Die Wirkung von Optimismus als Resilienzfaktor: Einflüsse auf das Schmerzerleben und den mimischen Schmerzausdruck

Inaugural-Dissertation

in der Fakultät Humanwissenschaften

der Otto-Friedrich-Universität Bamberg

vorgelegt von

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Bamberg, den 28.03.2023

Bamberg, 2023

Tag der mündlichen Prüfung: 18.07.2023

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URN: urn:nbn:de:bvb:473-irb-909422
DOI: https://doi.org/10.20378/irb-90942

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1 Einleitung

Die vorliegende Dissertation befasst sich mit der Wirkweise von Optimismus als Schmerz-Resilienzfaktor. Die Fragestellung wurde mittels vier Studien bearbeitet. Diese resultierten im Rahmen einer kumulativen Promotion in vier Fachartikeln, von denen drei bereits in Fachzeitschriften mit *Peer Review* veröffentlicht wurden, während sich der vierte in der Revision befindet. Der vorliegende Rahmentext dient der studienübergreifenden Darstellung des theoretischen Hintergrunds (Kapitel 2.1 und 2.2) und der Ziele (Kapitel 2.3) der Dissertation. Nach einer knappen Zusammenfassung der Einzelstudien in Kapitel 3 werden abschließend die Ergebnisse mit Hinblick auf die Ziele der Arbeit integrierend diskutiert und Erkenntnisse bezüglich der Fragestellung abgeleitet (Kapitel 4). Die Volltexte der Fachartikel sind abschließend in den Anhängen 1-4 abgedruckt.

2 Theoretischer Hintergrund

2.1 Optimismus als Schmerz-Resilienzfaktor

Nachdem in der Forschung über lange Zeit der Schwerpunkt auf der Erforschung von Krankheiten und Risikofaktoren lag, wird seit Antonovskys Theorie der Salutogenese (1987) der Frage nach Resilienzfaktoren und dem Erhalt der Gesundheit zunehmend eine ähnlich wichtige Rolle beigemessen. Resilienzfaktoren sind körperliche oder mentale Dispositionen, Grundhaltungen, Fähigkeiten oder Handlungsaspekte (Huber, 2009), die zu der Resilienz eines Menschen, d.h. zu seiner Widerstandsfähigkeit gegenüber Belastungen beitragen (Pooley & Cohen, 2010). Als ein wichtiger kognitiver Resilienzfaktor gilt Optimismus. Unter Optimismus versteht man generalisierte positive Erwartungen bezüglich der Zukunft (Scheier & Carver, 1985), d.h. die Tendenz, bei Vorhersagen zukünftiger Ereignisse positive Einschätzungen vorzunehmen, also beispielsweise anzunehmen, dass sich die Dinge zum Guten wenden und sich das eigene Leben erfreulich entwickeln wird. Optimismus lässt sich konzeptuell und empirisch von den verwandten Konstrukten Hoffnung und Selbstwirksamkeitserwartung abgrenzen (Rand, 2018). Im Gegensatz zu Optimismus sind bei Hoffnung die positiven Annahmen auf das eigene Selbst sowie das Erreichen persönlicher Ziele fokussiert (ebd.).

Selbstwirksamkeitserwartung beruht stark auf vorangegangenen Kompetenzerfahrungen und zeichnet sich im Gegensatz zum Optimismus immer durch eine internale Attribution (die Erwartung, Dinge aus eigener Kraft und durch eigene Fähigkeit positiv bewältigen zu können) aus (Schwarzer & Luszczynska, 2008).

Eine Vielzahl an Studien zeigt eine protektive Wirkung von Optimismus auf die psychische und körperliche Gesundheit (für einen Überblick siehe beispielsweise Avvenuti et al., 2016; Carver et al., 2010; Carver & Scheier, 2014).

Die vorliegende Arbeit beschäftigt sich mit der potenziell schmerzdämpfenden Wirkung von Optimismus, d.h. mit der Rolle von Optimismus als „Schmerz-Resilienzfaktor". Für die Mechanismen, über die Optimismus das Schmerzerleben beeinflusst, werden unterschiedliche Zusammenhänge diskutiert, für die jeweils empirische Evidenz vorliegt (siehe Abschnitt 2.2).

Die Forschung, die sich mit dem Zusammenhang von Schmerz und Optimismus beschäftigt, kann auf verschiedene Weise unterteilt werden. Zum einen lässt sich in Abhängigkeit von der Art des Schmerzes zwischen Studien mit experimentellem und Studien mit klinischem Schmerz unterscheiden. Zum anderen besteht bezüglich des Optimismus die Möglichkeit, für den Zusammenhang mit Schmerz entweder den dispositionellen Optimismus heranzuziehen oder situativen Optimismus experimentell zu induzieren, wie im Folgenden erläutert wird.

