) in Bezug auf Schmerzbewältigung (Schemer, Körfer, et al., 2019). Darauf aufbauend untersuchten wir in dieser Studie, ob die beiden Expositions-instruktionen sich bezüglich ihrer Ökonomie unterschieden. Wir nahmen an, dass der spezifische Vorteil einer Erwartungsverletzungsinstruktion ein schnelleres Ansprechen und eine geringere Anzahl der erforderlichen Wiederholungen sein könnte, d.h. die "Dosis" der Behandlung, um ein therapeutisches Ziel (d.h. "Ansprechen") zu erreichen.

Methoden: Gesunden Frauen (N = 116) wurden – durch eine experimentelle Manipulation – zunächst Befürchtungen in Bezug auf experimentelle Hitzereize induziert. Anschließend erhielten die Probandinnen eine therapeutische Instruktion, die entweder aus einem habituationsbasiertem Rational oder dem inhibitorischen Lernmodell (Erwartungsverletzung) abgeleitet wurde. Die Probandinnen wurden wiederholt Hitzereizen in Höhe ihrer zuvor gemessenen Schmerztoleranz ausgesetzt. Zur Überprüfung der Dosis-Wirkungsbeziehung wurde zuvor für die beiden therapeutischen Instruktionen jeweils ein Expositionskriterium definiert: In der Habituationsbedingung wurden die Durchgänge so oft wiederholt bis Probandinnen eine relevante Reduktion ihres Anspannungslevels berichteten, während in der Erwartungsverletzungsbedingung eine wesentliche Reduktion der Eintrittswahrscheinlichkeit der individuellen Befürchtung als Zielkriterium definiert wurde. Die abhängige Variable in beiden Bedingungen war die Anzahl der notwendigen Durchgänge bis zum Erreichen des

Kriteriums. Die Wirksamkeit der jeweiligen Expositionsinstruktionen auf die Schmerzbewältigung (objektiv: Schmerztoleranz; subjektiv: selbsteingeschätzte Schmerzbewältigung) wurde mithilfe einer multivariaten Varianzanalyse überprüft.

Ergebnisse: Probandinnen in der Erwartungsverletzungsbedingung benötigten weniger Expositionsdurchgänge zur Erreichung ihres Expositionsziels (M = 3.41, SD = 1.57) als Probandinnen in der Habituationsbedingung (M = 5.43, SD = 2.66), $t(114) = 4.98$, $p < .001$. Während in der Erwartungsverletzungsbedingung etwa 90% der Probadinnen nach nur drei Durchgängen das Expositionskriterium erreichten, erreichten die verbleibenden ca. 10% es auch innerhalb von zehn Durchgängen nicht. In der Habituationsbedingung zeigte sich ein anderes Muster, $\chi^2(6) = 39.79$, $p < .001$: Jede dritte (33%) erzielte eine wesentliche Angstreduktion, während jede fünfte auch in zehn Durchgängen keine wesentliche Reduktion berichtete (20%). Die Anweisung zur Erwartungsverletzung führte zu einer schnelleren Zielerreichung und höheren Ansprechraten als die Anweisung zur Gewöhnung. Die Instruktionen unterschieden sich nicht in ihrem Einfluss auf die kurz- und langfristige Zunahme der Schmerzbewältigung, weder subjektiv noch objektiv, (p-Werte $\geq .12$). Unabhängig von der experimentellen Bedingung wurde ein schnelleres Ansprechen auf die Instruktion durch höhere Schmerzängstlichkeit ($\beta = -.38$, $p = .005$) und geringere Katastrophisierungsneigung ($\beta = .38$, $p = .005$) vorhergesagt.

Diskussion: Unsere Ergebnisse deuten darauf hin, dass die therapeutische Anleitung zur Erwartungsüberprüfung einer Anleitung zur Habituation unter Gesichtspunkten der Effizienz überlegen ist: Zur Erreichung eines Expositionskriterium werden weniger Durchgänge benötigt, während sich der Einfluss auf Schmerztoleranz und Schmerzbewältigung nicht unterschied. Obwohl die Ergebnisse dieser experimentellen Untersuchungen mit gesunden Probandinnen nicht direkt auf Populationen mit klinisch relevanten Ausprägungen chronischer Schmerzen verallgemeinert werden können, liefern sie erste Hinweise darauf, dass therapeutische Instruktionen, die auf Überprüfung von individuellen Befürchtungen abzielen, Expositionseffekte beschleunigen könnten. Durch eine effizientere Gestaltung sollte sich Expositionstherapie besser in klinischen Behandlungsangeboten etablieren lassen. Ein früheres Erkennen von PatientInnen, die nicht von dem Verfahren profitieren und umschwenken auf ein anderes therapeutisches Angebot, bietet die Chance, SchmerzpatientInnen von weiteren negativen Behandlungserfahrungen zu schützen.

5 Diskussion

Im Rahmen dieses Dissertationsprojekts wurde der Einfluss von Erwartungen auf die Entstehung und Aufrechterhaltung von Schmerzstörungen sowie deren Nutzbarmachung für die psychologische Schmerztherapie untersucht. Konkret wurde der Einfluss von selbstkonzeptbezogenen Erwartungen auf die Schmerzchronifizierung (Studie I), die Persistenz bzw. Anpassung von dysfunktionalen Erwartungen durch erwartungsverletzende Erfahrungen (Studie II) und die Ökonomie therapeutischer Expositionsinstruktionen (Studie III) beleuchtet. Dazu wurden Stichproben mit unterschiedlichen Schmerzvorerfahrungen rekrutiert und verschiedene längsschnittliche Forschungsdesigns umgesetzt.

In Studie I und III lag der Fokus auf negativen Erwartungen, die im 'Fear-Avoidance Model' (Vlaeyen & Linton, 2000, 2012) als entscheidend für die Entwicklung eines chronischen Verlaufs angesehen werden und in Expositionstherapien widerlegt werden sollen. In Studie I konnten wir zeigen, dass Personen mit akuten Schmerzen, die erwarteten aufgrund der Schmerzen nicht so sein zu können, wie sie gerne wären (d.h. Selbstverstrickung mit Schmerz), nach drei Monaten mehr Schmerzbeeinträchtigungen beklagten. Der Einfluss zeigte sich auch über den prädiktiven Effekt von Katastrophisierung und Schmerzängstlichkeit hinaus. Wie bereits von einer anderen Forschergruppe gefunden (Vangronsveld, Morley, Peters, Vlaeyen, & Goossens, 2011) nahm die Selbstverstrickung über den Zeitverlauf ab, während Selbstdiskrepanzen stabil blieben. Die Ergebnisse legen nahe, dass die Bewertung des Schmerzes als bedrohlich und hinderlich für die Erreichung selbstwertrelevanter Ziele, einen negativen Verlauf der Schmerzproblematik begünstigt.

Während in Studie I der Fokus auf dem Einfluss von negativen Erwartungen bei der Entstehung von chronischen Schmerzen lag, wurde in Studie III in einem experimentellen Design, die Nützlichkeit, idiosynkratische Befürchtungen direkt zu überprüfen, im Vergleich zur Anleitung zur Habituation untersucht. Probandinnen, die zur Befürchtungsüberprüfung angeleitet wurden, benötigten signifikant weniger Expositionsdurchgänge, um ein zuvor festgelegtes Ziel zu erreichen als Probandinnen, die zur Habituation angeleitet wurden. Entscheidend ist, dass die Bedingungen sich nicht bezüglich schmerzrelevanter Zielkriterien (Schmerztoleranz, kognitive Bewältigung) im Anschluss an die Expositionsdurchgänge unterschieden und diese Effekte auch über eine Woche stabil blieben. Die Ergebnisse sind als Hinweise zu werten, dass therapeutische Expositionsinstruktionen, die zur expliziten Erwartungsüberprüfung instruieren, im Vergleich zur Abfrage des Anspannungslevels (Habituationsinstruktion) eine Möglichkeit darstellen, Expositionen ökonomischer zu gestalten. Glombiewski und Kollegen (2018) konnten zeigen, dass Expositionstherapie bereits nach fünf Expositionen zu Effekten führte, die klassischer kognitiver Verhaltenstherapie bezüglich der Beeinträchtigung überlegen sind. Auch eine Verlängerung um fünf weitere Sitzungen verbesserte den Effekt nicht. Unabhängig von der experimentellen Bedingung zeigte sich in Studie III, dass Probandinnen mit höherer Katastrophisierungsneigung mehr Durchgänge benötigten bzw. auch nach zehn Durchgängen das Kriterium nicht erreichten. Hohe Ängstlichkeit dagegen sagte ein schnelleres Ansprechen vorher, was sich mit dem Einsatzbereich des ‚*tailored treatment*' Ansatzes für hochängstliche SchmerzpatientInnen deckt. Die Ergebnisse könnten als Hinweis interpretiert werden, dass Menschen mit hohen Katastrophisierungsneigung weniger von Expositionstherapie profitieren (Flink et al., 2010).

Während in Studien I und III der Einfluss von Erwartungen auf die Chronifizierung und therapeutische Effekte untersucht wurde, wurde in Studie II experimentell untersucht, ob Erwartungen auch direkt das Schmerzerleben und damit die Lernerfahrungen beeinflussen. Wie in Studie III wurde die Erwartungsanpassung bzw. -persistenz infolge erwartungsverletzender Erfahrungen im Schmerzerleben von applizierten Hitzereizen über mehrere Durchgänge hinweg untersucht. Es zeigte sich, dass ProbandInnen, die aufgrund ihrer Bedingungsmanipulation erwarteten, Schmerz schlechter aushalten zu können, die Hitzereize als unangenehmer und intensiver wahrnahmen und trotz der Erfahrung, dass es über die Zeit – anders als erwartet – deutlich weniger intensiv und unangenehm wurde, immer noch unangenehmere und intensivere Schmerzen erwarteten als ProbandInnen, die den Schmerzabfall erwarteten. Diese Ergebnisse sind im Einklang mit den Befunden aus experimentellen Untersuchungen zum Einfluss von Erwartungen auf das Schmerzerleben (Hird, Charalambous, El-Deredy, Jones, & Talmi, 2019; Jepma et al., 2018). Interessanterweise zeigte sich, dass die Stärke der Erwartungsverletzung – unabhängig von der Bedingung – funktional mit der Generalisierung von Selbstwirksamkeitserwartungen zusammenhing. Der Einfluss von kognitiver Immunisierung (Rief et al., 2015) ließ sich in unserem Experiment nicht nachweisen. Unsere Ergebnisse liefern Hinweise auf den Einfluss von niedrigen Selbstwirksamkeitserwartungen auf die Schmerzwahrnehmung und die Erwartungspersistenz trotz gegenteiliger Erfahrungen.

5.1 Kritische Würdigung von Stärken und Limitationen

In der vorliegenden Dissertation wurden unterschiedliche Methoden (prospektive Erhebung, experimentelle Studien) im Längsschnitt (Studie I: 3 Monats-Nachuntersuchung; Studie II & III: 1 Woche) umgesetzt. Zudem wurden ProbandInnen mit unterschiedlicher Vorerfahrung und Beeinträchtigung (keine Schmerzen; subklinische Schmerzstörungen; akute Schmerzen) rekrutiert. Darüber hinaus wurden in den vorgestellten Studien verschiedene Erwartungen (Selbstverstrickung mit dem Schmerz) erfasst bzw. experimentell manipuliert (Schädlichkeit; Schmerzerwartung; Selbstwirksamkeit). Außerdem wurden zur Erfassung der Zielkriterien in Studie II und III jeweils verschiedene Datenquellen genutzt, sodass sowohl subjektive als auch objektive Daten vorlagen. Dabei erwiesen sich die replizierten (Studie III) bzw. neu entwickelten Paradigmen (Studie II) und die Erwartungsmanipulationen (Studie II & III) als nützlich zur Erfassung von Erwartungspersistenz bzw. -veränderung im Schmerzkontext. Bei der Interpretation der Ergebnisse sind jedoch einige Aspekte zu berücksichtigen, die die Aussagekraft der Ergebnisse einschränken.

Die mangelnde Repräsentativität der untersuchten Stichproben schränkt die Übertragbarkeit der Ergebnisse auf klinische Stichproben erheblich ein: Bei keiner der Studien wurde eine Stichprobe aus chronischen SchmerzpatientInnen untersucht. Es ist davon auszugehen, dass chronische SchmerzpatientInnen sich von gesunden und subklinischen Stichproben in ihrer Reaktion auf Schmerz unterscheiden. Beispielsweise konnten Peerdeman und Kolleginnen (2016) zeigen, dass PatientInnen mit chronischen Schmerzen deutlich schwächer auf Erwartungsinterventionen ansprechen als ProbandInnen mit akuten Schmerzen. Außerdem lässt sich das wichtigste Zielkriterium – die Schmerzbeeinträchtigung – in gesunden Stichproben nicht sinnvoll erfassen und damit auch der Einfluss einer Intervention auf die Beeinträchtigung nicht untersuchen. Die Einschränkungen der externen Validität experimenteller Untersuchung und selektiver Stichproben wurden zugunsten einer höheren internen Validität hingenommen, um die interessierenden Prozesse untersuchen zu können und standardisierte Schmerzreize zu nutzen. Beispielsweise wäre davon auszugehen, dass unterschiedliche Lerngeschichten, unterschiedliche Schmerzbilder und Beeinträchtigung einer chronischen Schmerzstichprobe die Ergebnisse konfundiert hätten. Auch aus ethischer Sicht empfiehlt es sich, Mechanismen zunächst an unbeeinträchtigten gesunden ProbandInnen zu untersuchen (Craske et al., 2018).

In Studie I wurden aufgrund des Untersuchungsgegenstand der Chronifizierung PatientInnen mit akuten Schmerzen eingeschlossen. Während die Stichprobe hinsichtlich der Alterspanne mit chronischen SchmerzpatientInnen vergleichbar war, bestand sie zu einem deutlich größeren Anteil aus Männern, obwohl Frauen höhere Prävalenzen für chronischen Schmerz haben. In Studie III wurden nur Frauen untersucht, um den Geschlechterunterschieden bei chronischen Schmerzen Rechnung zu tragen und für Versuchsleitereffekte zu kontrollieren. Allerdings wird auch hier dadurch die Generalisierbarkeit eingeschränkt. Da wir in Studie II

ProbandInnen mit subklinischen Schmerzbildern einschlossen, sahen wir einen Ausschluss von männlichen Probanden aufgrund höherer Prävalenzen nicht als notwendig an.

Während in Studie I der idiosynkratische Schmerz im Zeitverlauf untersucht wurde, manipulierten wir Befürchtungen in Studie II und III experimentell und verwendeten einen standardisierten Hitzereiz. In beiden Experimenten (Studie II & Studie III) wurden keine Kontrollbedingungen ohne Instruktion bzw. Manipulation umgesetzt. In einem Vorgängerexperiment zu Studie III (Schemer, Körfer, et al., 2019) wurde gezeigt, dass beide Expositionsinstruktionen wirksamer als eine reine Kontrollbedingung sind. In Studie II hätte es verschiedene Möglichkeiten für Kontrollgruppen gegeben: a) Bedingung, die keine Erwartungsmanipulation erfährt; b) Erwartungsmanipulation in gegenläufige Richtung (sodass Erfahrung, „schlimmer als erwartet" wäre). Möglicherweise wären die Effekte im Vergleich zu einer Kontrollgruppe ohne spezifische Instruktion noch deutlicher gewesen. Die unter b) genannte Kontrollgruppe wäre ethisch bedenklich.

Außerdem weist jede Studie auch spezifische Schwächen auf: Da es sich bei Studie I um eine Pilotstudie handelt, sind die Ergebnisse mit Vorsicht zu interpretieren. Aufgrund der geringen Stichprobengröße konnten nicht alle möglichen Prädiktoren (wie z.B. demographische Variablen) im Regressionsmodell berücksichtigt werden, ohne die Gefahr eines statistischen *‚overfittings'* zu riskieren (Riley et al., 2019). Wenngleich dies unter Berücksichtigung der fehlenden Korrelationen unwahrscheinlich erscheint, können wir nicht ausschließen, dass unsere Befunde sich besser durch andere psychologische Variablen (Depressivität; kritisches Reflexionsvermögen) und/oder sozioökonomische Faktoren erklären lassen.

In Studie III wurden therapeutische Expositionsinstruktionen isoliert in Bezug auf Wirksamkeit und Ökonomie untersucht. Eine direkte Generalisierung auf Expositionstherapie ist aufgrund der gesunden Stichprobe und den deutlichen Unterschieden in der zeitlichen Abfolge nicht zulässig. Da die beiden Bedingungen sich bezüglich der Anzahl an Expositionsdurchgängen unterschieden und es aufgrund der inhaltlichen Anlehnung an den Rationalen nicht möglich war, beispielsweise in beiden Bedingungen, das Angstlevel oder Erwartungen zu erfassen, bleibt die Beeinflussung zugrundliegender Mechanismen unklar. Aufgrund des gewählten Studiendesigns können wir nicht ausschließen, dass weniger Durchgänge in der Habituationsbedingung (d.h. gleiche Anzahl wie in der Befürchtungsüberprüfungsbedingung) zu den gleichen Veränderungen bezüglich der Wirksamkeit (Schmerztoleranz und kognitive Bewältigung) geführt hätten. Die Aussagekraft von Studie II ist dadurch limitiert, dass sie sich nur auf den Einfluss von „positiven Erwartungsverletzungen" im Sinne von „weniger schlimm als erwartet" beziehen. In Studien wurde wiederholt gezeigt, dass Erwartungen wahrscheinlicher und schneller angepasst werden, wenn die Erfahrung negativer als befürchtet ausfällt (Arntz & Lousberg, 1990; Arntz & van den Hout, 1988; Hird et al., 2019).

5.2 Implikationen für theoretische Modelle

Die Ergebnisse lassen sich in die im theoretischen Hintergrund vorgestellten Modelle einordnen und es lassen sich Implikationen für mögliche Erweiterungen der Modelle ableiten. Im Folgenden werden die Ergebnisse zunächst im Zusammenhang mit dem ‚ViolEx'-Modell und anschließend mit dem ‚Fear-Avoidance Model' diskutiert.

Die Ergebnisse von Studie II bestätigen die Annahmen des ‚ViolEx'-Modells (Rief et al., 2015), dass wahrgenommene Erwartungsverletzungen nicht zwangsläufig zu einer Erwartungsanpassung führen. Auch die Ergebnisse von Studie III stehen im Einklang mit der Annahme, dass sich Therapieeffekte durch Herausarbeiten der Erwartungsverletzung optimieren lassen. Die Befunde aus Studie I lassen sich auch mit dem ‚ViolEx'-Modell in Verbindung bringen, sind allerdings aufgrund der kleinen Stichprobe nur als Hinweise zu werten: Das Erleben erheblicher Einschränkungen in relevanten Lebensbereichen durch Schmerzen kann als erwartungsverletzende Erfahrung für das eigene Selbstkonzept angesehen werden. Solange der gegenwärtige Zustand jedoch als vorübergehend betrachtet wird, scheint eine Änderung der allgemeinen Erwartung nicht angebracht. Vielmehr wird die Erwartung mit einer Ausnahme aktualisiert, die als „kognitive Immunisierung" bezeichnet werden kann, wie z.B.: „Ohne die Schmerzen, könnte ich so sein, wie ich gerne wäre.". Denkbar wäre, dass die kognitive Immunisierung passive Bewältigungsstile wie Rumination, Vermeidungs- oder Durchhalteverhalten hervorruft und zu Gefühlen der Hilflosigkeit führt, da die Schmerzreduktion selbst begrenzt ist (Eccleston & Crombez, 2007). Der ständige Zielkonflikt zwischen Vermeidung von Schmerz und der Verfolgung von Lebenszielen und daraus resultierende Motivation lässt sich im ‚ViolEx'-Modell bislang nicht abbilden (Schrooten, Vlaeyen, & Morley, 2012). Wenn man davon ausgeht, dass Ziele und Werte hierarchisch angeordnet sind, lässt sich erklären, dass daraus gespeiste Erwartungen unterschiedlich bedeutsam (selbstwertrelevant) für das Individuum sind (Kruglanski et al., 2002). Des Weiteren sollten Kosten bzw. antizipierte Kosten der Erwartungsveränderung stärker im Modell berücksichtigt werden. Beispielsweise wäre es denkbar, dass die Kosten für eine Erwartungsänderung, an die sich tiefgreifende Verhaltensänderungen anschließen, subjektiv zu hoch wären und therapeutische Bearbeitung von Themen, wie z.B. Trauer über

Einschränkungen und verpasste Chancen vorzuschalten wären (Harris, Morley, & Barton, 2003).

Unter Berücksichtigung der Annahmen des ‚Fear-Avoidance Models' und dem daraus abgeleiteten ‚*tailored treatment*' Ansatzes der Expositionstherapie lässt sich der Befund aus Studie III, dass schmerzängstliche Probandinnen schneller von Expositionsinstruktion profitierten, erklären. Katastrophisierung als Hindernis für die Exposition ließe sich durch den Einsatz von Vermeidung (möglicherweise kognitiver Vermeidung) erklären. Die Ergebnisse aus Studie I lassen sich teilweise auch im 'Fear-Avoidance Model' einordnen: Höhere Katastrophisierung wird als Prädiktor für Beeinträchtigung beschrieben und wiederholt durch Studien belegt (z.B. Boersma & Linton, 2005). Da Verhaltenstendenzen und eingesetzte Bewältigungsstrategien nicht erfasst wurden, lässt sich lediglich spekulieren, durch welchen der alternativen im Modell beschriebenen Pfade der Zusammenhang von Selbstverstrickung auf Schmerzbeeinträchtigung vermittelt wurde. Der negative Einfluss von Ängstlichkeit auf Schmerzbeeinträchtigung scheint im Widerspruch zu stehen mit den Annahmen des Modells. Daher lässt sich vermuten, dass ProbandInnen, die Schmerzen als Hindernis bei der Erreichung wertorientierter Ziele ansahen, kein ängstliches Vermeidungs- und Schonverhalten zeigten, sondern möglicherweise durch stärkere Anstrengung versuchten, ihre Ziele trotz der Schmerzen zu erreichen. Im aktualisierten ‚Fear-Avoidance Model' (Vlaeyen & Linton, 2012) werden motivationale Aspekte stärker berücksichtigt (Crombez, Eccleston, Van Damme, Vlaeyen, & Karoly, 2012), allerdings wird die Verfolgung wertorientierter Ziele als dichotome Alternative zur Schmerzvermeidung aufgezeigt. Möglicherweise erscheint es für PatientInnen, die ihr Selbst und ihre Ziele als verstrickt mit Schmerzen erleben, eher eine zeitliche Priorisierung zu geben im Sinne von: „Wenn ich die Schmerzen los bin, kann ich wieder so wie früher sein.". Zwar wird dadurch auch eine Schmerzreduktion priorisiert, allerdings nicht zwangsläufig aus einer schmerzängstlichen Motivationslage heraus. Beispielsweise könnte auch eine hartnäckige Zielverfolgung ohne Berücksichtigung persönlicher Grenzen zu mehr Beeinträchtigung führen (vgl. Persistenzverhalten; Hasenbring & Verbunt, 2010).

5.3 Perspektiven für zukünftige Forschung

Aufbauend auf den Ergebnissen der Dissertation und unter Berücksichtigung der genannten Limitationen könnte zukünftige Forschung dazu genutzt werden, die Ergebnisse an größeren (Studie I und II) und klinischen Stichproben (Studie II und III) zu replizieren. Auch wäre es relevant zu untersuchen, ob die in Studie I gemessenen Erwartungen (Selbstverstrickung mit Schmerz) – so wie katastrophisierende Bewertungen (Flink et al., 2010) einen hinderlichen

Einfluss auf Expositionseffekte haben. Zukünftige prospektive Studien würden davon profitieren, Verhalten zu erfassen, um die vermittelnden Effekte (Vermeidungsverhalten vs. Durchhalteverhalten) besser zu verstehen. Dazu ließe sich ein ‚*ecological momentary assessment*' Ansatz (z.B. App-gestützt) sehr gut nutzen (May, Junghaenel, Ono, Stone, & Schneider, 2018). Falls sich unsere Befunde aus Studie I in einer größeren, repräsentativeren Stichprobe bestätigen lassen, sollten ökonomische präventive Interventionen evaluiert werden. Beispielsweise Ansätze zur wertorientiertem Verhalten aus der Acceptance and Commitment Therapie erscheinen hier vielversprechend (Yu & Mccracken, 2016; Yu et al., 2015).

Zukünftige Studien sollten den Einfluss der kognitiven Post-hoc Beurteilung (d.h. „Immunisierung“) weiter beleuchten, um zu erklären, warum Schmerzerwartungen manchmal trotz widersprüchlicher Erfahrungen nicht aktualisiert werden. Ein besseres Verständnis darüber, wie frühere Schmerzerwartungen aufrechterhalten bzw. durch (nicht) bestätigte sensorische Evidenz verändert werden, könnte zu einer Verbesserung der psychologischen Schmerztherapien (z.B. expositionsbasierte Behandlungen) beitragen. Um die in Studie II untersuchten Verarbeitungsprozesse besser zu erforschen, wäre es relevant zu wissen, welche Prozesse mit einer Schmerzstörung assoziiert sind bzw. als Vulnerabilitätsfaktoren für die Entwicklung einer Schmerzstörung anzusehen sind (Nees, Ruttorf, Fuchs, Rance, & Beyer, 2020). Daher sollte das Paradigma in Anlehnung an die Untersuchungen aus dem Depressionsbereich (Kube, Rief, & Glombiewski, 2016; Kube, Rief, Gollwitzer, Gärtner, & Glombiewski, 2019; Kube, Rief, Gollwitzer, & Glombiewski, 2018) jeweils in angepasster Form an einer gesunden und einer klinischen Stichprobe mit chronischen Schmerzen untersucht werden. Zur Untersuchung von kognitiver Immunisierung bedarf es eines standardisierten Inventars, das mehr Varianz abbildet als das von uns genutzte Rating. Das Design aus Studie II ließe sich möglichweise mit den therapeutischen Instruktionen aus Studie III kombinieren, um Expositionsprozesse feinkörniger abzubilden und schließlich auch an einer klinischen Stichprobe mit Exposition der idiosynkratischen Befürchtungen und Effekte auf die Schmerzbeeinträchtigung zu untersuchen.

5.4 Implikationen für die klinische Praxis

Zusammenfassend lassen sich aus den Ergebnissen der Dissertation Vorschläge und Ansatzpunkte für Prävention und Intervention durch erwartungsfokussierte Ansätze ableiten. Unter Berücksichtigung, dass in einem neueren RCT fünf Expositionssitzungen ebenso wirksam wie zehn waren (Glombiewski et al., 2018) und Exposition sich als kostengünstiger als graduierter Aktivitätenaufbau herausstellte (Goossens et al., 2015), liefern die Ergebnisse aus Studie III Hinweise darauf, dass durch eine therapeutische Instruktion zur Erwartungsüberprüfung Exposition noch ökonomischer gestaltet werden kann. Durch Erwartungsfokussierung eine Zeitersparnis zu erreichen, könnte die Implementierung im stationären Setting mit hoher Fallzahl und geringen zeitlichen Ressourcen erleichtern. Das eindeutige „*Response*-Muster“ legt nahe, dass in einem Erwartungsüberprüfungsansatz ‚*Responder*‘ schneller von ‚*Non-Respondern*‘ zu unterscheiden sind und dadurch PatientInnen, die als ‚*Non-Responder*‘ einzuordnen sind, weitere frustrierende Behandlungserfahrungen erspart werden könnten. Vorgeschaltete kognitive Ansätze könnten möglicherweise helfen, die Zahl der ‚*Responder*‘ zu erhöhen.

Unter Einbezug der Ergebnisse aus Studie II lässt sich sagen, dass eine alleinige Überprüfung der Erwartungen durch reale Erfahrungen nicht ausreichend ist: Die Erwartungen selbst haben nämlich Auswirkungen auf das Erleben, wodurch selbst Erwartungsverletzungen in eine positive Richtung (= „nicht so schlimm wie erwartet“) nicht zwangsläufig so verarbeitet werden. Auch der Befund, dass katastrophisierende Bewertungen das Ansprechen auf Expositionsübungen vermindert, legt nahe, dass katastrophisierende Befürchtungen durch eine direkte Konfrontation mit einer möglichst großen Erwartungsverletzung widerlegt werden können. Besonders bei PatientInnen mit erhöhter Katastrophisierungsneigung sollten diese Kognitionen möglicherweise zunächst durch kognitive Interventionen bearbeitet werden, bevor Expositionen durchgeführt werden, um eine selbsterfüllende Prophezeiung zu vermeiden. Dies scheint zunächst konträr zu Vorschlägen von Craske und Kollegen (2014), die vorschlagen, dass Expositionstherapien auf eine möglichst maximale Erwartungsverletzung abzielen sollten. Es lässt sich spekulieren, dass katastrophisierende Bewertungen die Erwartungsüberprüfung behindern, indem es eine Wahrnehmung der erwartungsverletzenden Erfahrung erschwert oder es zu einer Verzerrung in Richtung der vorherigen Erwartung kommt (vgl. Befunde von Studie II). Möglicherweise wird diese kognitive Verzerrung durch Immunisierungsprozesse mediiert. In dem Fall müsste man einen umgekehrt U-förmigen Zusammenhang zwischen erwartungsverletzender Erfahrung und Erwartungsanpassung annehmen: Weicht die Erfahrung deutlich merklich, jedoch nicht zu stark von der Vorhersage ab, wird die Erwartung angepasst. Wir leiten aus den Befunden ab, dass eine psychoedukative Vorbereitung sehr wichtig zu sein scheint. Dabei ist allerdings darauf zu achten, PatientInnen hierbei nicht von der Ungefährlichkeit überzeugen zu wollen, da dies paradoxe Effekte fördern kann (Crombez, Baeyens, & Eelen, 1994). Södermark und Kollegen (2020) konnten kürzlich zeigen, dass durch eine der Exposition vorgeschaltete Intervention zur Steigerung der Emotionsregulation, die Effekte und „Responserate“ der Expositionstherapie verbessert werden konnten.

Die vorläufigen Ergebnisse aus Studie I legen nahe, dass die Abfrage der Befürchtung helfen könnte, um RisikopatientInnen zu identifizieren (Nicholas, 2016). Wertorientierte Ansätze und Unterstützung bei einer realistischen Zielsetzung könnten ein niedrigschwelliges Angebot darstellen, um Chronifizierung frühzeitig zu verhindern. Auch wäre es denkbar, expositionstherapeutische Angebote in der primären Versorgung zu etablieren (van Erp, Huijnen, Jakobs, Kleijnen, & Smeets, 2019; Vlaeyen, den Hollander, et al., 2018). Vorteilhaft daran wäre, dass sich umgrenzte Befürchtungen einfacher überprüfen und widerlegen lassen, als Befürchtungen, die bereits auf viele Bewegungen und Kontexte generalisiert sind (Vlaeyen, 2015).

5.5 Fazit

Zusammenfassend unterstreichen die Ergebnisse der vorliegenden Dissertation die Relevanz von Erwartungen in der Entstehung, Aufrechterhaltung und Therapie chronischer Schmerzstörungen. Durch den vorläufigen Befund, dass Selbstverstrickung mit Schmerzen die Schmerzbeeinträchtigung drei Monate später vorhersagt, konnten selbstkonzeptrelevante negative Erwartungen als potenzieller Risikofaktor identifiziert werden. Darüber hinaus wurde in einer experimentellen Studie gezeigt, dass vorherige Erwartungen das Schmerzerleben in die erwartete Richtung beeinflussen können und damit eine Anpassung an erwartungsverletzende Erfahrungen erschweren. Gleichzeitig scheint die Stärke der Erwartungsverletzung entscheidend dafür zu sein, ob Erfahrungen auf Selbstwirksamkeitserwartungen generalisieren und sich in dem objektiven Maß einer höheren Schmerztoleranz niederschlagen. Damit konnten wir relevante Annahmen des ‚ViolEx'-Modells erstmalig in einem experimentellen Paradigma überprüfen und teilweise bestätigen. Aus einer direkten Gegenüberstellung von zwei therapeutischen Instruktionen (Habituation vs. Erwartungsüberprüfung) zur Schmerzexposition lassen sich Hinweise darauf ableiten, dass die direkte Überprüfung von idiosynkratischen Befürchtungen, zu schnelleren Erfolgen bei der Expositionstherapie führt. Dies liefert vielversprechende Hinweise, dass eine stärkere Fokussierung auf die Befürchtungen der PatientInnen, Expositionstherapien zu größerer Akzeptanz bei PatientInnen und BehandlerInnen verhelfen könnte.

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Anhang A: Studie I

"Not until my pain is gone…": How the entanglement of self and pain predicts disability three months after acute pain

LONGITUDINAL PILOT STUDY ON PAIN DISABILITY

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Abstract

Objective. The transition from acute to chronic pain is poorly understood, including psychological risk factors that are crucial for early prevention. A potential risk factor is the perception of limited functioning and pain-related restrictions in daily activities and social roles as a threat for the identity – the sense of self. The main objective of this pilot longitudinal study was to investigate the predictive value of self-discrepancy and self-pain enmeshment (i.e., perception of pain as an obstacle to become the person one wants to be) for disability three months later.

Methods. In a longitudinal study, individuals with acute pain were recruited at a University hospital and filled in self-report questionnaires at baseline and three months later (N = 25; 72% male; age: M = 50.04, SD = 17.6). The influence of self-discrepancy and self-pain enmeshment on disability was tested in a hierarchical multiple regression analysis.

Results. Aside from pain catastrophizing (β = .76, p = .002) and pain anxiety (β = -.60, p = .01), the self-pain enmeshment (ideal-self; β = .43, p = .01) predicted disability three months later (ΔR^2 = .17, p = .01).

Conclusion. This study provides new insights in the interplay of self-related expectations and pain-related disability: Individuals feeling enmeshed with pain have higher disability three months later according to our preliminary findings. This suggest (ideal-)self-pain enmeshment to be a novel candidate for a psychological risk factor of pain chronification.

Keywords: Pain chronification; Recovery; Risk factors; Self-discrepancy; Self-enmeshment

Highlights:

- Perceiving pain as a threat for the self predicted disability after three months.
- Self-pain enmeshment explained variance over and above fear and catastrophizing.
- Preliminary evidence for self-pain enmeshment as a risk factor for chronic pain.

1. Introduction

Acute pain is the primary reason to seek healthcare [1]. While most patients reengage with life after healing, one in sixth patients who attended an emergency room due to injury develops chronic pain [2]. Once pain has become chronic, it is incompletely responsive to currently available therapies [3]. Thus, identifying risk factors that contribute to the transition from acute to chronic pain is crucial, because they might allow for prevention at an early stage [4]. Psychological factors have found to be predictive for pain chronification [5,6]. Among them, pain catastrophizing and pain-related fear have been found to predict pain-disability [7,8].

Pain interferes with functioning and interrupts daily activities, thereby affecting a person's identity – the sense of self [9–11]. Anticipated constraints due to pain increases the distance to an *ideal* self (self-discrepancy ideal/actual; i.e., being a loving father), while it reduces the distance to a *feared* self (self-discrepancy feared/actual; i.e., being an impatient father) [12,13], according to self-discrepancy theory [14]. Self-pain enmeshment is considered as the perception of pain as an invincible obstacle when reaching for valuable life goals (e.g., 'Pain hinders me from being the father I want to be') [15]. Yet, it is unknown whether self-discrepancies and self-pain enmeshment contribute to the emergence of chronic pain. We hypothesized that self-discrepancies and self-pain enmeshment predicts disability three months after pain onset above and beyond pain catastrophizing and pain-related fear.