2.1.1 Dispositioneller vs. situativer Optimismus

Wie eine Vielzahl der in der Persönlichkeitspsychologie untersuchten Variablen wird auch Optimismus als *Trait-State*-Variable konzeptualisiert. So werden sowohl eine zeitlich vergleichsweise überdauernde Disposition zu mehr oder weniger Optimismus (*Trait*-Optimismus, dispositioneller Optimismus) als auch spezifische, von Zeitpunkt zu Zeitpunkt bzw. von Situation zu Situation variierende Zustände von mehr oder weniger Optimismus (*State*-Optimismus, situativer Optimismus) angenommen (z.B. Kluemper et al., 2009). *Trait*-Optimismus scheint sich aus der Kombination genetischer Prädisposition sowie der bisherigen Lebenserfahrungen zu ergeben (Mavioglu et al., 2015) und ist somit schwerer direkt zu beeinflussen, während ein kurzfristiger Zustand von (situativem) Optimismus durch

verschiedene Techniken hervorgerufen werden kann (siehe 2.1.3), was eine experimentelle Manipulation dieser Variable erlaubt.

2.1.2 Optimismus messen

Ein weitverbreitetes Instrument zur Erfassung von dispositionellem Optimismus ist der *Life Orientation Test Revised Version* (*LOT-R*; Scheier et al., 1994, validierte deutsche Fassung von Glaesmer et al., 2008). Dieser Fragebogen enthält 10 Items. Von diesen erfassen je drei Optimismus (z.B. „Alles in allem erwarte ich, dass mir mehr gute als schlechte Dinge widerfahren“) und Pessimismus (z.B. „Wenn bei mir etwas schieflaufen kann, dann tut es das auch“), die übrigen vier dienen als Distraktoren.

Es existieren weitere Skalen zur Messung von Optimismus. Diese sind zum Teil Bestandteil umfassenderer Instrumente wie des *Minnesota Multiphasic Personality Inventory* (MMPI; Greene, 2000), zum Teil basieren sie auf anderen Konzeptionen von Optimismus, wie der *Attribution Style Questionnaire* (Peterson et al., 1982). Dieser schreibt einem optimistischen Attributionsstil die Merkmale der internalen, stabilen und globalen Attribution bei positiven Ereignissen und der externalen, variablen und spezifischen Attribution bei negativen Ereignissen zu.

Um situativen Optimismus zu messen, was beispielsweise bei experimenteller Beeinflussung von Optimismus relevant ist, kann die *Future Expectancies Scale* (*FEX*; Hanssen et al., 2013, deutsche Fassung von Peters et al., 2016) verwendet werden. Im Gegensatz zum *LOT-R* nennt dieser Fragebogen konkrete Lebensbereiche und fragt die momentane subjektive Wahrscheinlichkeit ab, mit der diese positiv bzw. negativ geprägt sein werden (z.B. „Sie werden viel Zufriedenheit aus Ihrem Beruf ziehen.“ „Sie werden gute und andauernde Freundschaften knüpfen.“). Alternative Maße für situativen Optimismus sind die *Optimism-Pessimism Scale* (OPS, Dember et al., 1989), welche jedoch für ihre Multi-Dimensionalität und Komplexität kritisiert wird (Chang et al., 1994) sowie die kürzlich entwickelte, zum Zeitpunkt der Studienplanung und -durchführung noch nicht vorliegende *State Optimism Measure* (SOM, Milstein et al., 2019).

2.1.3 Optimismus induzieren

Um, wie oben beschrieben, *State* Optimismus experimentell zu induzieren, hat sich die Methode des *Best Possible Self Task* (*BPS*; King, 2001) bewährt. Es handelt sich um eine Vorstellungs- und Schreibübung, bei der sich die Versuchsperson sich selbst in der Zukunft vorstellt, wenn alle ihre Träume sich erfüllt haben und sie alle ihre Ziele erreicht hat. Über dieses bestmögliche zukünftige Selbst wird 15 min ununterbrochen geschrieben, danach soll sich das Geschriebene für 5 min vor dem inneren Auge so bildhaft wie möglich vergegenwärtigt werden. Experimentelle Studien zeigen, dass ein einmaliges Durchführen der BPS-Übung zu kurzfristigen signifikanten Anstiegen im *State* Optimismus führt (Peters et al., 2010; Hanssen et al., 2013; Peters et al., 2016). Als äquivalente neutrale Aufgabe wird für die Kontrollgruppe die Aufgabe gestellt, sich einen alltäglichen Tagesablauf vorzustellen und diesen detailgenau schriftlich zu beschreiben (*Typical Day Task*, *TD*). Andere Möglichkeiten zur Optimismus-Induktion wie beispielsweise semantisches Priming (Fosnaugh et al., 2009), bei dem das Konzept Optimismus durch die Präsentation von Wörtern aus dem entsprechenden semantischen Feld unbewusst mental aktiviert werden soll, sind bislang Einzelfälle und in der Schmerzforschung noch nicht etabliert.

2.1.4 Problem der Kausalität

In Studiendesigns, in denen die Versuchspersonen der unabhängigen Variable, in diesem Fall dem Optimismus, nicht zufällig zugewiesen werden können, ist die Frage der Kausalität nicht ohne Weiteres zu beantworten. Wird eine negative Assoziation zwischen Optimismus und Schmerz festgestellt, könnte diese erstens darauf zurückzuführen sein, dass Optimismus zu weniger Schmerzen führt. Zweitens ist denkbar, dass ein z.B. genetisch prädisponiertes geringeres Schmerzerleben im Laufe des Lebens zu einem höheren Grad an Optimismus geführt hat. Drittens könnte es Wechselwirkungen, d.h. eine gegenseitige Beeinflussung der beiden genannten Prozesse geben, welche zu einer Auf- oder Abwärtsspirale führt. Viertens ist es denkbar, dass Drittvariablen wie z.B. genetische Prädispositionen oder positive Antworttendenzen sowohl zu (Angaben von) höherem Optimismus als auch zu niedrigerem Schmerz führen und sich die Schmerz-Optimismus-Korrelation daraus ergibt. Um Aussagen über die Kausalität treffen zu können, sind experimentelle Designs, in denen Optimismus

manipuliert (siehe 2.1.3) und so Versuchspersonen zufällig hohem oder niedrigem Optimismus zugeteilt werden können, unabdingbar.

2.1.5 Optimismus im biopsychosozialen Schmerzmodell

Schmerz wird nach Übereinkunft der *International Association for the Study of Pain* (IASP) als eine unangenehme sensorische und emotionale Empfindung definiert, welche mit tatsächlicher oder potenzieller Gewebeschädigung verbunden ist bzw. einer derartigen Empfindung ähnelt (Raja et al., 2020). Das biopsychosoziale Schmerzmodell, ein in der Forschung und Anwendung weithin etabliertes Konstrukt, sieht Schmerz als einen dynamischen Prozess, der aus dem Zusammenspiel von biologischen, psychischen und sozialen Faktoren entsteht und wiederum auf diese rückwirkt (Keefe & France, 1999). Bei Optimismus handelt sich um einen psychischen Faktor. Dieser kann über verschiedene Mechanismen (siehe 2.2) auf die Schmerzverarbeitung wirken und zudem, wie im folgenden Abschnitt (2.1.6) erläutert werden wird, mittels der Schmerzkommunikation soziale Faktoren beeinflussen.

Schmerz als multidimensionales Konstrukt umfasst sensorische, affektive, vegetative und motorisch-behaviorale Komponenten (Keefe & France, 1999; Göbel, 1992; Kunz et al., 2008; Prkachin, 1992; Tracey & Mantyh, 2007). Diese werden von psychischen Variablen wie Optimismus potenziell auf unterschiedliche Weise und in unterschiedlicher Stärke beeinflusst. Bislang wurden lediglich einige der genannten Komponenten in ihrem Zusammenhang mit Optimismus untersucht. Ein großer Fokus lag, vor allem im Bereich des klinischen Schmerzes, auf dem Schmerz-Selbstbericht. So konnten negative[1] Zusammenhänge zwischen Optimismus und Ratings von Schmerzintensität und -aversivität sowie Schmerztoleranz festgestellt werden (z.B. Geers et al., 2008; Costello et al., 2002; Hanssen et al., 2013; Hanssen et al., 2012). Daneben sind einzelne Studien zu finden, die vegetative/autonome Komponenten von Schmerz (Herzrate und Blutdruck, Geers et al., 2008) untersuchten. Zu weiteren vegetativen Komponenten wie beispielsweise der sympathischen Hautreaktion (*Sympathetic Skin Response*, *SSR*) sowie zu zentralnervösen Komponenten des Schmerzes wie etwa

[1] In der gesamten Arbeit wird „negativer Zusammenhang“ bzw. „negative Assoziation“ zwischen Optimismus und Schmerz im Sinne einer statistischen Korrelation mit negativem Vorzeichen verwendet, d.h. einem Zusammenhang von höherem Optimismus mit niedrigerem Schmerz. Analog bezieht sich „positiver Zusammenhang/Assoziation“ auf einen Zusammenhang von höherem Optimismus mit stärkerem Schmerz.

schmerzevozierten Potenzialen liegt bislang keine Forschung vor, die deren Zusammenhang mit Optimismus untersucht. Auch im Bereich der motorisch-behavioralen Schmerzkomponenten, wie etwa der mimischen Schmerzreaktion, gibt es nach bestem Wissen der Autorin bislang keine Befunde.

2.1.6 Optimismus und Schmerzausdruck

Die Schmerzreaktion umfasst neben dem Schmerzempfinden auch den Schmerzausdruck, d.h. die durch Schmerzreize hervorgerufenen Veränderungen in Mimik, Gestik und anderem beobachtbaren Verhalten. In Gegenwart von Beobachtenden hat diese Schmerzexpression eine kommunikative Funktion, man spricht auch von der „Schmerzbotschaft“ (vgl. z.B. Karmann et al., 2014). Es wird vermutet, dass sich diese evolutionär nützlich erwiesen haben könnte, indem einen Appell oder wichtige Informationen an das Gegenüber senden (z.B. Werben um Empathie und Zuwendung, Warnung vor Gefahr o.ä.; Williams, 2002), die Verhalten bei diesem initiieren sollen (z.B. Hilfeleistung oder Flucht).