2. Methods

2.1 Participants and Ethics

Thirty participants (22 males) suffering from acute pain (≤ 3 months) in at least one part of the body (e.g., limb, back) were recruited from the outpatient clinic at a University hospital. In 67% of the participants, pain was caused by an accident, while the others reported spontaneous pain in a joint or abdomen. The average pain intensity reported during the last 24 hours was moderate to high (M = 5.38, SD = 2.2; scale from '0'=no pain to '10'=worst pain imaginable), with a duration ranging from 0 to 61 days (*M* = 15.48, *SD* = 20.3). To examine predictors of disability prospectively, we excluded individuals with chronic pain at baseline. The study was approved by the hospital's ethics committee ("Klinisches Ethikkomitee UKGM"; AZ: 189/19).

2.2 Procedures

After giving informed consent, participants completed a battery of paper-pencil questionnaires (t1, see section 2.3). After three months, participants were again contacted for follow-up via phone due to the COVID-19 crisis (t2).

2.3 Measures

Demographic data and all other measures were assessed via self-report. At t1, self-discrepancies were assessed using a self-developed questionnaire in which participants describe their ideal and feared selves in three life domains most important to them (e.g., intimate relationship; family; friends/social bonds; interests/hobbies; job/education). Next, participants rated how close they feel to their ideal and feared selves on a 11-point Likert scale. To assess self-pain enmeshment, participants rated how likely they feel to become what they want (ideal self) vs. fear (feared self), given that pain persists versus subsides. Internal consistencies for ideal and feared selves were Cronbach's α = .80 and α = .81, respectively. Pain-related fear was assessed with the Pain Anxiety Symptoms Scale (PASS-D-20 [16]; α = .89) and catastrophizing by the Pain catastrophizing scale (PCS, [17]; α = .91). The Pain Disability Index – Expect (PDI-E [18]; α = .87), a modified version of the PDI [19], assesses the expected disability in three months for seven life domains. Depression and anxiety severity were assessed by Hospital Anxiety and Depression Scale (HADS [20]; α = .70).

At t2, apart from self-discrepancy, self-pain enmeshment, and HADS, we assessed the disability during the past three months with the Graded Chronic Pain Scale (GCPS [21]).

3. Results

Statistical analyses were conducted using IBM SPSS® (Windows v.22: SPSS Inc, Chicago, IL). From t1 to t2, five participants dropped out (four could not be contacted again; one withdrew participation due to a lack of time). The sample at follow-up consisted of 25 participants (18 males) with an average age of 50.0 years (*SD* = 17.6). Most participants (68%) were in a relationship (20% single, 12% divorced). Primary education was reported by 56% as the highest degree (20% high school, 24% University), 64% were employed (16% unemployed, 20% retired). T-tests for dependent samples with Bonferroni corrected alpha levels were conducted to examine changes from t1 to t2 in relevant variables (see Table 1).

Table 1

Changes in questionnaire scores from baseline (t1) to follow-up measure (t2)

	t1	t2		
	M (*SD*)	*M* (*SD*)	*t* (24)	*p*
Self-Discrepancy (Actual/Ideal)	2.47 (1.69)	2.60 (2.17)	-.28	.78
Self-Discrepancy (Actual/Feared)	3.79 (3.09)	2.45 (2.15)	2.05	.05
Self-Pain Enmeshment (Ideal)	3.86 (2.09)	3.01 (1.60).	3.04	.006
Self-Pain Enmeshment (Feared)	3.36 (2.23)	3.29 (1.65)	.14	.89
Depressive/Anxious Symptoms	13.44 (5.21)	10.96 (4.27)	2.02	.06

Note. $N = 25$. Bonferroni corrected alpha level = .01.

Bivariate correlations showed that self-pain enmeshment (ideal) correlated with disability, $r = .49$, $p = .01$, while self-pain enmeshment (feared), $r = .12$, $p = .56$, and both self-discrepancies (ideal/actual), $r = .07$, $p = .74$, and (feared/actual), $r = .18$, $p = .40$, did not. To test whether self-pain enmeshment (ideal) predicted pain disability after three months above and beyond established predictors (i.e., catastrophizing and pain-related fear), we conducted a hierarchical multiple regression analysis. Pain intensity was not included, as it did not correlate with disability, $r = .31$, $p = .14$.

The results of the regression analysis are shown in Table 2. In step one, pain catastrophizing and pain-related fear were found to have a significant effect, $F(2,22) = 6.2$, $p = .007$ and accounted for 36% of the variance. In step two, pain-enmeshment (ideal) was included, $F(3,21) = 7.77$, $p = .001$ and explained another 17% of the variance.

Table 2

Hierarchical multiple regression analysis for prediction of pain disability at three-month follow-up

Model and predictors	B	*SE*(B)	β	R^2	ΔR^2
Step 1				.36**	.36**
Pain catastrophizing	2.43	.70	.84**		
Pain anxiety	-1.03	.48	-.52*		
Step 2				.53**	.17*
Pain catastrophizing	2.19	.62	.76**		
Pain anxiety	-1.18	.42	-.60*		
Self-pain enmeshment (Ideal self)	5.22	1.92	.43*		

Note. B = regression coefficient. *SE*(B) = standard error of regression coefficient. β = standardized coefficient. R^2 = R-square. ΔR^2= change in R-square. * = p<.05. ** = p<.01.

4. Discussion

The aim of this pilot study was to test whether self-discrepancies and self-pain enmeshment are risk factors for pain chronification and thus, prospectively predict disability after three months. As expected, a higher self-pain-enmeshment predicted disability over and above pain catastrophizing and pain-related fear, with a substantial amount of explained variance. Thus, we found preliminary evidence for a novel candidate for a psychological chronification risk factor, which is independent from other well-known psychological factors.

In the current sample, the threatening character of pain for the self [10,22] diminished during the process of recovery. In line with previous findings [23], self-discrepancies remained stable; yet, self-pain enmeshment declined. To our knowledge, this is the first study in this field using a follow-up period of three months which is of interest as it accords to the time criterion for chronic pain. The stability of ideal-self discrepancies and the descriptive decrease of feared-self discrepancies is explainable, considering that personal goals are harder to reach when pain interferes with daily activities for a certain time [24]. This suggests that although individuals experience discrepancies, they do not attribute those solely to their pain. However, as t2 was conducted during COVID-19 pandemic, we cannot rule out that perceived discrepancies are due to pandemic situation.

Yet, it is unknown which processes mediate the impact of enmeshment on disability. Putting our results in the context of self-regulatory processes (e.g., Dual Process Model [25]), one can assume that enmeshment results from a tenaciously goal pursuit style (i.e., assimilative focus). On a behavioral level, both avoidance and persistence behavior – established risk factors for pain chronification – might mediate this relationship [26–28]. Because behavioral measures were not assessed in this study, it cannot be concluded whether avoidance or persistence behavior can account for the differences in disability. As lower pain-related fear predicted higher pain disability, one can assume that persistence rather than avoidance behaviors mediate the effect of self-pain enmeshment on disability. Future studies might use ambulatory assessment to investigate behavioral patterns as potential mediators. On a theoretical level, recent models on belief updating (e.g., the ViolEx model [29]) might help to understand how discrepancies between the expected and actual performance are processed.

Early preventive interventions might the divert the transition from acute to chronic pain in individuals with high pain-enmeshment. For instance, interventions such as cognitive restructuring might be beneficial to adjust personal expectations or claims: Either the importance of a certain goal that is blocked due to the current disability can be reappraised (e.g., “I won’t lose my friends, if I miss a few football trainings”) or, when striving for a certain value, the specific goal could be changed (e.g., “If I cannot play football, I still can meet my team mates”). Brief psychological interventions (e.g., deriving from the Acceptance and Commitment Therapy) at an early stage might help patients at risk to escape the entrance of a life-long process of suffering.

An important limitation of our study is the small sample. Thus, future studies with larger samples are warranted to replicate or disconfirm our findings. Relatedly, we could not include further potential predictors of disability that might have been interesting (e.g. sociodemographic variables, anxiety and depression scores), since the small sample size limited the number of predictors that could be included without risking overfitting [30]. Second, most of the participants were male which is atypical in pain populations and reduces the generalization to chronic pain populations. Third, pain disability could not be assessed at t1 as for several participants, pain has just emerged.

To conclude, this prospective study provides preliminary evidence that the expected inability to be the person one wants to be in the presence of pain (i.e., the self-pain enmeshment with the ideal self) is a relevant factor in the transition from acute to chronic pain.

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Conflict of Interest

The authors have no competing interests to report.

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Anhang B: Studie II

How expectancy violations facilitate learning to cope with pain – An experimental experiential learning approach

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Abstract

Expectations for painful sensations constitute a core feature of chronic pain conditions, and an important clinical question is whether such expectations are revised when disconfirming experiences (e.g., less pain than expected) are made. To approach this question, we developed an experimental experiential learning paradigm (using painful thermal stimulations) where individuals with subclinical pain (*N*=73) were provided with experiences that confirmed vs. disconfirmed their prior expectations. We hypothesized that expectation change would occur as a function of expectation violations, and we examined how disconfirming experiences in the experiential learning model influence participants' pain tolerance and their ability to cope with pain (self-efficacy) one week later. Expectation violation was higher in the expectation-disconfirmation than in the expectation-confirmation condition, $p = .021$, partial $\eta^2 = .11$. Contrary to our hypothesis, the expectation-confirming condition showed greater expectation change in pain intensity than the disconfirmation-condition, $p = .021$, partial $\eta^2 = .08$. Across groups, the magnitude of the expectation violation in the first trial was related to increases in participants' pain tolerance and self-efficacy one week later. The results indicate that experiencing less pain than expected may not necessarily entail an update of pain expectations, eventually due to reduced precision afforded to new information. Yet, our results suggest that expectation violations can facilitate learning to cope with pain, since not prior expectations per se, but the magnitude of the first expectation violation was associated with increases in pain tolerance and self-efficacy, pointing to the potential of using expectation-violation instructions in exposure-based treatments of chronic pain.

Keywords

Expectation change; Experiential learning; Expectancy violation; Pain perception

Summary

Expectation-disconfirming experiences boost learning: Not prior expectations per se, but the magnitude of expectation violations was associated with learning to cope with pain.

1. Introduction

Expectations about detrimental consequences of certain movements make individuals suffering from chronic pain more sensitive to painful sensations and fuel a self-reinforcing vicious circle as described in the fear-avoidance model [8,52–54]. An important clinical question is whether such expectations are adjusted if disconfirming experiences are made [30]. A theoretical framework to approach this question is "predictive processing", postulating that previous experiences form prior predictions that are used as a template, to which new sensory input is compared [3,40,42,55]. If new information does not match the prior, a prediction error is computed that can be used to update the prior [1,2,17,23]. This process, however, does not go unbiased: Information that confirms prior expectations is prioritized, leading to a confirmation bias in judging pain [24,28]. Empirical evidence for this notion has been provided by Jepma and colleagues [22] who found that pain prediction and perception reciprocally influenced each other at a trial-by-trial level.

Biased experiences of pain in the light of prior expectations is especially important as chronic pain patients tend to overpredict future pain (e.g., [10]). Although exposure-based treatments have been designed to correct such an overestimation of pain and threat expectancies (e.g., [52]), the generalization of new learning experiences during exposure is not always successful [7,15,51]: Riecke and colleagues [44] demonstrated that exposure therapy successfully changed harm expectations, but not pain expectations. Recently, Kube, Rozenkrantz, Rief, & Barsky [31] have introduced a psychological mechanism that may account for the phenomenon of persistent pain expectations: according to the concept of cognitive immunization, people reinterpret disconfirming experiences in such a way that the discrepancy between predicted and actual outcome is reduced, for example by attributing the experience of less pain than expected to exceptional circumstances.

Yet, research testing these assumptions in (sub-)clinical pain conditions is scarce. Therefore, we aimed to investigate in an experimental approach how people who frequently experience pain respond to expectation-disconfirming experiences, and what predicts whether they update their general expectation to cope with pain. Specifically, we applied painful thermal stimulations that either confirmed (expectation-confirmation condition) or disconfirmed (expectation-disconfirmation condition) participants' previous expectations and examined their influence on experiential learning, expectation updating and the transfer to other painful situations. In terms of a manipulation check, we expected participants in the expectation-disconfirmation condition, compared to participants in the expectation-confirmation condition, to have higher pain expectancies and report a higher discrepancy between their predicted and experienced pain. Our main hypothesis was that participants in the expectation-disconfirmation condition, compared to participants in the expectation-confirmation condition, would show a larger update of their pain expectancies in response to decreasing thermal stimulations. To further specify this hypothesis, we examined whether participants from the disconfirmation-condition would generalize the disconfirming experience to a greater extent, in terms of increased pain tolerance and the ability to cope with painful sensations in other situations (i.e., pain-related self-efficacy). Also, we investigated whether the engagement in cognitive immunization strategies hinders the aforementioned transfer effects and mediates the effects of an expectation violation on the update of participants' pain-related self-efficacy.

2. Methods

2.1. Participants and ethics

We recruited via Universities' mailing lists and announcements and aimed to reach people who frequently experience any type of subclinical pain. We included people who frequently experience acute pain episodes (e.g., back pain, headache, abdominal pain). Per inclusion criterion, such pain episodes had to be experienced as mild in terms of the corresponding disability, as scored by the graded chronic pain status [25,27]. In other words, participants were excluded if they reported moderately or highly disabling pain, since we aimed to have a relatively homogeneous sample to ensure the internal validity of our experimental study. Other inclusion criteria were: 18-65 years old; sufficient German language knowledge; absence of any medical illness (e.g., Raynaud's disease, hypertension, neuropathy, coronary diseases, diabetes). As an incentive for participation, participants received either course credit or financial compensation (20€). The study's protocol was approved by the local ethics committee of the Psychology Department (AZ: 2019-15) and was preregistered on aspredicted.org (#26764; 09/01/2019).

We expected a medium effect based on the existing literature on expectation change [29,30] and similar experimental paradigms with thermal pain [48]. Thus, an a-priori power analysis with G*Power (expected $f = 0.25$; power = .95; $\alpha = .05$) indicated a required sample size of at least 108 participants.

2.2. Experimental design

We tested our hypotheses in a standard heat pain paradigm, applying thermal stimulations to participants' non-dominant arm (for the detailed procedure see *2.3.2.*). We allocated participants randomly to one of two experimental conditions. The experimental conditions differed in terms of the verbal suggestions that were provided to the participants in relation to their expected pain perception: Participants from the expectation-confirmation condition were informed that they would react less sensitively to the subsequent thermal pain stimulations due to habituation, while participants from the expectation-disconfirmation condition were informed that they would react more sensitively due to sensitization. In fact, the temperature of painful stimulations was decreased for all participants; hence, participants' expectations were supposed to be either disconfirmed ("expectation-disconfirmation condition") or confirmed ("expectation-confirmation condition") by the subsequent application of thermal stimulations. The exact procedure of the expectancy manipulation and the pain assessments is described below (see *2.3.1.*).

Our experimental design consists of two levels: On a “micro level”, subsequently referred to as e*xperiential learning*, we examined participants’ responses to changing levels of pain from trial to trial. On a “*macro level*”, we analyzed the transfer from the experiential learning part to more distal outcomes, such as pain-related self-efficacy. Regarding the experiential learning part, the experimental design comprised the between-subjects factor “Condition” (expectation-disconfirmation versus expectation-confirmation) and the within-subjects factor “Trial”, ranging from trial 0 to trial 2. With respect to the transfer to the “*macro level*”, there was again the between-subjects factor “Condition” and another within-subjects factor “Time” (baseline versus post versus follow-up).

2.3. Procedure

The first part of the study procedure (t0) consisted of the informed consent, assessment of the inclusion criteria, demographics, and baseline questionnaires via the online survey platform Unipark® (Fig. 1). Next, participants signed up for the following experimental part (t1), which was conducted one week later and comprised the baseline pain tolerance assessment, the expectancy manipulation, and the post pain tolerance. Another week later, participants came in again for a follow-up assessment, comprising the follow-up pain tolerance and additional questionnaires (t2). All sessions took place in a laboratory room at two sites: The University of Marburg and the University of Koblenz-Landau.

2.3.1. Cover story and manipulation of expectations

The experimental procedure was carefully embedded into a cover story to prevent demand effects. As part of the cover story, participants were told that the study aimed at understanding the relationship of real-life pain experiences and the appraisal of pain in the lab.

Regardless of their actually reached temperature during the baseline assessment, all participants received standardized feedback on their pain tolerances. Their ostensible pain tolerances were entered on a sheet next to a simulated normal distribution of pain tolerance in the general population (mean 47°C). The individuals' (fake) values were mapped in the lower quartile, and this was commented by the experimenter who stated: "Your pain tolerance is below average, this means you are more sensitive to pain. These results are totally in line with what we had expected based on the literature". The goal of this verbal suggestion was to evoke initially negative expectations among participants regarding their responses to painful stimulations in order to minimize possible baseline differences in participants' pain expectancies.

Next, participants were informed that in the following three trials, they would not have the opportunity to stop the painful stimulation, but that the measurement would stop automatically at a harmless temperature. As part of the expectancy manipulation, we induced different expectations concerning the upcoming pain experience: Participants in one experimental condition received the following information: "Your skin will become more sensitive over time; that is, you will sensitize to the thermal pain. Thus, we expect that the painful experience will become more intense and more unpleasant over time." This information was supposed to induce the expectation of increasing pain, which in fact was disconfirmed afterwards through the temperature decrease; that is why we labelled this condition "expectation-disconfirmation". Participants from the other condition received the following information: "Your skin will become less sensitive over time; that is, you will habituate to the thermal pain. Thus, we expect that the painful experience will become less intense and less unpleasant over time." This information was intended to be consistent with participants' subsequent experience, that is, reduced pain perception due to the decrease of the temperature of the thermal stimuli applied; that is why we labelled this condition "expectation-confirmation".