Während es beim selbstberichteten Schmerz Hinweise darauf gibt, dass Optimismus mit geringerem Schmerzerleben verbunden sein kann (siehe 2.1.5), dagegen aber keine Belege für eine *positive* Korrelation von Optimismus mit Schmerz bestehen, sind bezüglich der *Expression* von Schmerz zwei Richtungen denkbar: Einerseits liegt es nahe, dass ein geringeres subjektives Schmerzerleben zu einem geringeren Ausdruck von Schmerz (z.B. über nonverbale Kommunikationskanäle wie die Schmerzmimik) führt, da vielfach eine positive Korrelation zwischen beiden Variablen gezeigt wurde (Kunz et al., 2004; Rahu et al., 2013; Wang et al., 2017). Andererseits gibt es Hinweise, dass Optimismus zu mehr wahrgenommener bzw. tatsächlich verfügbarer sozialer Unterstützung führt (Brissette et al., 2002; Dougall et al., 2001). Somit wäre es denkbar, dass höherer Optimismus mit einer stärkeren Bereitschaft einhergeht, negative und potenziell Schwäche offenbarende innere Zustände seinen Mitmenschen mitzuteilen, weil von diesen eher Hilfe und Unterstützung als Abwertung oder Ausnutzung des Zustands erwartet werden. Befunde aus dem Schmerzbereich stützen diese Annahme: In einer Studie an gesunden Versuchspersonen konnte gezeigt werden, dass diese in Gegenwart ihres Partners mehr Schmerz zeigten als in Gegenwart eines unbekannten Versuchsleiters (Karmann et al., 2014).

Welcher der beiden gegenläufigen Mechanismen – mehr oder weniger Schmerzausdruck bei höherem Optimismus – überwiegt bzw. ob sie sich beide in ihrer Wirkung aufheben, soll einer der Untersuchungsgegenstände der vorliegenden Arbeit sein.

Da die Schmerzmimik als markantester und informativster nonverbaler Kanal des Schmerzausdrucks gilt (Karmann, 2014), wurde in der zugehörigen Studie diesem Maß der Vorzug vor anderen Verhaltensparametern gegeben.

2.1.7 Zeitliche Dimension der Wirkung von Optimismus auf Schmerz

Es gilt zu berücksichtigen, dass in der Forschung sowohl bezüglich der unabhängigen Variable Optimismus als auch bezüglich der abhängigen Variable Schmerz eine große Bandbreite bezüglich des erfassten zeitlichen Rahmens zu finden ist: Messungen von Optimismus reichen von einer einmaligen Erfassung einer zeitlich relativ überdauernden Disposition mittels eines Trait-Fragebogens über Verlaufsmessungen während mehrwöchigen Optimismus-fördernden Trainings bis hin zu Messungen von kurzfristigen, durch Induktion für die Dauer einer experimentellen Sitzung erzeugten Optimismus-*States*. Schmerzmessungen reichen von einem selbstberichteten Durchschnittswert über Tage oder Wochen bis hin zu einmaligen oder wiederholten Selbstberichten während *einer* experimentellen Session, während welcher wiederum die Dauer der schmerzhaften Stimuli zwischen Millisekunden und Minuten variieren kann und der Abstand der Messung zum Beginn der Stimulation variabel ist. Die für die vorliegende Arbeit berücksichtigten zeitlichen Faktoren werden in 2.3 spezifiziert.

2.2 Mechanismen des Zusammenhangs zwischen Optimismus und Schmerz

Nimmt man, wie vor allem auf Basis einer experimentellen Studie von Hanssen et al. (2013) naheliegt, eine kausale Wirkung von mehr Optimismus auf weniger Schmerz an, so stellt sich die Frage, auf welche Weise sich diese Wirkung vollzieht, d.h. welche Faktoren bzw. Prozesse den Zusammenhang mediieren könnten. Es werden in Abhängigkeit von der im vorigen Absatz beschriebenen zeitlichen Dimension und von der Art des Schmerzes verschiedene Mediatorvariablen diskutiert, für welche in unterschiedlichem Grad empirische Evidenz vorliegt:

2.2.1 Schmerzkatastrophisieren

Mehrere experimentelle Studien geben Hinweise darauf, dass Schmerzkatastrophisieren den Zusammenhang zwischen Optimismus und Schmerz mediiert (Hanssen et al., 2013; Goodin et al., 2013; Hood et al., 2012). Als Schmerzkatastrophisieren bezeichnet man negative mentale Prozesse während des Schmerzerlebens, die die Dimensionen Magnifikation des Schmerzes, Grübeln und Hilflosigkeit umfassen (Sullivan, 2009; Pulvers & Hood, 2013; Campbell et al., 2010a). Dem Schmerzkatastrophisieren wird unter anderem eine kommunikative Funktion zugeschrieben: Nach dem *Communal Coping Model* diene es als eine Form des Copings dazu, das Schmerzerleben und Schmerzverhalten zu verstärken, um Nähe, Unterstützung und empathische Reaktionen der sozialen Umwelt zu maximieren (Sullivan, 2001, 2004; Keefe et al., 2000; Cano, 2004). Schmerzkatastrophisieren gilt allerdings als Prädiktor für stärkeres Schmerzempfinden (Campbell et al., 2010b; Sullivan, 2009; Adams, 2007) und geht mit einem höheren Risiko der Schmerzchronifizierung sowie höherer Beeinträchtigung durch Schmerzen einher (Khan et al., 2011; Quartana et al., 2009). Bei optimistischeren Menschen wurde eine schwächere Neigung zu katastrophisierenden Gedanken festgestellt (Goodin et al., 2013; Hood et al., 2013; Hanssen et al., 2013; für einen Überblick Pulvers & Hood, 2013). Konzeptuell liegen dem Optimismus positive Bewertungsprozesse (in diesem Fall des Schmerzes und seiner Folgen), dem Schmerzkatastrophisieren negative Bewertungsprozesse zugrunde. Da bislang wenig empirische Evidenz zu Schmerzkatastrophisieren bei Optimismus existiert und insbesondere noch nicht untersucht wurde, ob eine experimentelle Induktion von Optimismus das Schmerzkatastrophisieren in der konkreten Schmerzsituation reduzieren kann, widmet sich ein Teil der vorliegenden Arbeit dieser Fragestellung.

2.2.2 Coping

Es wurde vielfach gezeigt, dass Optimismus mit aktivem, problemfokussierten *„approach Coping*“ verbunden ist, welches – im Gegensatz zum passiven, vermeidendem *„avoidant Coping*“ – darauf abzielt, den Stressor zu eliminieren bzw. dessen Wirkung abzuschwächen (Solberg Nes & Segerstrom, 2006; Goodin & Bulls, 2013; Geers et al., 2008; Garofalo, 2000). Dieser Befund lässt sich auf Basis von Erwartungs-mal-Wert-Theorien der Motivation theoretisch untermauern (z.B. Atkinson, 1957): Optimismus führt tendenziell zu positiveren Erwartungen bezüglich der eigenen Fähigkeiten und Bewältigungsmöglichkeiten sowie

bezüglich der Wahrscheinlichkeit eines positiven Ausgangs einer Situation, woraus sich eine höhere Motivation ergibt, eine bestimmte Aufgabe aktiv anzugehen.Pessimistische Erwartungen bezüglich Handlung und Ergebnis führen dagegen eher dazu, schnell aufzugeben oder sich einer Herausforderung komplett zu entziehen (Garofalo, 2000). Auf den Schmerz übertragen könnte das bedeuten, dass niedrigeres Schmerzerleben bei Optimisten[2] möglicherweisen unter anderem darauf zurückzuführen ist, dass sie in aktiverer und zielführenderer Weise mit dem Schmerz umgehen. Das kann beispielsweise in Bezug auf muskuloskelettalen Schmerz bedeuten, aktiv nach Informationen zu suchen, sich um Behandlungsmöglichkeiten zu kümmern, diese regelmäßig in Anspruch zu nehmen und Compliance bei deren Durchführung zu zeigen (z.B. eigenständige krankengymnastische Übungen, regelmäßige Einnahme von Medikamenten etc.). Auch Änderungen in Lebensstil und Lebensumständen, die eine Besserung von Schmerzen begünstigen können, werden potenziell eher tatsächlich durchgeführt und konstant beibehalten, wenn die Erwartung besteht, dadurch einen günstigen Einfluss auf die Schmerzen nehmen zu können (Luo, 2007; Weinstein, 1989). Jedoch ist zu berücksichtigen, dass diese Bemühungen bei unheilbaren Krankheiten, die mit nicht oder nur wenig besserbaren Schmerzen verbunden sind, erfolglos und mit psychischer Belastung verbunden sein können. In diesem Fall gelten Ablenkung und Akzeptanz als funktionalere Strategien (Esteve et al., 2007). Tatsächlich scheinen Optimisten im Fall einer nicht änderbaren Situation sowohl auf emotionsfokussiertes Coping, welches Akzeptanz, das Suchen von Unterstützung oder positive Umbewertung beinhaltet, umzuschwenken (Solberg Nes & Segerstrom, 2006) als auch trotz der Schmerzen aktiv zu bleiben und den gewohnten Tätigkeiten weiter nachzugehen (Saariaho et al., 2011), was in der genannten Studie zu einer Besserung des chronischen Schmerzes führte. Optimisten verfügen folglich über ein flexibleres Copingverhalten, das dazu führt, dass sie bei änderbaren Situationen eher aktives Coping betreiben, während sie bei nicht selbst beeinflussbaren Situationen schneller zur Akzeptanz übergehen, ohne vergeblich wertvolle Energie- und Kraftressourcen zu verschwenden. Optimisten sind somit allem Anschein nach in der Lage, je

[2] Um der einfacheren Lesbarkeit willen werden im Folgenden „Personen mit einer hohen Ausprägung von dispositionellem Optimismus/Pessimismus/Schmerzkatastrophisieren“ verkürzt als „Optimisten/Pessimisten/Schmerzkatastrophisierer“ bezeichnet. In diese Begriffe ebenso wie in jegliche Personenbezeichnungen im grammatikalischen Maskulinum werden Personen jeglicher Geschlechtsidentität einbezogen.

nach vorliegenden Umständen flexibel zu unterschiedlichen Arten des Copings greifen und so aus der jeweiligen Situation das Beste zu machen.