2.3.2. Thermal painful stimulation with decreasing temperatures

In the three subsequent trials, participants received thermal stimuli with varying temperatures. Unbeknownst to the participants, they were exposed to lower temperatures in each trial, with a *decrease* of 0.5°C per trial – *independently of the condition*. The specific temperatures for each trial were calculated as follows: trial 0 = average of the person's pain tolerance from the two baseline measures; trial 1 = temperature from trial 0 - 0.5°C; trial 2 = temperature from trial 0 - 1°C. Accordingly, the thermal stimuli applied in the three trials were supposed to be perceived as increasingly less painful. The use of this temperature decrease was examined beforehand in a small pilot study ($N = 15$; testing three different temperature declines: (1) -1°C per trial; (2) -0.5°C; (3) -0.25°C) and was found to be perceived as less intense and less unpleasant, as intended. At the same time, most participants did not get suspicious about the temperature decrease (in terms of lower temperature or shorter duration) as initiated by the experimenter.

Prior to each trial, participants rated their expected pain intensity and pain unpleasantness. After each trial, they rated their actually experienced pain intensity and unpleasantness. Of note, we used the first rating of participants' expected pain intensity and unpleasantness (i.e., prior to trial 0) as a manipulation check with respect to the expectancy manipulation: if the above-described instructions provided to the participants were successful in eliciting the expectation of increasing vs. decreasing pain, participants from the expectation-disconfirmation condition should report higher estimates of expected pain intensity and unpleasantness than participants from the expectation-confirmation condition. Further, we designed this sequence of three trials with continuously decreasing temperature as a model of experiential learning: In particular, this design allowed us to investigate whether participants update their pain expectancy from trial to trial, and whether this update is influenced by participants' initial expectations (that is, differs between the two conditions).

After participants completed the three trials with decreasing temperatures, the experimenter asked the participants how they appraised their experiences with the thermal pain. After participants described their experiences of less painful stimulations, the experimenter emphasized what the participant said with the following standardized feedback, adjusted to their actual experiences: For participants in the expectation-disconfirmation condition, the experimenter explained: “Despite sensitization of your skin, you managed to tolerate higher temperatures, and even rated them as being less intense and unpleasant. This is absolutely contrary to what we expected, and I haven’t seen this in other participants before.” For participants in the expectation-confirmation condition, the experimenter said: “As we had expected, you managed to tolerate further painful stimulations and even rated them as less intense and unpleasant. This is totally in line with what the literature tells us and what we have seen in many others.”. In doing so, the experimenter also asked the participants how this laboratory experience compares to their everyday pain.

2.3.3. Post- and follow-up measures

After the three trials resembling experiential learning as described above, participants’ pain tolerance was assessed again in a post-assessment. As part of the post-assessment, participants also completed questionnaires addressing various domains of pain perception; to do so, participants were instructed to refer to the thermal pain they had just experienced in the experiment. One week later, participants completed a follow-up assessment, comprising both another assessment of their pain tolerance in the heat pain paradigm and additional questionnaires. For the additional questionnaires on pain perception, participants were asked to refer to a pain episode during the last week; this reference was used to examine the extent to which participants transferred the experience from the lab situation to other pain situations. If they reported to have had no pain episodes in the last week, they were asked to refer to their expected next pain episode.

2.3.4. Debriefing

To assess the credibility of the experimental manipulation and the cover story, participants were asked at the end of the follow-up appointment if anything seemed suspicious to them. If so, they were asked afterwards what they supposed to be part of the experimental manipulation. Finally, participants were debriefed regarding the manipulation and the true purpose of the study.

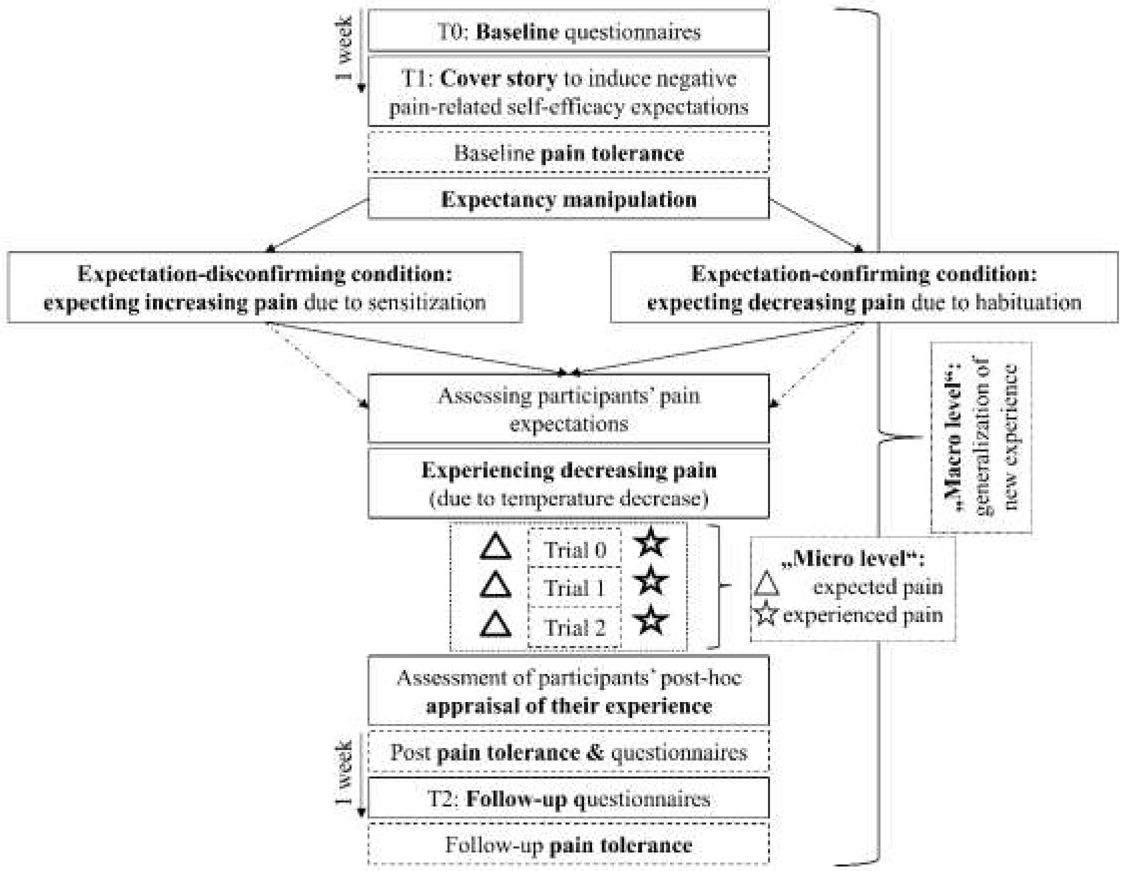

Figure 1. Illustration of the study design and procedure. At t0, inclusion criteria, demographic variables and baseline pain questionnaires were assessed. One week later (t1), participants were exposed to thermal heat pain while measuring their baseline pain tolerance. Regardless of their actual pain tolerance, participants were informed that their tolerance was below average, as part of the cover story. Depending on their group allocation, participants were subsequently informed about either increasing pain or decreasing pain in the following trials. In fact, the temperature of the thermal stimulations was decreased for all participants in the following three trials. Thus, participants from the expectation-disconfirmation condition experienced less pain than expected, while the temperature decrease was consistent with the expectations of participants from the expectation-confirmation condition. Before each of the three trials, participants rated their expected pain on visual analogue scales; analogously, they rated their actually experienced pain after each trial. This part of the study was considered an experiential learning model. After the last trial (trial 2), the experimenter asked the participants to evaluate their experiences in relation to their prior expectations. Afterwards, the post pain tolerance was conducted and several questionnaires concerning the experimental experiences were administered. One week later (t2, follow-up), pain tolerance was assessed again, and participants completed some questionnaires about the coping with pain in the past week, in order to examine possible transfer effects from the experiential learning part to their ability to cope with pain outside the laboratory (= generalized pain-related self-efficacy). Finally, participants were debriefed with respect to the real purpose of the study.

2.4. Measures

2.4.1. Pain tolerance

Painful stimuli were applied on the non-dominant inner forearm via thermal heat inflictions using a thermode (Thermal Sensory Analyzer: TSA II; Medoc Ltd, Ramat Yishai, Israel). The temperature was raised with a slope of 0.5°C/s, starting at the baseline temperature of 32°C, until participants were unable to tolerate the pain – or up to the maximum temperature of 51°C; then, the measurement was stopped automatically and the temperature returned to the baseline level of 32°C. The highest temperature reached displayed the individual pain tolerance. The procedure was repeated in two consecutive measures with a rest period of 30 seconds in between. The mean of both measures was used as participant's pain tolerance. For the second assessment, the thermode was applied to an upper position on the same non-dominant arm to avoid changes in sensitivity to heat stimuli [15,47].

2.4.2. Pain intensity and unpleasantness

After each thermal painful stimulation, participants rated their subjective pain intensity on a 10-cm visual analogue scale (VAS) with the verbal anchors ("no pain" to "worst pain imaginable") and pain unpleasantness on a VAS with the verbal anchors ("bearable" to "unbearable"). The VASs are accentuated by a color spectrum from light green (left) to purple (right).

After the baseline assessment of participants' pain tolerance, they also rated the expected pain intensity and expected pain unpleasantness before each trial on VASs.

2.4.3. Expectation violation: discrepancy between expected and experienced pain

Expectation violation was quantified by computing the difference between participants' expected pain estimates and their actually experienced pain, separately for pain intensity and pain unpleasantness. This score could range from -10 to +10 and was calculated for each trial (0-2) separately. Positive values indicate that the experienced pain was less intense or unpleasant than expected, while negative values indicate that the experienced pain was more intense or unpleasant than expected.

2.4.4. Expectation change: adjustment of expectations to new experiences

To have an estimate of the degree to which participants update their pain expectations, we computed the adjustment of participants' expectations for trial 1 and trial 2 in relation that the first expectation in trial 0. Specifically, we quantified changes in pain expectations by computing the difference in participants' expected pain (intensity and unpleasantness, respectively) from trial 0 to trial 1 (= "first expectation change") and trial 0 to trial 2 (= "total expectation change"). The change scores were computed using the following formula: $\frac{expected\ pain\ in\ trial\ X}{expected\ pain\ in\ trial\ 0} - 1$. Negative values indicate that expectations were changed in the direction of reduced intensity and unpleasantness, while positive values indicate that expectations were changed in the direction of increased intensity and unpleasantness.

2.4.5. Generalization of new experiences: pain-related self-efficacy

Pain-related self-efficacy is defined as the personal assessment of one's ability to cope with pain. In our study, we examined whether participants used the experience of decreasing pain from trial 0 to trial 2 to adjust their pain-related self-efficacy, that is, their ability to cope with painful sensations in their everyday lives. For this purpose, we used a well-established German questionnaire to assess self-rated pain-coping ("*Fragebogen zur Erfassung der Schmerzverarbeitung"* [18]). This scale comprises the subscales cognitive and behavioral coping strategies, each with 12 items that are rated on a 6-point-scale (ranging from 0 = "not at all" to 5 = "absolutely true"). Accordingly, the sum scores can range from 0 to 60 for each subscale, and from 0 to 120 for the total score, reflecting participants' overall expected ability to cope with pain. The internal consistency of the scale in our sample was Cronbach's $\alpha = .705$.

2.4.6. Demographics and self-report questionnaires

Demographic data (e.g., sex, age, education, and family and employment status) were assessed by brief self-report items. Moreover, we assessed the following questionnaires at baseline to control for relevant confounding factors: Pain Self-Efficacy Questionnaire (PSEQ, [39]; FESS, [33]), Pain Anxiety Symptoms Scale (PASS-D-20, [35]), Pain catastrophizing scale (PCS, [36,50]), Pain Sensitivity Questionnaire (PSQ, [46]), Pain Vigilance and Awareness Questionnaire (PVAQ, [34]) and the Cognitive Flexibility Inventory [13]. Further descriptions and the psychometric properties of questionnaires can be found in Supplemental Material A.

2.4.7. Post-hoc appraisal ("cognitive immunization")

We were interested in how participants appraised the experience of decreasing pain as performed in our experimental design, particularly with respect to the reliability of the experience and its transfer to participants' normal pain experiences. Since our study was the first to address this question and to examine expectation change vs. maintenance in a subclinical pain population, we explored participants' appraisal in open-ended interview questions. Specifically, we asked participants how they appraised the experience of decreasing pain (which either confirmed or disconfirmed what they had expected). Participants' answers were noted by the experimenter and were analyzed using qualitative methods. For analyzing participants' post-hoc appraisal, we distinguished between their appraisal of the experiences during the experimental session (in terms of their reliability; "cognitive immunization") and the generalization of these experiences to other pain experiences outside the laboratory ("generalization"). Data were analyzed by two independent raters. When coding participants' statements, the raters examined the extent to which they devalued the experience from the laboratory assessment; that is, they examined whether participants showed cognitive immunization tendencies. To include participants' appraisal of the new learning experience as a mediator variable in subsequent analyses, we computed two sum scores reflecting the extent to which participants devalued the experience. First, participants' answers regarding the appraisal of the reliability of the experimental experience were categorized into 2 = "immunization", 1 = "undecided/put "on hold" and 0 = "no immunization" (= approval of the experiences). Second, the generalization of the experience was scored by categorizing participants' answers into 2 = "no generalization", 1 = "undecided/put "on hold" and 0 = "generalization" to other situations outside the lab. That is, for both sum scores, high values reflect a higher tendency to devalue the experience from the laboratory assessment.

2.5. Statistical analyses

Data were analyzed using IBM SPSS® (Windows v.22: SPSS Inc, Chicago, IL). Participants' data were excluded if data of an entire session (t0, t1, t2) were missing. In case of a single missing data point, we imputed it by the last observation carried forward (LOCF) method. To check for multivariate outliers, Cook's distance and leverage values were calculated. A case was further investigated if its leverage value was greater than three times the average ($3(k+1)/n$) (k = number of predictors in the model) and its Cook's distance (> 1). We did not reveal any data point that had an undue influence on the model.

To check for baseline differences between the conditions in pain-relevant variables and demographic data, T- and chi-square tests were carried out. Using t-tests, we examined possible baseline differences between the groups for pain tolerance, pain intensity and unpleasantness. As a manipulation check, we performed a t-test to examine group differences in participants' expected pain intensity and unpleasantness in trial 0. As an extended manipulation check, we examined whether the two conditions differed in the discrepancy between expected and actual pain experienced, that is, the experience of an expectation violation. To this end, we conducted a 3 (Trial: trial 0 vs. trial 1 vs. trial 2) x 2 (Condition: expectation-confirmation vs. expectation-disconfirmation condition) mixed ANOVA with the expectation violation difference score (as described above) for pain intensity and pain unpleasantness as the dependent variables.

To test our main hypothesis, that is, the update of pain expectations, a 2 (Trial 1 vs. Trial 2) x 2 (Condition: expectation-confirmation vs. expectation-disconfirmation condition) mixed ANOVA with changes in the expected pain intensity and changes in the expected pain unpleasantness in comparison to trial 0 as dependent variables was conducted. For both the extended manipulation check and the main hypothesis, baseline pain tolerance was included, as a covariate as the temperature applied from trial 0 to 2 varied across individuals based on their individual pain tolerance from the baseline pain assessment. The assumptions of the statistical tests (normal distribution, homogeneity of covariance matrices) were fulfilled. If the assumption of sphericity was violated, though, as indicated by a significant Mauchly's test, we report Greenhouse-Geisser corrected degrees of freedom.

To investigate transfer effects from the experiential learning part of our study (i.e., expectation update) , we performed t-tests for independent samples with Bonferroni-corrected alpha levels to examine group differences regarding changes in pain tolerance and changes in pain-related self-efficacy.

To investigate whether cognitive immunization is an obstacle that hinders learning from new experience, a mediation analysis was performed using the SPSS macro PROCESS. The change in participants' pain-related self-efficacy was the criterion variable. The total expectation violation score (= mean score of all discrepancies between expected and experienced pain intensity and unpleasantness) was used as the predictor variable. Participants' cognitive immunization score was included as a mediator variable. The indirect paths are estimated on the basis of collected data and additionally, bootstrapping procedures were used [14]. On the basis of 10,000 bootstrapping samples taken from the original data, the standard error, and a 95%-confidence interval, the significance of the indirect effect was tested. [43].

Furthermore, we performed correlational analyses to examine whether changes in participants' pain tolerance were related to 1) the magnitude of the expectation violation (difference between predicted and experienced pain) and 2) the extent to which participants updated their pain expectations. Also, we performed a hierarchical multiple regression analysis to test if changes in pain-related self-efficacy can be predicted by the magnitude of the expectation violation (step 1) and changes in participants' pain tolerance (step 2). The results of this analysis are reported in Supplemental Material B and Supplementary Table B1.

3. Results

3.1. Sample and baseline characteristics

Due to the current Covid-19 pandemic, data collection could not be continued beyond March 2020, since laboratory examinations with physical contact to participants had not been permitted any longer. When data collection was finished, a total of 171 participants signed up online. In the initial screening, 136 persons met the inclusion criteria and completed the t0 online questionnaires. In total, 87 signed up, agreed to participate, and showed up for experimental part t1 (expectation-disconfirmation: $n = 45$, expectation-confirmation: $n = 42$). From t1 to t2, six persons dropped out. Because of missing data from at least one experimental session due to technical problems, data from another seven participants could not be used in the analyses. Another participant had to be excluded as she experienced the thermal heat pain as "pleasant" and rated it as 0 (= "no pain") repeatedly. Thus, all subsequent analyses are based on data from 73 participants (expectation-disconfirmation: $n = 40$; expectation-confirmation: $n = 33$).