Während Coping ein wichtiger Mechanismus für klinischen, insbesondere auch für chronischen, Schmerz sein könnte, kommen bei vergleichsweise kurzen, experimentellen Schmerzerlebnissen, in denen die Relevanz für die eigene Gesundheit gering und Copingmöglichkeiten auf behavioraler Ebene beschränkt sind, möglicherweise andere Mechanismen zum Tragen (siehe 2.2.4 und 2.2.5).

2.2.3 Gesundheitsverhalten

Während Coping kognitives oder motorisches Verhalten umfasst, welches in *Reaktion* auf eine Herausforderung erfolgt (Latack & Havlovic, 1992), könnten in Bezug auf klinischen Schmerz auch *präventive* Verhaltensweisen, die der allgemeinen Erhaltung der Gesundheit zuträglich sind, eine Rolle spielen. Es wurde gezeigt, dass Optimisten tendenziell einen gesünderen Lebensstil haben, beispielsweise weniger rauchen, mehr Sport treiben sowie mehr Vorsorgeuntersuchungen wahrnehmen (Ylöstalo et al., 2003; van der Welde, 1992 Mulkana & Hailey, 2001). Dies alles könnte auf Jahre und Jahrzehnte gesehen eine geringere Prävalenz von Schmerzen bewirken.

2.2.4 Bewertungsprozesse und emotionale Faktoren

Insbesondere für die Entstehung und Aufrechterhaltung chronischer Schmerzen scheinen kognitive und emotionale Prozesse eine wichtige Rolle zu spielen, wie zum Beispiel im Rahmen des *fear-avoidance model of chronic musculoskeletal pain* postuliert wird (Vlaeyen, 2012). Nach dem biopsychosozialen Schmerzmodell sind Ängste und negative Bewertungen der eigenen Lage sowie dysfunktionale soziale Interaktionen wichtige Faktoren (Gatchel, 2013). Diese Faktoren sind bei Optimisten tendenziell günstiger ausgeprägt (Carver et al., 2010; Chang, 1998; Zenger et al., 2010). Auch bei kurzen, experimentellen Schmerzen spielen *Appraisal*-Prozesse eine Rolle (Forsythe et al., 2011). Es ist denkbar, dass Optimisten bei der Bewertung der Stärke eines Schmerzes eher günstige Vergleiche heranziehen (z.B. „Das ist doch gar nicht so stark, bei einem Bienenstich würde es viel mehr schmerzen.“) und stärker um eine positive (Re-)Interpretation bemüht sind. Kuzmanovic et al. (2016) beschreiben

Optimismus als die Motivation, eine möglichst belohnende Sichtweise einzunehmen und weisen bei optimistischen Update-Prozessen eine erhöhte Aktivität im Belohnungssystem nach.

2.2.5 Aufmerksamkeit

Es wurde gezeigt, dass Optimisten grundsätzlich dazu tendieren, ihre Aufmerksamkeit auf die positiven Aspekte einer Situation zu richten (Peters et al., 2016; Segerstrom, 2001). Auch im Umgang mit Schmerzen scheinen Optimisten ihre Aufmerksamkeit häufig vom Schmerz wegzulenken (Bargiel-Matusiewicz & Krzyszkowska, 2009; Geers et al., 2008). Somit kann angenommen werden, dass Optimisten eine Schmerzsituation infolge eines anderen Aufmerksamkeitsfokus anders verarbeiten als Pessimisten und sich daraus ein anderes, nämlich schwächeres, Schmerzempfinden ergeben kann. Es gibt viele Hinweise darauf, dass eine Aufmerksamkeitslenkung auf den Schmerz – was in einer Schmerzsituation in der Regel den negativen Aspekten dieser Situation entspricht – diesen verstärkt (Lautenbacher et al., 2009; Villemure & Bushnell, 2002). Bei klinischen Schmerzen könnte vor diesem Hintergrund der Grad an Optimismus, vermittelt über den Aufmerksamkeitsfokus, mit entscheidend dafür sein, wie sehr Aktivitäten des Lebens *trotz* des Schmerzes genossen werden können und wie stark die Lebensqualität durch den Schmerz eingeschränkt ist.

2.3 Ziele der Dissertation

Aus dem in Kapitel 2 dargelegten theoretischen Hintergrund lassen sich folgende Ziele für die vorliegende Dissertation ableiten:

1) Trotz einer Vielzahl an Studien zur Assoziation zwischen Schmerz und Optimismus liegt bisher kein Übersichtsartikel zur Gesamtschau dieser Studien vor. Aus diesem Grund scheint es gewinnbringend, den aktuellen Forschungsstand in Form eines systematischen *Reviews* aufzubereiten, um die aktuelle Datenlage umfassend zu erfassen und Hinweise für Forschungslücken sowie für Variablen zu erhalten, die Einfluss auf den Optimismus-Schmerz-Zusammenhang nehmen oder diesen vermitteln.

2) Nachdem die kausale Rolle von Optimismus für das Schmerzempfinden noch nicht eindeutig geklärt ist, soll diese Fragestellung mittels experimenteller Studien, die sich einer Optimismus-Manipulation bedienen, weiter erhellt werden.

3) Da bisher nur wenige Schmerzparameter bezüglich ihres Zusammenhangs mit Optimismus untersucht wurden, soll die Erforschung der Optimismus-Schmerz-Beziehung auf ein multidimensionales Schmerzkonstrukt übertragen werden. Neben Selbstberichten von Intensität und Aversivität werden dazu vegetative (sympathische Hautreaktion), zentralnervöse (schmerzevozierte Potenziale) sowie Verhaltensparameter (Schmerzmimik) erfasst.

4) Bezüglich der in Abschnitt 2.1.7 dargelegten zeitlichen Dimension wird zunächst in der Übersichtstudie die gesamte zeitliche Bandbreite in die Untersuchung eingeschlossen, wobei der Einfluss der zeitlichen Dimension explizit Berücksichtigung erfährt. In den eigenen experimentellen Studien liegt der Fokus dann exklusiv auf kurzen, phasischen Schmerzreizen und einer Messung der Reaktionen auf diese Reize im Millisekunden- (Studie 4) bis Sekundenbereich (Studie 2 und 3) nach Stimulus-Onset. Folglich wird durch das gewählte experimentelle Design die Wirkung von Optimismus auf frühe Schmerzkomponenten erforscht.

5) Aufgrund der bekannten Auswirkungen von Optimismus auf soziale Interaktionen liegt ein besonderer Schwerpunkt der Arbeit darauf, die Wirkung von Optimismus auf den mimischen Schmerzausdruck zu untersuchen. Es soll ergründet werden, ob einer der beiden in 1.1.6 erläuterten gegenläufigen Mechanismen – mehr oder weniger Schmerzausdruck bei höherem Optimismus – überwiegt bzw. ob sie sich beide in ihrer Wirkung aufheben.

6) Da Hinweise vorliegen, dass Optimismus über eine Verringerung von Schmerzkatastrophisieren zu niedrigerem Schmerzerleben führt, wird zur weiteren Aufklärung dieses potenziellen Mechanismus erforscht, ob eine Optimismus-Induktion situatives Schmerzkatastrophisieren während einer experimentellen Schmerzstimulation verringern kann. Zudem soll im Rahmen einer differenziellen

Fragestellung getestet werden, ob dabei das dispositionelle Schmerzkatastrophisieren eine moderierende Wirkung entfaltet, sodass die Optimismus-Manipulation je nach Level an dispositionellem Katastrophisieren eine unterschiedlich starke Wirkung entfaltet und somit Personen mit unterschiedlich starker Neigung zu Schmerzkatastrophisieren unterschiedlich stark von einer Manipulation ihres Optimismus profitieren.

Abbildung 1 veranschaulicht die im Rahmen dieser Arbeit zu untersuchenden Zusammenhänge in grafischer Form.