Participants' age ranged from 18 to 63 years ($M = 25.12$; $SD = 8.25$) and 69.9 % were female. The conditions did not differ in any of the socio-demographic variables (all p-values $\geq .223$; all t-values $\leq$-1.23; all χ^2-values ≤ 2.65) (Table 1). The conditions did not differ significantly in any of the baseline questionnaire measures (all p-values $\geq .240$, all t-values ≤ 1.19) (Table 2).

Table 1

Demographic characteristics separately for conditions.

	Expectation-disconfirmation condition (*n* = 40)	**Expectation-confirmation condition (*n* = 33)**
Sex, female/male/diverse	30 (75%)/10 (25%)/0 (0%)	21 (63.6%)/11 (33.3%)/1 (3.0%)
Age in years, *M* (*SD*)	24.05 (6.25)	26.42 (10.12)
Family status		
Single	33 (82.5%)	24 (72.7%)
In a relationship	7 (17.5%)	9 (27.3%)
Children	1 (2.5%)	1 (3.0%)
Educational level, *N* (%)		
No educational degree		
Primary degree	2 (5.0%)	1 (3.0%)
High-school degree	31 (77.5%)	26 (78.8%)
University degree	7 (17.5%)	6 (18.2%)
Employment status, *N* (%)		
Employed	6 (15.0%)	3 (9.1%)
unemployed	4 (10.0%)	3 (9.1%)
In training / university student	29 (72.5%)	26 (78.8%)
Retirement pension	0 (0%)	1 (3.0%)
Disability pension	1 (2.5%)	0 (0%)
Pain disability (past 6 months)		
daily activities	3.05 (1.93)	3.24 (2.52)
family and leisure time	2.8 (2.26)	2.55 (2.65)
work	2.7 (1.92)	2.70 (2.79)
Pain frequency (past 6 months)	1.28 (0.51)	1.15 (0.44)
0-6 days	30 (75%)	29 (87.9%)
7-14 days	9 (22.5%)	3 (9.1%)
15-30 days	1 (2.5%)	1 (3.0%)
Pain intensity (present)	1.52 (1.8)	1.58 (2.26
Maximum pain (past weeks)	4.33 (2.4)	4.06 (2.57)

Table 2

Baseline scores of questionnaires separately for conditions.

	Expectation-disconfirmation condition (*n* = 40)	Expectation-confirmation condition (*n*=33)
FESV (CC)	45.53 (9.06)	45.12 (5.62)
FESS	44.00 (9.26)	45.61 (11.29)
PASS	32.95 (16.59)	34.00 (17.86)
PCS	20.98 (11.28)	22.30 (11.22)
PSQ	43.10 (20.63)	39.85 (16.51)
PVAQ	39.74 (10.01)	39.18 (8.91)
CFI	100.25 (10.01)	103.09 (11.50)

FESV (CC) = German pain coping questionnaire (subscale cognitive coping). FESS = German adaption of the pain self-efficacy questionnaire. PASS = Pain anxiety symptoms scale. PCS = Pain catastrophizing scale. PSQ = Pain sensitivity questionnaire. PVAQ = Pain vigilance and awareness questionnaire. CFI = Cognitive flexibility inventory.

3.2. Baseline differences in pain perception

Participants from the two conditions did not differ in their baseline pain tolerances, $t(70) = -1.39$, $p = .169$, Cohen's $d = 0.33$, pain intensity, $t(71) = .19$, $p = .240$, Cohen's $d = 0.28$, and pain unpleasantness, $t(71) = 0.54$, $p = .588$, Cohen's $d = 0.13$.

3.3. Manipulation check

In terms of a manipulation check, a t-test revealed that the expectancy manipulation was successful in inducing group differences in the expected pain intensity, $t(71) = 2.6$, $p = .011$, Cohen's $d = 0.61$, and unpleasantness, $t(71) = 2.07$, $p = .042$, Cohen's $d = 0.49$, prior to the first trial. As expected, participants from the expectation-disconfirmation condition reported higher estimates (pain intensity: $M = 6.40$, $SD = 1.59$; pain unpleasantness: $M = 6.18$, $SD = 1.81$) than participants from the expectation-confirmation condition (pain intensity: $M = 5.36$, $SD = 1.79$; pain unpleasantness: $M = 5.27$, $SD = 1.93$).

To test whether the expectation violation is higher in the expectation-disconfirmation than in the expectation-confirmation condition, we conducted a multivariate Trial by Condition

ANCOVA with participants' baseline pain tolerance as a covariate. For the main effect of Trial, a non-significant trend was found, Pillai trace = 0.12, $F(4, 66) = 2.31$, $p = .067$, partial $\eta^2 = .035$, pointing to increasing differences between expected and experienced pain. The main effect of Condition was significant, Pillai trace = 0.11, $F(2, 68) = 4.09$, $p = .021$, partial $\eta^2 = .11$, indicating overall greater expectation violations in the expectation-disconfirmation condition than in the expectation-confirmation condition. The Trial by Condition interaction was not significant, Pillai trace = 0.05, $F(4, 66) = 0.943$, $p = .445$, partial $\eta^2 = .054$.

Expectation violation for pain intensity

Regarding pain intensity, a mixed ANOVA with Greenhouse-Geisser correction indicated a non-significant trend for the main effect of Trial, $F(1.74, 130.92) = 3.07$ $p = .057$, partial $\eta^2 = .043$. Post-hoc tests revealed non-significant trends regarding group differences for all trial comparisons: trial 0 vs. trial 1, $F(1, 69) = 3.20$, $p = .078$, with larger expectation violation in trial 1 ($M = 0.62$, $SD = 1.14$) than in trial 0 ($M = 0.04$, $SD = 1.31$); trial 1 vs. trial 2, $F(1, 69) = 2.86$, $p = .095$, with smaller expectation violation in trial 2 ($M = 0.56$, $SD = 1.13$). The main effect of Condition was significant, $F(1, 69) = 6.34$ $p = .014$, partial $\eta^2 = .08$, with higher expectation violation in the expectation-disconfirmation condition, ($M = 0.66$, $SD = 0.85$) than in the expectation-confirmation group ($M = 0.15$, $SD = 0.93$).

Expectation violation for pain unpleasantness

Regarding pain unpleasantness, the mixed ANOVA indicated a significant main effect of Trial $F(2, 138) = 4.53$, $p = .012$, partial $\eta^2 = .06$. Post-hoc tests revealed significant differences for the comparison of trial 1 vs. trial 2, $F(1, 69) = 6.8$, $p = .011$, with higher expectation violation in trial 1 ($M = 0.90$, $SD = 1.27$) than in trial 2 ($M = 0.66$; $SD = 0.97$), and a non-significant trend for the difference between trial 0 and trial 1, $F(1, 69) = 2.97$, $p = .089$, with higher values in trial 1 than in trial 0 ($M = 0.19$, $SD = 1.68$). The main effect of Condition was also significant, $F(1, 69) = 5.20$, $p = .026$, partial $\eta^2 = .07$, with larger expectation violation in the expectation-disconfirmation condition ($M = 0.81$, $SD = 0.77$) than in the expectation-confirmation condition ($M = 0.35$, $SD = 0.84$). Fig. 2 illustrates the results for expectation violation for intensity and unpleasantness separately in the two conditions, respectively.

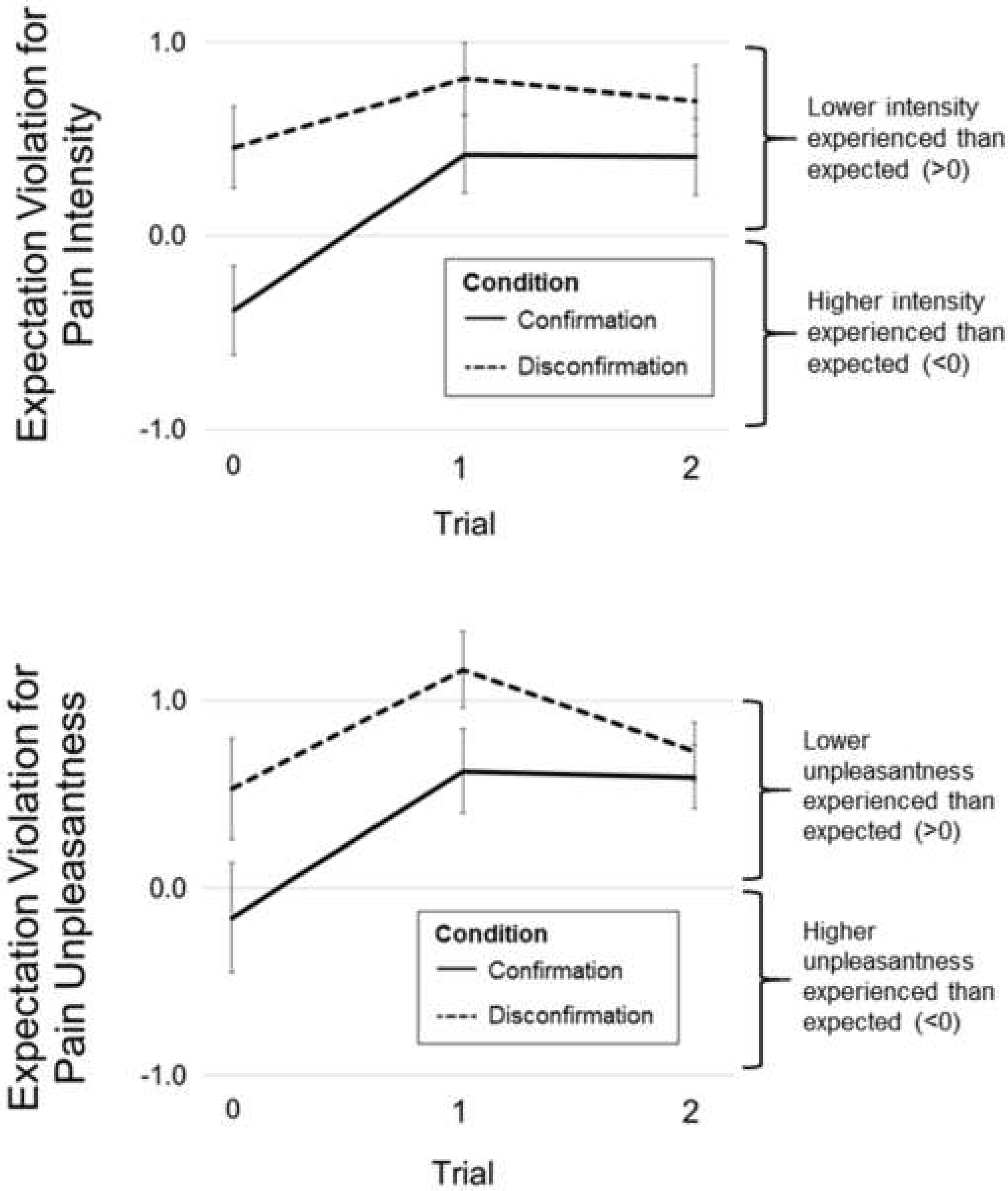

Figure 2. Illustration of the results for expectation violation for pain intensity (upper figure) and pain unpleasantness (lower figure) over the course of three thermal painful stimulations with decreasing temperature (= manipulation check). Expectation violation here reflects the difference between predicted and actually experienced pain. Expectation-confirmation condition: n = 33, Expectation-disconfirmation condition n = 39[a]. [a] One participant's data was excluded due to missing data in pain tolerance at baseline (included as a covariate).

3.4. Main analyses

3.4.1. Main hypothesis: expectation change

To examine the extent to which participants updated their pain expectations from trial 0 to trial 1 (= "first expectation change") and from trial 0 to trial 2 (= "total expectation change"), and whether this update differs between the two conditions, we conducted 2x2 a mixed ANOVA with Condition and Trial as factors and baseline pain tolerance as a covariate. The main effect of Trial was not significant, Pillai trace = 0.04, $F(2, 68) = 1.23$, $p = .298$, partial $\eta^2 = .035$, neither was the main effect of Condition, Pillai trace = 0.05, $F(2, 68) = 1.64$, $p = .201$, partial $\eta^2 = .046$. However, a non-significant trend was found for the Trial by Condition interaction, Pillai trace = 0.08, $F(2, 68) = 2.89$, $p = .062$, partial $\eta^2 = .078$.

Expectation change in pain intensity

Regarding pain intensity, the mixed ANOVA revealed a significant Trial by Condition interaction, $F(1, 69) = 5.61$, $p = .021$, partial $\eta^2 = .08$, for expectation change in pain intensity with greater expectation change from trial 0 to trial 2 ($M = -15.91$, $SD = 3.47$) than from trial 0 to trial 1 ($M = -1.09$, $SD = 2.81$) and greater expectation changes for the expectation-confirmation condition ($M_{\text{trial 1}} = -1.31$, $SD_{\text{trial 1}} = 29.85$; $M_{\text{trial 2}} = -19.95$, $SD_{\text{trial 2}} = 37.97$) than for the expectation-disconfirmation condition ($M_{\text{trial 1}} = -0.75$, $SD_{\text{trial 1}} = 17.71$; $M_{\text{trial 2}} = -11.69$, $SD_{\text{trial 2}} = 21.14$).

Expectation change in pain unpleasantness

Regarding pain unpleasantness, the mixed ANOVA revealed a non-significant trend for the Trial by Condition interaction, $F(1, 69) = 3.52$, $p = .065$, partial $\eta^2 = .05$ for expectation change in pain unpleasantness, with greater expectation change from trial 0 to trial 2 ($M = -19.28$, $SD = 4.41$) than from trial 0 to trial 1 ($M = -2.02$, $SD = 4.28$) and greater expectation changes for the expectation-confirmation condition ($M_{\text{trial 1}} = -5.46$, $SD_{\text{trial 1}} = 32.01$; $M_{\text{trial 2}} = -27.35$, $SD_{\text{trial 2}} = 31.77$) than for the expectation-disconfirmation condition ($M_{\text{trial 1}} = 1.68$,

$SD_{\text{trial 1}} = 40.78$; $M_{\text{trial 2}} = -10.88$, $SD_{\text{trial 2}} = 44.06$). Fig. 3 illustrates the results for expectation change (i.e., expected intensity and unpleasantness) separately for the two conditions.

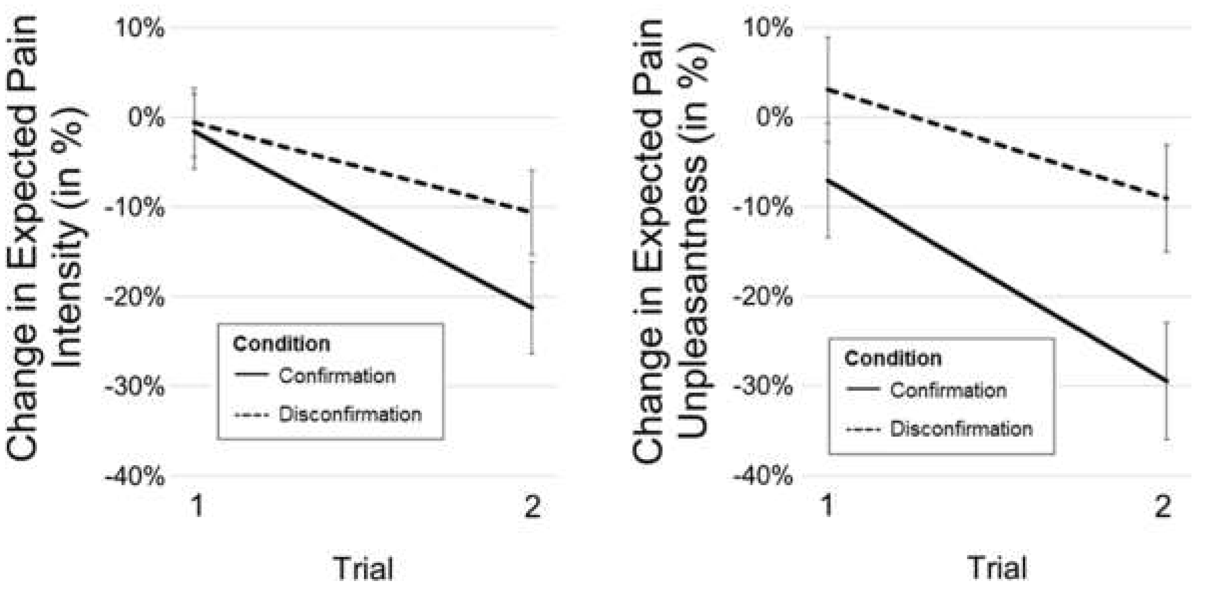

Figure 3. Illustration of the results for expectation change for pain intensity (left figure) and pain unpleasantness (right figure) over the course of three thermal painful stimulations with decreasing temperature separated for conditions. Change scores are calculated as the percentage decrease in expected pain from trial 0 to trial 1 and from trial 0 to trial 2, respectively, using the following formula: $\frac{expected\ pain\ in\ trial\ X}{expected\ pain\ in\ trial\ 0} - 1$. Expectation-confirmation condition: n = 33, Expectation-disconfirmation condition n = 39[a]. [a] One participant's data was excluded due to missing data in pain tolerance at baseline (included as a covariate).

3.4.2. Changes in pain tolerance and pain-related self-efficacy

Descriptively, the increase in all distal outcomes was larger for the expectation-disconfirmation condition (Pain tolerance increase (baseline to post): $M = 0.65$, $SD = 1.39$; Pain tolerance increase (baseline to follow-up): $M = 0.60$, $SD = 1.42$; Pain-related self-efficacy increase (t1 to t2): $M = 2.43$, $SD = 9.44$) than for the expectation-confirmation condition (pain tolerance increase (baseline to post): $M = 0.38$, $SD = 0.88$; pain tolerance increase (baseline to follow-up): $M = -0.55$, $SD = 1.28$; pain-related self-efficacy increase (t1 to t2): $M = 1.85$, $SD = 7.70$). However, t-tests revealed that the conditions differed neither in their changes in pain tolerance from baseline to post, $t(65.2) = .99$, $p = .326$, Cohen's $d = 0.23$, nor in their changes in pain tolerance from baseline to follow-up, $t(70) = .14$, $p = .886$, Cohen's $d = 0.09$ Likewise, the groups did not differ in their changes in pain-related self-efficacy from t1 to t2, $t(71) = .28$, $p = .779$, Cohen's $d = 0.07$.

3.4.3. Post-hoc appraisal

In total, most participants did not report cognitions that pointed to the engagement in cognitive immunization strategies after the experiment ($n = 61$). However, there were more participants in the expectation-disconfirmation condition ("immunization: $n = 3$, "*on hold*": $n = 7$) than in the expectation-confirmation condition ("immunization": $n = 0$; "on hold": $n = 2$) who stated cognitions categorized as cognitive immunization, $\chi^2(3) = 7.92$, $p = .048$. Exemplary statements expressing such cognitive immunization tendencies were for example: "My skin got warmer and thus, the pain did not feel as worse as before."; "It was because of the weather that I could cope so well.". With respect to the generalization of experiences, the response patterns did not differ between the two conditions, $\chi^2(4) = 3.13$, $p = .537$ (expectation-disconfirmation condition: "no generalization": $n = 12$, "on hold": $n = 13$ vs. expectation-confirmation condition: "no generalization": $n = 15$; "on hold": $n = 7$). Examples for cognitions of these categories are: "During the experiment, I knew that the pain would stop eventually. When I have headaches, I do not know how long they will last.", "Pain inside my body [referring to back pain] is worse than pain applied from the outside.".

3.4.4. Cognitive immunization as an obstacle for the generalization of experiences on pain-related self-efficacy

To test if immunization hinders the generalization of new experiences (i.e., successful coping with pain), in terms of inhibiting the update of pain-related self-efficacy, we conducted a mediation analysis. The results of this mediation analysis show that neither the effect of expectation violation on cognitive immunization, $b = 0.018$, $SE = 0.07$, $p = .792$, nor the effect of cognitive immunization on pain-related self-efficacy, $b = 4.41$, $SE = 2.41$, $p = .070$ reached significance. The indirect effect of expectation violation on pain-related self-efficacy through immunization was not significant either, *b* = 0.08, *SE* = 0.03, [-0.46, 0.80]. Thus, these results indicate that the effects of expectation violation on the generalization of the experience to successfully cope with pain were not mediated by the participants' engagement in cognitive immunization strategies.

3.4.5. Relationship between expectation violation and changes in pain tolerance and pain-related self-efficacy

To further explore whether the processes examined in our experiential learning model on the "micro level" (that is, expectation violation and expectation update, as examined in extended manipulation check and the main hypothesis) correlated with changes on the "macro level" , that is, changes in pain tolerance and pain-related self-efficacy (capturing possible transfer effects from the experiential learning model), we computed Pearson correlations (Table 3). These results indicate that the larger the first expectation violation in both pain qualities (intensity and unpleasantness), the larger the increase in pain tolerance from pre to post and from pre to follow-up, irrespective of the experimental condition. Moreover, the second expectation violation with respect to pain unpleasantness correlated positively with the increase in pain tolerance from pre to post. Expectation changes regarding the expected pain intensity (that is, a decrease in the expected intensity from trial to trial) correlated negatively with an increase in pain tolerance for all measures. This means that the more participants adapted their expectations to the decreasing pain experience, the more they showed an increase in their pain tolerances from baseline to post and from baseline to follow-up. A similar correlational pattern was found for expected pain unpleasantness; however, only the correlation between the second expectation change and changes in pain tolerance from baseline to post reached significance.

Table 3

Pearson correlations between expectation violation and expectation change with increase in pain tolerance and changes in pain-related self-efficacy.

	Expectation Violation						Expectation Change			
	Pain Intensity			Pain Unpleasantness			Pain Intensity		Pain Unpleasantness	
Pain tolerance	trial 0	trial 1	trial 2	trial 0	trial 1	trial 2	trial 1	trial 2	trial 1	trial 2
baseline to post	.28*	.00	-.10	.34**	.24*	-.03	-.31**	-.34**	-.18	-.26*
Baseline to follow-up	.24^{+}	.06	-.13	.29*	.09	-.15	-.26*	-.28*	-.19	-.19
FESV (t2-t1)	.12	-.09	-.19	.34**	-.12	-.05	-.12	-.05	-.19	-.14

$^{+}$ = $p \leq .1$. * = $p \leq .05$. ** = $p \leq .01$. FESV (t2-t1) = difference score in pain-related self-efficacy.

The change in pain-related self-efficacy correlated positively with the first expectation violation in pain unpleasantness. However, it did not correlate with expectation violation in pain intensity and expectation change at any trial. These results indicate that the larger the first discrepancy between expected and experienced pain unpleasantness (expectation violation), the more likely participants generalize this experience, in terms of updating their generalized pain-related self-efficacy.

4. Discussion

The aim of this study was to examine how participants with subclinical pain adjust experimentally induced pain expectations in the light of (dis-)confirming experiences (i.e., decreasing pain), and how this (dis-)confirming experience affects participants' ability to cope with pain.

In line with a growing body of research [6,20,24,26,28], we were able to experimentally induce specific pain expectations, reflected by the successful manipulation check: Pain expectations were higher in the expectation-disconfirmation condition than in the expectation-confirmation condition. Further strengthening the validity of our experimental paradigm, the results confirmed that participants from the expectation-disconfirmation condition (expecting increasing pain but actually experiencing decreasing pain) showed greater expectation violations than participants from the expectation-confirmation condition. Furthermore, we examined how participants updated their pain expectancies when experiencing decreasing levels of pain. Contrary to our hypothesis, we found that participants from the expectation-confirmation condition updated their pain expectations from trial to trial to a greater extent than participants from the expectation-disconfirmation condition (as indicated by the Trial by Condition interaction in the main analysis), although this effect reached significance only for expected pain intensity. The non-significant trend for expected pain unpleasantness might be discussed as follows: First, it is possible that three trials had not been enough to elicit an expectation update; relatedly, the discrepancy between expected and experienced stimulus might not have been large enough. Second, it is conceivable that this effect would have been significant if we had reached the required sample size. Thus, future studies may aim to recruit larger samples, and may consider the possibility of providing larger discrepancies between pain expectation and sensory input and using more than three trials. Nevertheless, the direction of the trend is remarkable: expectation update was larger in the expectation-confirmation condition, that is, our results suggest that noticing a discrepancy between predicted and perceived pain does not necessarily initiate an expectation change. At first glance, this might be considered as contradicting the proposed relationship of prediction errors and learning under the predictive coding framework, assuming that prediction errors entail an update of the prior prediction [16,17,55]. However, recent work suggests that prior predictions of physical sensations can become immune to updating if disconfirming sensory input is afforded little precision (i.e., reliability) [3,31,40]. Conceivably, this is what happened in the expectation-disconfirmation condition: since they expected more intense painful sensations, they perceived the decreasing pain as less reliable, thereby entailing little expectation update, while participants from the expectation-confirmation condition updated their expectations more in line with the decreasing painful sensations. This idea is supported by recent studies that have provided evidence for self-reinforcing loops in pain perception, suggesting that pain expectancies are updated to a smaller extent if the painful stimulation deviates from the prediction not in the expected direction [22]. Moreover, Hird and colleagues [21] provided evidence for a "tipping point" at which the discrepancy between pain prediction and experience becomes so large that the degree of update decreases.

Furthermore, our finding of reduced expectation updating in line with decreasing pain can be linked to the psychological literature on post-hoc appraisal processes, which may hinder hasty updating as described in the model of violations of expectation ("ViolEx"-model [45], proposing that, depending on how the individual appraises the disconfirmatory experience, expectation updating may sometimes fail to occur. To further examine these processes, we used an additional data source: We asked participants how they appraised their experiences of decreasing pain with open-ended questions. In line with our hypothesis, expectation-disconfirmation was related to the enhanced report of cognitive immunization strategies as compared to the expectation-confirmation condition. However, we failed to demonstrate that such cognitive immunization strategies mediate the effects of expectation violations on changes in pain-related self-efficacy. To interpret the results of this mediation analysis, there are some methodological and statistical limitations worth considering: As we used categorical scores, the variance in cognitive immunization was quite small, and the distribution was skewed. Thus, quantitative instruments for measuring cognitive immunization against – and barriers to the generalization of – disconfirming experiences are needed. Another explanation of the absence of the mediation effect might be that implicit ('unconscious') processes are at play.

In addition to the results regarding experiential learning at the "micro level" (i.e., experiencing expectation violations and updating predictions accordingly), some interesting findings have come up in relation to the "macro level", that is, transfer effects. As hypothesized, pain tolerance and pain-related self-efficacy increased over the course of the experiment. Conditions did not differ in their increases, although there was a descriptive trend for a larger increase in the expectation-disconfirmation condition. Irrespective of the condition, the magnitude of the first expectation violation and the initial expectation update correlated with the increase in pain tolerance and changes in pain-related self-efficacy. Furthermore, consistent with the assumptions of predictive coding and the ViolEx-model [45], the extent of expectation violations regarding pain unpleasantness predicted subsequent changes in pain-related self-efficacy. In other words, experiencing a large expectation violation in the first trial predicted changes in participants' general ability to cope with their normal pain conditions one week later, and so did increases in pain tolerance. Thus, our results suggest that processes at the experiential learning level in the lab facilitated the generalization of the experience to cope with pain (= generalized pain-related self-efficacy). Importantly, an expectation violation, but not the mere expectation at baseline was crucial for the generalization of new learning experiences, our results show. These findings support the hypothesis that the magnitude of the prediction error plays a functional role for learning [4,5,12,32,37,38].

These findings have several clinical implications: Exposure-based treatments for chronic pain are designed to challenge idiosyncratic threat expectations and falsify them if they reflect an overestimation of threat [52]. Recently, it has been discussed that a maximal violation of participants' expectations may result in enhanced learning in exposure therapy for anxiety disorders [7]. This notion is supported by the present results, indicating that a large expectation violation predicted greater update of participants' generalized pain-related self-efficacy one week later. At the same time, our results also suggest that people can be reluctant to update their expectations in line with disconfirming experiences, as the reduced expectation adjustment in the expectation-disconfirmation condition indicates. Speculatively, if expectations continue to be resistant to updating and learning from new experience, this may facilitate the transition from acute to chronic pain as well as the maintenance of dysfunctional threat beliefs in chronic conditions [11,52]. When aiming to modify patients' pain expectations, it might be important to consider the extent to which new information contradicts prior predictions. In particular, there is some evidence for an inverse u-shaped relationship of the magnitude of the prediction error and learning; that is learning from new experiences is greatest if new experiences are unexpected enough to be perceived as surprising, but remain still in a certain range of previous expectations [49]. If new expectations are not surprising at all or totally unexpected (out of range), expectation updating is less likely. Therefore, patients' expectations might be discussed prior to the exposure treatment, and patients could be "prepared" to learn from disconfirming experiences by discussing what experiences are to be expected.

One limitation of our study is that standardized heat stimuli rather than the individual's idiosyncratic pain were applied. We did so for reasons of controllability, at the expense of limiting the extent to which the experience of coping with pain in the laboratory can be transferred to participants' normal pain perception. Second, we did not include a control condition (e.g., without induced expectation) to compare our results to unbiased expectation updating. Third, unlike other studies with predictive cues, where expectations are induced by a conditioning protocol [26,56], we used verbal information to induce expectations. Thus, our procedure probably involved more top-down rather than bottom-up processes. Furthermore, as we recruited participants with subclinical pain, the generalization of our findings to chronic pain patients is questionable. Indeed, Peerdeman and colleagues [41] have shown that chronic pain conditions were less influenced by expectation interventions than acute pain. Moreover, we examined expectation-disconfirmation only in a "less painful than expected" but not in a "more painful than expected" direction. As expectation updating in pain has shown to be faster in a "worse-than expected" direction [21], our findings only apply to disconfirming evidence in a "better than expected" direction. A further limitation is the small sample size, which, though inevitable due to the Covid-19-related restrictions for laboratory research, influenced the chance to detect significant effects.

In conclusion, our findings suggest that expectation violations can facilitate learning to cope with pain, since not prior expectations per so, but the magnitude of the expectation violation was associated with increases in pain tolerance and pain-related self-efficacy. Future studies might further elucidate the influence of cognitive post-hoc appraisal to explain why pain expectations sometimes fail to be updated despite disconfirming experiences. A better understanding of how prior pain expectations are maintained vs. changed by (dis-)confirming sensory evidence might contribute to an improvement of psychological pain therapies (e.g., exposure-based treatments).

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Data availability statement

The data that support the findings of this study are available from the corresponding author upon reasonable request.

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Supplemental Materials

Supplemental Material A: Description and Psychometrics Properties of Additional Questionnaires

As another measure for pain self-efficacy, the German adaption of the Pain Self-Efficacy Questionnaire (PSEQ, [6]; FESS, [2]) was used. The scale consists of 10 items assessing broad self-efficacy expectations in daily activities in consideration of the pain on a 6-point scale (ranging from 0 = "not at all convinced" to 5 = "completely convinced"). The sum score can range from 0 to 50 and the sample showed a very good internal consistency (Cronbach's α = .910).

Pain anxiety was assessed with the Pain Anxiety Symptoms Scale (PASS-D-20, [4]). The scale consists of 20 items assessing pain-related anxiety on a 6 -point scale ranging from 0 = "never" to 5 = "always". The sum score ranges from 0 to 100, and in the present sample, the scale showed a very good internal consistency (Cronbach's α = .914).

The Pain Catastrophizing Scale (PCS, [5,8]) assesses catastrophizing beliefs with 13 items on a 5-point scale ranging from 0 = "not at all true" to 4 = "absolutely true". Sum scores can range from 0 to 52, and the scale had a very good internal consistency in this sample (Cronbach's α = .919).

Moreover, participants' reaction towards pain as sensitivity and vigilance were assessed by the Pain Sensitivity Questionnaire (PSQ, [7]) and the Pain Vigilance and Awareness Questionnaire (PVAQ, [3]) with good (PVAQ: Cronbach's α = .802) to very good internal consistency (PSQ: Cronbach's α = .927).

As a general measure of cognitive (in-)flexibility, the Cognitive Flexibility Inventory [1] was used. This scale comprises 20 items, assessing cognitive flexibility in different situations on a 7-point Likert scale with the verbal anchors "do not agree at all" to "totally agree" The internal consistency was acceptable (Cronbach's α = .765).

Supplemental Material B: Regression Analysis for Pain Self-Efficacy

For this regression analysis, we included those variables as predictors that correlated significantly with pain-related self-efficacy as reported above, that is, the first expectation violation for pain unpleasantness (step 1) and increases in pain tolerance (step 2). Changes in pain-related self-efficacy were used as the criterion.

The results of this regression analysis are shown in Supplementary Table B1. The regression analysis indicated that in step one, the first expectation violation in pain unpleasantness had significant effects, $F(1, 70) = 8.93$, $p = .004$ and accounted for 11.3% of the variance of the generalization of pain-related self-efficacy from the experiment to coping with pain outside the lab. Including the increase in pain tolerance from pre to post and from pre to follow-up as predictors in step two, added another 17.2% explained variance, which was significant, $F(3, 68) = 9.05$, $p < .001$. Of note, in this step, only increases in pain tolerance from baseline to post had significant effects ($\beta = -.611$; $p < .001$).

Supplementary Table B1

Hierarchical multiple regression analysis for prediction of changes in pain-related self-efficacy.

Model and predictors	*B*	*SE*(*B*)	β	R^2	ΔR^2
Step 1				.113**	.113**
Expectation Violation, Pain Unpleasantness (trial 0)	1.60	0.53	.34**		
Step 2				.285***	.172**
Expectation Violation, Pain Unpleasantness (trial 0)	2.17	0.52	.46***		
Pain Tolerance Increase (Baseline to Post)	-4.47	1.19	-.61***		
Pain Tolerance Increase (Baseline to Follow-up)	1.86	1.03	$.29^{+}$		

B = regression coefficient. *SE*(*B*) = standard error of regression coefficient. β = standardized coefficient. R^2 = R-square. ΔR^2= change in R-square. $^{+} = p < .1$. * = $p < .05$. ** = $p < .01$. *** = $p < .001$.

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Anhang C: Studie III

An Experimental Analogue Study on the "Dose-Response Relationship" for Exposures to Pain: The more, the better?

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Abstract

Objectives. Novel suggestions derived from the inhibitory learning model on how to enhance exposure therapy instructions have been debated with enthusiasm in the last few years. However, little is known about the new approach of focusing on an expectancy violation compares to the traditional habituation rationale of exposure therapy. Therefore, we compared therapeutic instructions derived from these two competing theories in healthy female participants in an experimental heat pain paradigm.

Design & Methods. Participants (*N*=116) received a therapeutic instruction derived from either a habituation-based or the inhibitory learning model (expectation violation) prior to aversive stimulation with thermal pain. Participants were repeatedly exposed to heat pain at their previously measured pain tolerance limit until a predefined exposure goal was reached.

Results. The expectation violation instruction led to faster goal attainment and higher response rates than the habituation instruction. Both instructions led to increased pain tolerance in the short and long term (1-week follow-up).

Conclusions. Our results suggest that exposure using an expectation violation instruction is especially time effective. Although the findings from this analogue design cannot be directly generalized to populations with clinically relevant levels of chronic pain, they point to some important theoretical and clinical implications for the treatment of pain.

Keywords

Exposure therapy; Inhibitory learning model; Expectation violation; Dose-response relationship

1. Introduction

For decades of research, exposure therapy has been shown to be a highly effective intervention for various mental health problems, such as anxiety,[1–3] obsessive compulsive disorder,[4] and post-traumatic stress disorder.[5] More recently, Vlaeyen and colleagues have adapted exposure therapy to chronic low back pain.[6] Such exposure-based treatment approaches expose patients to situations they normally avoid, ie, exhibiting certain movements that may be perceived as threatening.[7] Several randomized controlled trials and single-case studies have demonstrated that exposure therapy is effective in treating back pain[6,8–12] and chronic regional pain syndromes.[13,14]

Notwithstanding the indisputable effectiveness of exposure therapy, a debate about the central underlying mechanism has arisen in the last decade. In particular, the long-standing assumption that habituation (ie, experiencing that a certain unpleasant state subsides over time) is the underlying mechanism has been challenged.[15–19] Supposedly, not habituation, but a violation of an individual's expectations leads to successful and long-lasting extinction.[16,20,21] That is, it is assumed that making the experience that a feared outcome does not occur results in more sustained symptom reduction. For people suffering from pain, this means that they could be guided to test their expectation, "exhibiting this movement will damage my spinal cord" by performing the respective movement. When doing these exercises, patients normally experience that their expectation of physical harm is disconfirmed, thus leading to enhanced activity and reduced impairment.[22,23] Yet, despite widespread enthusiasm for such an "inhibitory learning model",[15,24,25] little is known about how it compares directly to habituation-based approaches.[25–28]

Some recent studies have compared habituation- and inhibitory learning-based (expectation violation) approaches. The evidence attained from studies that do not involve pain points toward either no differences between the two instructions[29] or slightly superior effects of the inhibitory learning approach.[21,30,31] The first direct comparison in an experimental study on pain[31] revealed that, in comparison to a control instruction, both instructions improved cognitive pain coping, but only the expectation violation instruction increased pain tolerance.

Besides the mere effectiveness of a specific treatment, its efficacy might also be taken into account when considering its implementation into routine care, which is characterized by high case load and efficient time scheduling.[32,33] Thus, if one has two treatment options at hand, which are similarly effective, but one outperforms the other in terms of the time required to achieve the predefined outcome, the more efficacious treatment might be preferred. Following this reasoning, it has been suggested that one advantage of expectation violation-based exposure therapy might be the lower number of repetitions needed, that is, the treatment "dose" to achieve a therapeutic goal ("response")[34] This might be because habituation is not deemed crucial to defining a single session and an entire exposure-based treatment as successful.[35] Indeed, a recent randomized controlled trial comparing a short-term and a long-term version of exposure therapy for patients with chronic back pain revealed faster improvement when fewer sessions were offered.[36] This means that exposure therapy for pain has the potential to bring about significant improvement very quickly; yet, it is not clear whether this can be best achieved by focusing on habituation-based or expectation violation-based instructions.

Therefore, the aim of the current study is to investigate the efficacy and the "dose-response relationship" of different instructions for pain exposure. We compared a habituation-based instruction and an expectation violation-based instruction in pain-free female participants confronted with thermal heat stimulation after inducing fear of bodily harm. We replicated and expanded the design of a previous study[31] by adding a one-week follow-up and by tailoring the number of exposure trials. For reasons of feasibility, we decided to use an analogue sample to investigate differences in the efficacy of two exposure instructions deriving from distinct theoretical approaches.[37] Although the generalization of results from analogue samples to a clinical population is questionable, Craske and colleagues suggested examining fear extinction in healthy individuals and analogue samples prior to clinical samples to understand the underlying processes.[19]

We hypothesized that participants in the expectation violation condition would require fewer exposure trials than those in the habituation condition to attain a predefined exposure goal (hypothesis 1: "dose-response relationship"). Relying on previous findings,[31] we expected no differences in relevant pain outcomes between conditions (hypothesis 2: "changes in pain perception"). In addition, we were interested in potential predictors of the response, because although exposure has proven effective for treating pain patients in multidisciplinary settings with limited time and resources, high dropout rates have been reported compared to cognitive-behavioral therapy treatments.[36] Hence, it might be important to identify baseline patient characteristics that bear predictive value for treatment outcomes or relapse.[33,38,39] Accordingly, we examined pain anxiety and pain catastrophizing as two potential predictors of the treatment response. These variables were chosen as exposure has been found especially effective for patients with elevated levels of fear,[36] while high catastrophizers did not improve from exposure treatments.[40]

2. Methods

2.1 Participants

A power analysis for MANOVAs ($\alpha = .05$; power = .80) indicated that a sample of 111 participants was needed to detect significant effects. Based on the results of Schemer and colleagues,[31] we expected medium to large effects. Participants were recruited through flyers and advertisements. They received either course credit or monetary reimbursement for participation. We excluded individuals who suffer from medical illnesses (acute/chronic pain, Raynaud's disease, hypertension, neuropathy, coronary diseases, and diabetes). To rule out sources of error variance, males were excluded due to sex differences in pain sensitivity,[41] habituation,[42,43] and reported pain.[44] The institutional ethics committee at the department approved this study's protocol (AZ: 2017-41k).

2.2 Study Design

The procedure (similar to [31]; for further details, see Appendix, Table A1) consisted of three parts, approximately 1 week apart each (see Figure 1). Participants were randomly assigned to either a habituation instruction ($N = 58$) or an expectation violation instruction ($N = 58$). For investigating whether the therapeutic instructions differentially affected pain perception (pain tolerance, intensity, and unpleasantness) as well as cognitive pain coping, all measures were conducted after the exposure trials (post-test) and 1 week later (follow-up).

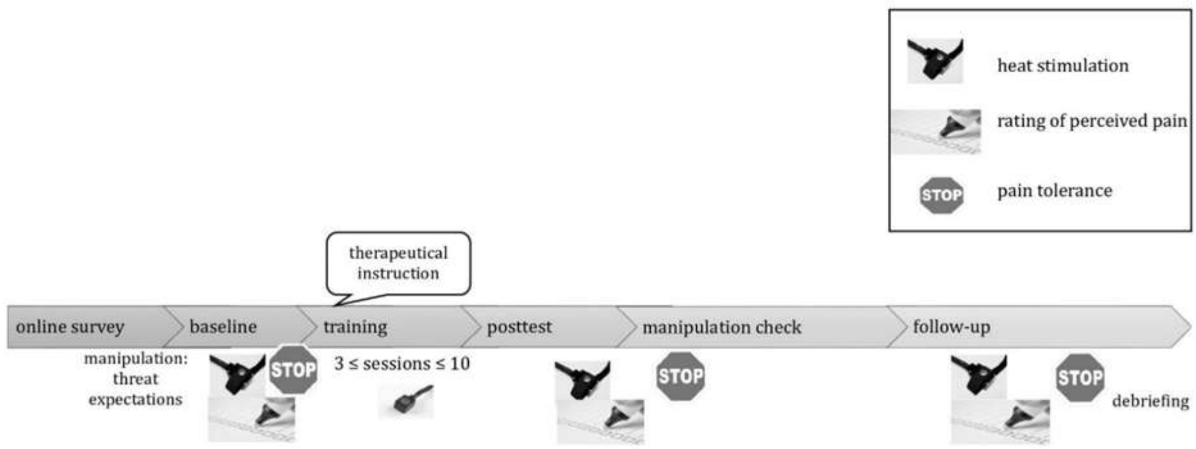

Figure 1. Study design and procedure. After completing a battery of questionnaires online, the participants signed in for a laboratory assessment consisting of three parts: (a) baseline (t0); the manipulation of threat expectations was followed by the baseline of pain tolerance, intensity, and unpleasantness; (b) following the presentation of the therapeutic instruction (randomized allocation to either habituation or expectation violation), the participants underwent several exposure trials until a predefined exposure goal was reached. During these exposure trials, the participants were exposed to nociceptive thermal stimuli; (c) a post-test (pain tolerance, intensity, unpleasantness) and a post-assessment of questionnaires was followed by a manipulation check. In a 1-week follow-up, pain tolerance, intensity, unpleasantness, and the questionnaires were conducted again before the aims of the study were disclosed to the participants.

Demographic data were assessed by brief self-report items and further outcome variables (sections 2.3.3–2.3.5) online prior to the laboratory appointment. After giving their informed consent, participants' threat beliefs were manipulated as described in section 2.2.1.

Pain was operationalized as applied heat stimulation by a thermode (Thermal Sensory Analyzer: TSA II; Medoc Ltd, Ramat Yishai, Israel) on the non-dominant forearm. Temperature was raised, starting at 32°C, with a slope of 0.5°C per second to the maximum of 52°C. First, in the baseline phase, we tested the participants' individual pain tolerance. Then, depending on the allocated instruction condition, the exposure-based treatments were explained. Next, participants were asked to apply the strategy they had just learned (habituation vs. expectation violation) when confronted with the heat stimulation. Participants then rated the credibility of the instructions they had been given. In the post-test phase, they were instructed to reflect on what they had learned before the measurement of their post-training pain tolerance and completed the same questionnaires (sections 2.3.3–2.3.5) again. At follow-up, after pain tolerance and questionnaires (sections 2.3.3–2.3.5) were assessed, participants rated the credibility of the threat manipulation, and they were debriefed about the manipulation and its purpose.

2.2.1 Threat Induction

To evoke fear of pain, participants were asked to sign a declaration of alleged side effects (eg, skin redness, fainting). To enhance personal relevance, the experimenter claimed that due to appearing skin redness, she was required to measure the skin thickness, as it would correlate with the likelihood of side effects occurring. The experimenter falsely described a sham measure as an indicator by which to evaluate an individual's vulnerability to the occurrence of side effects. After informing each participant that her value was allegedly "borderline higher risk" for side-effects to occur, fear was enhanced again by claiming intensifying temperatures accompanied by the inability of stopping it themselves. Participants were not informed that the temperature would not rise above their previously measured pain tolerance.

2.2.2 Intervention: Exposure Instructions and Determination of an Exposure Goal

Exposure instructions consisted of two parts: First, participants listened to standardized instructions via loudspeaker, in which the exposure rationale was elaborated based on the respective theory about underlying mechanisms. These instructions were used in other studies before.[31,45] Second, participants were guided to either focus on their emotional or cognitive response via standardized questions. These questions were based on detailed manuals similar to previous studies.[31] Experimenters were trained in conducting the standardized protocol.

The habituation instruction focused on changes in the emotional response to the feared stimulus. The exposure rationale was explained as a process of fear habituation each time someone faces a feared situation. The experimenter then encouraged participants to verbalize their emotional response (eg, fear, distress, anxiety, discomfort) prior to the exposure trials. Before and after each trial, participants were asked to indicate and rate their momentary emotional response (eg, how distressed do you feel before the next trial?) on an 11-point scale (0 = neutral; 10 = very high). The individual exposure goal was reached when the level of the emotional response was reduced by half of its initial score (eg, from "8" to "4").

The expectation violation instruction focused on the cognitive response to the feared stimulus. The exposure rationale was explained as a systematic testing of individual predictions about negative outcomes through exposure experience. The experimenter encouraged participants to formulate their central concerns about the exposure trials with the thermode. The concerns being mentioned by the participants (eg, "my skin will burn and blister") at this point were the expectations that were supposed to be disconfirmed subsequently. Specifically, prior to each trial, participants were asked to estimate the expected likelihood of experiencing their feared outcome (eg, how likely do you think it is, that you skin will burn and blister during the next trial?) on an 11-point scale (0 = not likely; 10 =very likely). The individual exposure goal was reached when the likelihood of the concern's occurrence fell to at least half of its initial score (eg, from “8” to “4”). To investigate the dose-response relationship, we undertook a specifically adapted treatment approach in which the amount of confrontation to thermal pain (ie, the number of exposure trials) was adjusted individually for each participant. Within these limits, participants continued to train until they had reached half of their initially reported emotional response levels (for the habituation condition) or half of their initial estimated likelihood (for the expectation violation condition).

2.3 Measures

2.3.1 “Dose”

The dependent variable was the number of trials participants needed to reach their exposure goal which reflects the treatment “dose”. Specifically, training continued until participants had demonstrated sufficient progress in reaching the *a priori* defined exposure goal (see 2.2.2), with a minimum of three trials and a maximum of 10 trials. The minimum was set due to the fact that only 50% of participants in the previous study reported a decrease in distress within three trials.[31] The maximum was oriented at the feasibility of actual treatment session, eg, .[36] Of note, we used different methods to determine the exposure goal for the two conditions for the following reason. As we hypothesized the instruction to differ in terms of efficacy, we put effort into explaining and implementing each rationale precisely while not confusing it with key terms of the other condition, respectively. Accordingly, the defined exposure goals differed between conditions by analogue to the therapeutic procedure of the different rationales. Thus, the stop criterion (information for the experimenter) differed between conditions, but the dependent variable was identical in both conditions (‘number of trials needed’). Worthy of note, all participants were not previously informed about a specific number of trials to avoid this being interpreted as a safety signal

2.3.2 Pain Tolerance, Pain Intensity, and Pain Unpleasantness

Pain tolerance was assessed by asking participants to tolerate the thermal heat for as long as possible and to terminate it as soon as they were no longer willing to bear it. Participants subsequently rated their pain intensity on an 11-point scale (0 = no pain; 10 = worst imaginable pain) and pain unpleasantness on an 11-point scale (0 = bearable; 10 = unbearable).

2.3.3 Cognitive Pain Coping

Participants were asked to complete the cognitive pain-coping subscale of the German Questionnaire (FESV),[46] which addressed their heat-pain experience. The instructions were adapted according to the experimental setting [31] with good internal consistency (Cronbach's α = .80). Of note, we assessed cognitive pain coping three times (baseline; post-training; and follow-up) to examine whether it changed through treatment, and whether the two experimental conditions differed herein.

2.3.4 Pain Catastrophizing

We applied the Pain Catastrophizing Scale (PCS)[47,48] to measure the participants' pain catastrophizing. Participants are instructed to reflect on previous painful experiences and to mark the degree to which they experience each of 13 feelings or thoughts when feeling or expecting pain on a 5-point scale (0 = not at all; 4 = all the time). The internal consistency of the adapted questionnaire was good (Cronbach's α = .90).

2.3.5 Pain Anxiety

The 20-item short version of the Pain Anxiety Symptoms Scale (PASS)[49] was used to measure fear of pain. Participants rated the frequency of their experiences of fear and anxiety responses to pain on a 5-point scale (0 = never, 4 = always). At t1 and t2 in our study, the participants were asked to rate the heat pain they had experienced. The escape/avoidance subscale of the PASS was adapted for this purpose. For example, the item "As soon as pain comes on, I take medication to reduce it" was changed to "As soon as pain begins, I try to somehow reduce it." Given that we adapted the questionnaire used during the experiment, we evaluated its internal consistency based on the present sample. The internal consistency of the adapted questionnaire was good (Cronbach's $\alpha = .89$).

2.3.6 Confounding Baseline Variables

Moreover, we assessed the following questionnaires at baseline to control for relevant confounding factors: Beck's depression inventory,[50] Pain Sensitivity Questionnaire,[51] Pain Vigilance and Awareness Questionnaire.[52]

2.4 Statistical Analyses

2.4.1 Data Preparation

Data analyses were conducted using IBM SPSS® (Windows v.22: SPSS Inc, Chicago, IL). In cases of individual missing data points, the data were substituted via the multiple imputation method after detecting no significant deviation from randomness via the Little MCAR test. Participants' data were excluded if data of an entire session were missing systematically.

2.4.2 Data Analyses

First, the differential effects of the instruction on the number of exposure trials needed were tested with a *t*-test for independent samples. Condition differences in potential distribution patterns in exposure trials needed were subjected to a chi-square test (hypothesis 1). Second, we carried out a repeated 2 (time: post vs. follow-up) x 2 (condition: expectation violation vs. habituation) mixed ANOVA with pain tolerance, intensity, unpleasantness, and cognitive pain coping as the dependent variables (hypothesis 2). Differences in the various instructions' efficacy should result in a significant interaction of time and condition. The assumptions for this test (normal distribution, homogeneity of covariance matrices) were fulfilled adequately. In addition, we calculated the effect sizes (Cohen's d and partial eta square). Third, predictions of the number of trials needed based on pain anxiety and pain catastrophizing were assessed via a hierarchical multiple regression analysis.

3. Results

3.1 Baseline Characteristics

In total, 180 participants completed the online survey, and 121 of them participated in the experimental part. One withdrew her participation due to the threat manipulation. Four participants were excluded from our analyses because the data from an entire session (t0, t1, or t2) were missing. Thus, we analyzed data from 116 participants whose ages ranged from 18 to 41 years (*M* = 22.6, *SD* = 3.2). The demographic data are shown in Table 1, and the means and standard deviations for the baseline measures are reported in Table 2.

Table 1

Participants' demographic characteristics for both conditions

Measure	Habituation condition (*N* = 58)	Expectation violation condition (*N* = 58)
Highest educational degree		
High school	100%	98.3%
No completed traineeship	67.2%	67.2%
Completed traineeship	6.9%	5.2%
University degree	24.1%	24.1%
Given birth	1.7%	1.7%
Self-reported severe pain experience	48.3%	41.4%

Notes. Values are expressed as means (*M*) and standard deviations (*SD*). % = percentage of the total sample. None of the reported differences were significant (Age: $\chi^2(13) = 13.75$, $p = .39$; High school: $\chi^2(1) = 1.01$, $p = .32$; completed traineeship: $\chi^2(3) = .48$, $p = .92$, pain experiences: $\chi^2(1) = .56$, $p = .455$).

Table 2

Baseline values of variables of interest for both groups

Measure	***M* (*SD*)**		***p***
	Habituation condition (*N* = 58)	Expectation violation condition (*N* = 58)	
Pain Tolerance	47.71 (0.24)	47.08 (0.26)	0.08
Pain Intensity	8.17 (0.14)	7.64 (0.18)	0.02*
Pain Unpleasantness	8.14 (0.25)	7.72 (0.21)	0.21
Cognitive Pain Coping	47.07 (1.10)	47.74 (1.36)	0.70
Pain Anxiety	48.15 (1.81)	48.19 (2.03)	0.99
Pain Catastrophizing	29.21 (1.17)	30.1 (1.21)	0.60

Notes. Values are expressed as means (*M*) and standard deviations (*SD*) for the baseline questionnaires. *p < .05. **p < .001.

The multivariate analyses indicated no significant differences among conditions on baseline questionnaire (depressive symptoms, pain sensitivity, pain vigilance), Pillai's trace = .99, $F(6,109) = 1.44$, $p = .208$. A multivariate ANOVA revealed no significant differences among instruction conditions for conducted measures (pain tolerance) and self-reported pain experiences (pain unpleasantness, pain anxiety, pain catastrophizing, cognitive pain coping) at baseline. However, for pain intensity we noted significant differences between the two conditions, $F(1, 114) = 5.26$, $p = .024$, showing greater intensity in the habituation condition.

3.2 Hypothesis Tests

3.2.1 Hypothesis 1: "Dose-Response Relationship"

A *t*-test for independent groups revealed a significant group difference in the number of exposure trials needed, $t(114) = 4.98$, $p < .001$, Cohen's $d = 0.93$, with an average of ~ 3 trials in the expectation violation condition ($M = 3.41$, $SD = 1.57$) and an average of ~ 5 trials in the habituation condition ($M = 5.43$, $SD = 2.66$). In line with our main hypothesis, the number of necessary exposure trials differed between conditions, $\chi^2(6) = 39.79$, $p < .001$. A histogram of the detailed proportion of trials needed for each condition is shown in Figure 2.

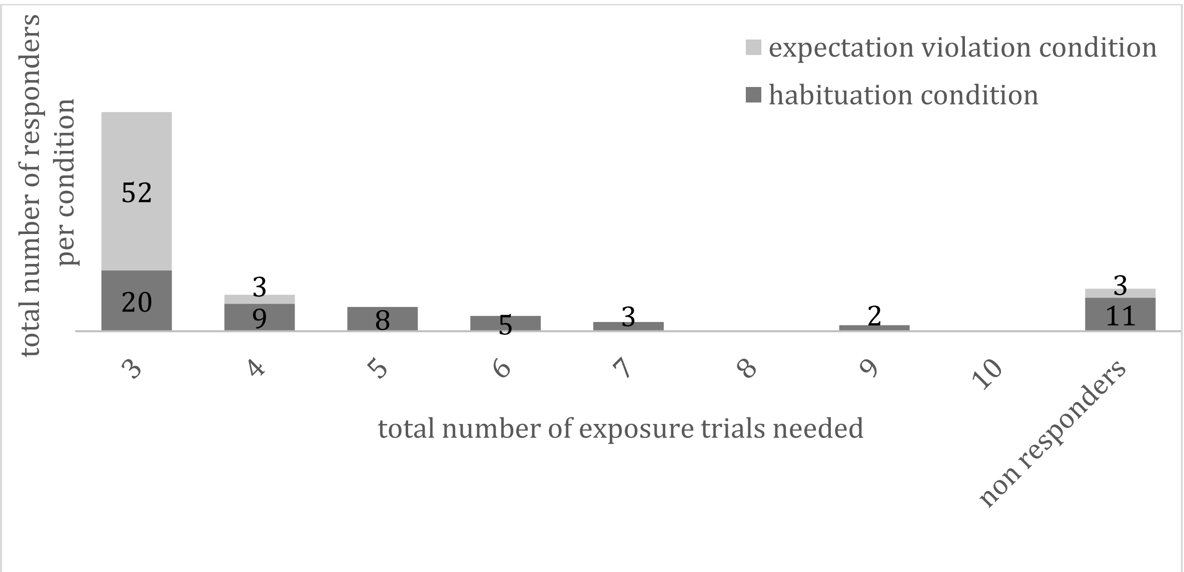

Figure 2. Number of exposure trials (dose) needed to achieve the predefined exposure goal (responder) by instruction condition.

3.2.2 Hypothesis 2: "Changes in Pain Perception"

To test whether the conditions differed in relevant pain outcome measures after treatment, we conducted a multivariate Time by Condition ANOVA. Due to baseline differences, pain intensity and pain tolerance were included as covariates. Neither the main effect of time, Pillai trace = 0.12, $F(4, 109) = 0.86$, $p = .488$, partial $\eta^2 = 0.03$, nor condition, Pillai trace = 0.06, $F(4, 109) = 1.84$, $p = .126$, partial $\eta^2 = 0.06$, nor the Time by Condition interaction, Pillai trace = 0.03, $F(4, 109) = 0.93$, $p = .450$, partial $\eta^2 = 0.03$, was significant. These results indicated that condition groups did not differ in any pain outcome at any time.

3.2.3 Research Questions: "Predictors"

As shown in Table 3, pain anxiety negatively predicted the number of trials, whereas pain catastrophizing was a positive predictor. Higher pain anxiety levels predicted a lower number of trials needed, and higher pain catastrophizing levels predicted a higher number of trials needed. Considered together, these three predictors accounted for 24% of the variance in the model. Introducing the interaction terms pain anxiety *Condition and pain catastrophizing*Condition did not explain additional variance in the model.

Table 3

Hierarchical multiple regression analysis for prediction of number of exposure trials needed

Model and predictors	***B***	***SE*(*B*)**	**β**	***R*²**	**Δ*R*²**
Step 1				.18***	.18***
Condition	-2.02	.41	-.42***		
Step 2				.24***	.06*
Condition	-2.11	.40	-.44***		
Pain Catastrophizing	0.10	.36	.38**		
Pain Anxiety	-0.06	.02	-.38**		
Step 3				.25***	.008
Condition	-2.09	.40	-.44***		
Pain Catastrophizing	0.21	.11	.79		
Pain Anxiety	-0.13	.07	-.77		
Pain Catastrophizing*Condition	-.73	.69	-.49		
Pain Anxiety*Condition	.69	.68	.47		

Notes. B = regression coefficient. SE(B) = standard error of regression coefficient. *p < .05. **p < .01. ***p < .001. ΔR2= change in R-square.

4. Discussion

In this study, we compared the effects of a habituation-based and an expectation violation-based instruction as therapeutic strategies for exposure to presumed harmful pain stimulations in a pain-free sample. A novel feature of this study was the investigation of the "dose-response relationship", that is, the number of exposure trials needed for each exposure instruction to meet a predefined exposure goal In line with our main hypothesis, the number of exposure trials needed to achieve the predefined exposure goal differed between instructions: participants in the expectation violation condition needed a lower "dose" (ie, number of exposure trials) to reach their predefined goal (decrease of the likelihood of feared outcome) than participants in the habituation condition (decrease of distress). Specifically, almost 90% of the participants from the expectation violation condition needed only the minimum number of trials (3 trials = *fast responders*), but the remainder did not reach the exposure goal within 10 sessions (= *non responders*). whereas participants from the habituation condition needed significantly more trials to reach their goal: A third reached their goal within the minimum number of trials (= *fast responders*) and a fifth failed to reach it at all (= *non responders*), the others reached their goal between four to nine sessions (= *normal* to *late responders*). In terms of pain perception, both instructions were successful in increasing participants' pain tolerance (including the corresponding intensity and unpleasantness measures) from baseline to post-treatment. This effect also held at the 1-week follow-up. Cognitive pain coping did not change during the training course. We found that habituation and expectation violation did not differ in terms of pain-related outcomes. Thus, our results suggest that while habituation and expectation violation may be similarly effective in terms of pain perception, expectancy violation might be the more economic approach due to the lower number of trials required.

Our finding that participants in the expectation violation condition required fewer trials to achieve similar effects as participants in the habituation condition can be linked with the inhibitory learning approach.[15,16] They reported, extinction learning can be enhanced by maximizing the discrepancy between prediction and experience (ie, expectancy violation). What is potentially advantageous about this approach is an individual's awareness of one's concrete expectation. Accordingly, focusing on cognitive change during exposure has been deemed beneficial.[21,53] By having their concrete concern in mind, participants can thus evaluate the experience by reflecting upon this expectation. In contrast, with regard to the habituation instruction, the individual has no concrete task other than to observe his or her physical and emotional reaction without engaging in any avoidance behavior.[54] Based on the assumption that both approaches work through the same underlying mechanism of action,[55] learning should take longer when reaching for habituation as more cognitive loops are necessary compared to the more "straightforward" expectation violation instruction. We assume the following cognitive appraisal when targeting habituation: In the absence of expected harm, a person's tension should diminish.[56] The person tries to figure out why he or she feels less tense, with mere attempts to explain the experience to himself or herself potentially revealing that it was not such an awful experience after all.

Similar to,[31] we failed to detect any differences between the two exposure instructions in their efficacy for pain coping. Nevertheless, in that previous study the expectation violation but not the habituation instruction increased pain tolerance in comparison to a control group. Similarly, only the expectation violation instruction led to distinct changes in physiological activation. In contrast, we could not replicate the increase in cognitive pain coping over time. This discrepancy might be the result of the omission of a control condition in the present study. Our results are in line with other experimental studies comparing the two exposure approaches.[29] Although aiming at expectation violation was no more effective than aiming at habituation, both instructions were more effective than a no-treatment control group.

One might interpret our results as an indication that both mechanisms are effective, but that expectation violation may be considered a “shortcut.” It might possess an advantage thanks to its context of cognitive preparation, as the individual has been given precise instructions as to what they should focus on. Taking into account that chronic pain is often treated in multidisciplinary (inpatient) settings with restricted schedules, rapid responses seem highly relevant.[36,57]

Higher levels of pain anxiety and lower levels of pain catastrophizing were predicted fewer trials needed, independently of the instruction type. This may appear contradictory at first glance: while higher pain anxiety was associated with fewer trials needed, higher pain catastrophizing was related to more trials needed. This apparently contradictory pattern might be resolved by considering the following: Exposure therapy is especially pertinent for highly fear-avoidant chronic pain patients[7,58] and has recently been found effective only for patients with elevated levels of fear-avoidance beliefs.[36] A faster response in persons with higher anxiety scores is therefore in line with this finding. Furthermore, there is empirical evidence suggesting that patients who manifest high levels of catastrophizing and fear benefit less from therapy,[15,40,59] and its reduction predicts and mediates the outcomes of both physical and psychological treatments.[60,61] Catastrophizing was identified as a moderator of treatment outcome, particularly for exposure treatment; indeed, exposure was effective only for patients with low or moderate levels of catastrophizing, whereas high catastrophizers did not improve from the treatment.[40] Catastrophizing might impede exposure therapy, as individuals with high levels are less willing to confront themselves. Thus, they might avoid situations that violate their threat expectations and exposure-based treatments alike.

4.1 Limitations and Strengths

The most notable limitation was our clinically unrepresentative sample. Our participants were healthy and not seeking pain treatment. In order to enhance the internal validity of our study, we used strict eligibility criteria and self-selection processes, which, however, further restricted the generalizability of our findings. Our study cohort was characterized by a restricted age range, overrepresented students or academics, and included only females. Our results' generalizability to males might have also been limited due to gender-specific differences in pain perception and reporting. Moreover, concerning age range, educational levels, and motivational state, our sample was not representative for patients with chronic pain, eg, .[62] Nevertheless, our research approach with an analogue sample offers insights into the underlying mechanisms of change in fear of pain. Unlike our study sample, patients suffering from chronic pain presented different learning histories and had dissimilar experiences, all of which could exert complex, confounding influences on the parameters of interest. In line with that, participants did not significantly differ in how they experienced pain. Standard means of eliciting pain can therefore be applied in non-clinical populations in future research, without an idiosyncratic effect on individuals with chronic pain. A single-trial exposure treatment is not representative of exposure therapy, which is usually delivered by repeated sessions over weeks or months accompanied by other interventions such as cognitive restructuring. However, to compare the effects of different instructions, isolating the sole effect of exposure therapy and reducing it to a specific duration is advantageous. Therein lies the superiority of well-controlled efficacy trials over clinical trials for investigating the effects of single treatment parameters that could enhance clinical practice (also see).[35] If a parameter is found to be effective in cost-effective analogous samples, its effectiveness should undergo further investigation in clinical trials with representative samples and interventions in a second step.[37,63] A further limitation of our study was that the main outcome of the study (trials needed to achieve exposure goal) was determined differently for the conditions. Although inevitable due to the different explanations provided to the participants, as noted above, this potentially compromises our findings, as we cannot rule out the possibility that distress decreases slower than expectancy and that this explains the between condition differences and not the instructions themselves. This issue might be addressed in future by using physiological measures in addition to self-report measures.

An important aspect of this study was its replication of a previous study,[31] strengthening the validity of the previous results. To improve the previous study's design, we made the following changes: We adapted the instructions to better implement the theoretical criteria of clinical techniques (see)[15,18] while aligning them (same number of questions requiring similar cognitive load). To test for effect stability and to expand comparability to exposure therapy, a 1-week follow-up was established. As suggested by Craske and colleagues,[64] exposure trials should be conducted at separate occasions with time intervals long enough to enable long-term learning, a factor based on findings from studies with rodents in which the consolidation of extinction learning works best with training sessions spaced apart.[65] This is considered especially important as the expectation violation approach derived from the inhibitory learning model is supposed to minimize the return of fear (see).[15]

In clinical practice, a particular criterion needs to be pre-defined that indicates when the exposure session can be terminated. As the criterion ought to be derived from the presumed mechanism of change, different exposure criteria for our instruction conditions were inevitable[26,28] and explicitly required to analyze the efficacy of different exposure-based approaches.[45,66] In the previous study,[31] only 50% of participants reported a decrease in their fear levels over the course of three exposure trials. Thus, we extrapolated that three trials are insufficient for habituation to occur in most participants.

4.4 Directions for Future Research

While the present research was a laboratory study focusing on heat pain tolerance, future studies examining different exposure instructions might focus on more clinically relevant outcomes such as disability and global functioning.[23] In addition, exposure in chronic pain can be optimized in three ways based on future research. First, studies that shed light on the underlying mechanisms of action are likely to help to optimize the treatment (eg, evidence-based criteria for a successful session). Second, research on individual characteristics such as the catastrophizing tendencies that predict treatment response, non-response, or dropout are particularly relevant[67,68] to plan individual treatments (eg, prevention of side effects and unnecessary strain) and to minimize direct and indirect financial costs for the health care system. Third, in line with the agenda of personalized medicine to administer patients "the right drug at the right dose at the right time",[69] future research should inform psychotherapists about differential indications such as which therapeutic instruction is most effective for which patient.[70]

4.5 Clinical Implications

Although our study was designed as an experimental analogue study in healthy participants, some cautious conclusions about treating pain in clinical practice might be drawn. As such, our main finding, showing that the respective exposure goal was achieved faster in the expectancy violation approach than in the habituation approach, can be seen as an argument favoring this approach. In doing so, instructing patients to formulate and re-examine their concrete individual concerns might help to reduce excessive and disabling fear-avoidance beliefs.[71] Introducing a re-evaluation of beliefs might be especially helpful in chronic pain patients, as they experience a transition of the informational character of pain experiences (ie, pain loses its useful signal character for harm prevention in chronic conditions). There is recent evidence that shorter exposure outperforms longer versions in chronic pain[36] and obsessive-compulsive disorder.[72] The impact of specific therapeutic instructions requires further investigation in clinical samples.

4.6 Conclusion

Two therapeutic exposure instructions were found to be effective in increasing the tolerance of threatening thermal pain. Moreover, the expectation violation instruction proved to be superior in terms of the number of trials needed to achieve the predefined exposure goal. Independently of the therapeutic instruction, high levels of pain anxiety and low levels of pain catastrophizing predicted faster responses. Our results suggest that expectation violation is an effective shortcut for exposure treatments, although replication in samples with chronic pain is clearly warranted.

Data availability statement

The data that support the findings of this study are available from the corresponding author upon reasonable request.

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5 Appendix

A

Table A1

Conducted changes in the study design of the replication

Conducted changes	Schemer et al[31]	Present study design
Omission of the control condition	Control group	No control group
Additional follow-up	No follow-up	Follow-up
Exposure goal	Fixed number of exposure trials (3); no predefined exposure goal	Tailored number of exposure trials (3-10); predefined exposure goal (reduction by half)
Alignment of instructions	Possibly more cognitive load in the expectation violation condition compared to both other conditions	Alignment of instructions and questions (similar amount of cognitive load)
Position of heat stimulation on forearm	Different arms, same spot	Same arm, different spots
Threat manipulation	Information about possible side effects Cover story with ethical committee Sham measurement of skin thickness Uncertainty of experimenter	Additionally, referring to the redness of the participant's skin as a sign of side effects (→ strengthening the personal threat beliefs)
Order of the manipulation check	Debriefing→ manipulation check	Manipulation check → debriefing
Credibility rating and adherence to instructions	At the end of the training	Additional rating after each training trial

Anhang D: Curriculum Vitae und Publikationen

Diese sind nicht Teil dieser Veröffentlichung.

Anhang E: Eidesstattliche Erklärung

Hiermit versichere ich, meine Dissertation

"*Die Entstehung, Aufrechterhaltung und Therapie chronischer Schmerzen im Kontext von Erwartungsverletzungen*"

selbst und ohne fremde Hilfe verfasst zu haben. Ich habe keine anderen als die angegebenen Quellen und Hilfsmittel genutzt. Alle vollständig oder sinngemäß übernommenen Zitate sind als solche gekennzeichnet.

Die Dissertation wurde weder in der vorliegenden noch in einer ähnlichen Form bei einer anderen in- oder ausländischen Hochschule anlässlich eines Promotionsgesuchs oder zu anderen Prüfungszwecken eingereicht.

Marburg, Juli 2020

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