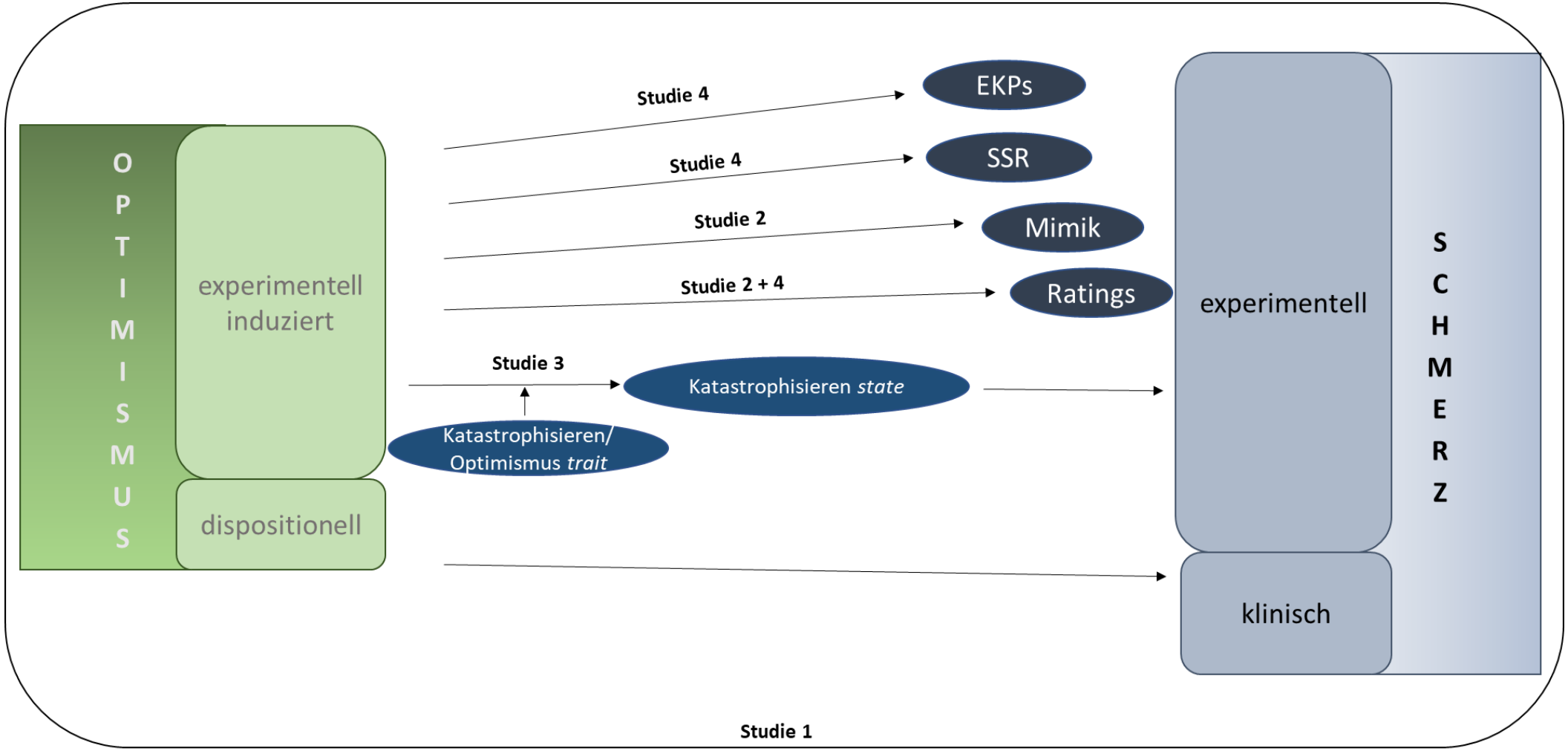


Abbildung 1. Zusammenfassende Darstellung der Ziele der Dissertation. EKPs = Ereigniskorrelierte Potenziale; SSR = sympathische Hautreaktion.

3 Eigene Arbeiten

3.1 Übersichtsartikel zum Zusammenhang von Schmerz und Optimismus (Studie 1, siehe Anhang 1)

3.1.1 Theoretischer Hintergrund

Als Forschungseinstieg in das Thema „Optimismus als Schmerz-Resilienzfaktor“ wurde ein Übersichtsartikel (*Systematic Review*) verfasst, der Studien zusammenfasst, die sich mit dem Zusammenhang zwischen Optimismus und Schmerzempfinden beschäftigen. Da bis zu diesem Zeitpunkt keine Übersichtsarbeit vorlag, die mittels einer systematischen Datenbanksuche mit spezifizierten Kriterien den aktuellen Forschungsstand abgebildet hätte, erschien es sinnvoll, ein *Systematic Review* zu erstellen. Zwei vorangegangene, nicht systematische, Übersichten befassten sich mit Studien zum Zusammenhang von Optimismus und chronischem Schmerz bis zum Jahr 2000 (Garofalo, 2000) sowie mit Studien zum Zusammenhang von Optimismus und (klinischem und experimentellem) Schmerz aus den Jahren 2000-2013 (Goodin & Bulls, 2013). Ziel war es, zu untersuchen, wie viele Studien negative Assoziationen von Schmerz und Optimismus gefunden hatten und mögliche moderierende Faktoren zu identifizieren, die beeinflussen könnten, ob ein derartiger Zusammenhang gefunden wird oder nicht. Es sollten dabei klinischer und experimenteller Schmerz sowie dispositioneller und situativer Optimismus mit einbezogen werden. Als Schmerzvariablen wurden Selbstberichte zu Schmerzintensität, Schmerzaversivität und Schmerzhäufigkeit, Schmerzschwellen, Toleranz, non-verbal behaviorale sowie physiologische Parameter aufgenommen.

3.1.2 Methoden

Mittels eines Suchalgorithmus mit Schlagworten zu Optimismus und Schmerz wurde in den wissenschaftlichen Datenbanken *PubMed*, *Web of Science* und *PsychInfo* nach einschlägigen Artikeln recherchiert.

Aus den 1034 Treffern blieben nach Anwendung verschiedener Ausschlusskriterien (z.B. kein *Peer Review*, keine distinkten Maße für Schmerz oder Optimismus, kein statistisches Maß für

den Zusammenhang zwischen den beiden Variablen, Sprache nicht englisch) 69 Artikel bestehen (siehe Abbildung 2). Diese wurden nach folgenden Kriterien klassifiziert:

- durchschnittliches Alter der Versuchspersonen (< 30, 30-60, > 60 Jahre)
- Geschlecht (männliche Probanden, weibliche Probandinnen, beides)
- Stichprobengröße (klein: n < 50, mittel: n = 50-100, groß: n > 100)
- Design der Studie (Querschnitt, Längsschnitt, experimentell)
- Stellenwert des Optimismus-Schmerz-Zusammenhangs in der Studie (Hauptuntersuchungsgegenstand vs. nicht primäres Ziel der Studie)
- Qualität der Studie nach einem von der *Newcastle-Ottawa Scale* für Metaanalysen (Peterson et al., 2011) inspirierten Qualitätsindex (niedrig: ≤ 7, mittel: 7,5-9, groß: ≥ 9,5; möglicher Range 1,5-11 Punkte)

Für jede dieser potenziell moderierenden Variablen wurde der Prozentsatz an signifikanten negativen Assoziationen zwischen Optimismus und Schmerz in den einzelnen Klassen der Variablen berechnet. Mittels Binomialtests wurde auf signifikante Abweichungen von einer Gleichverteilung getestet.

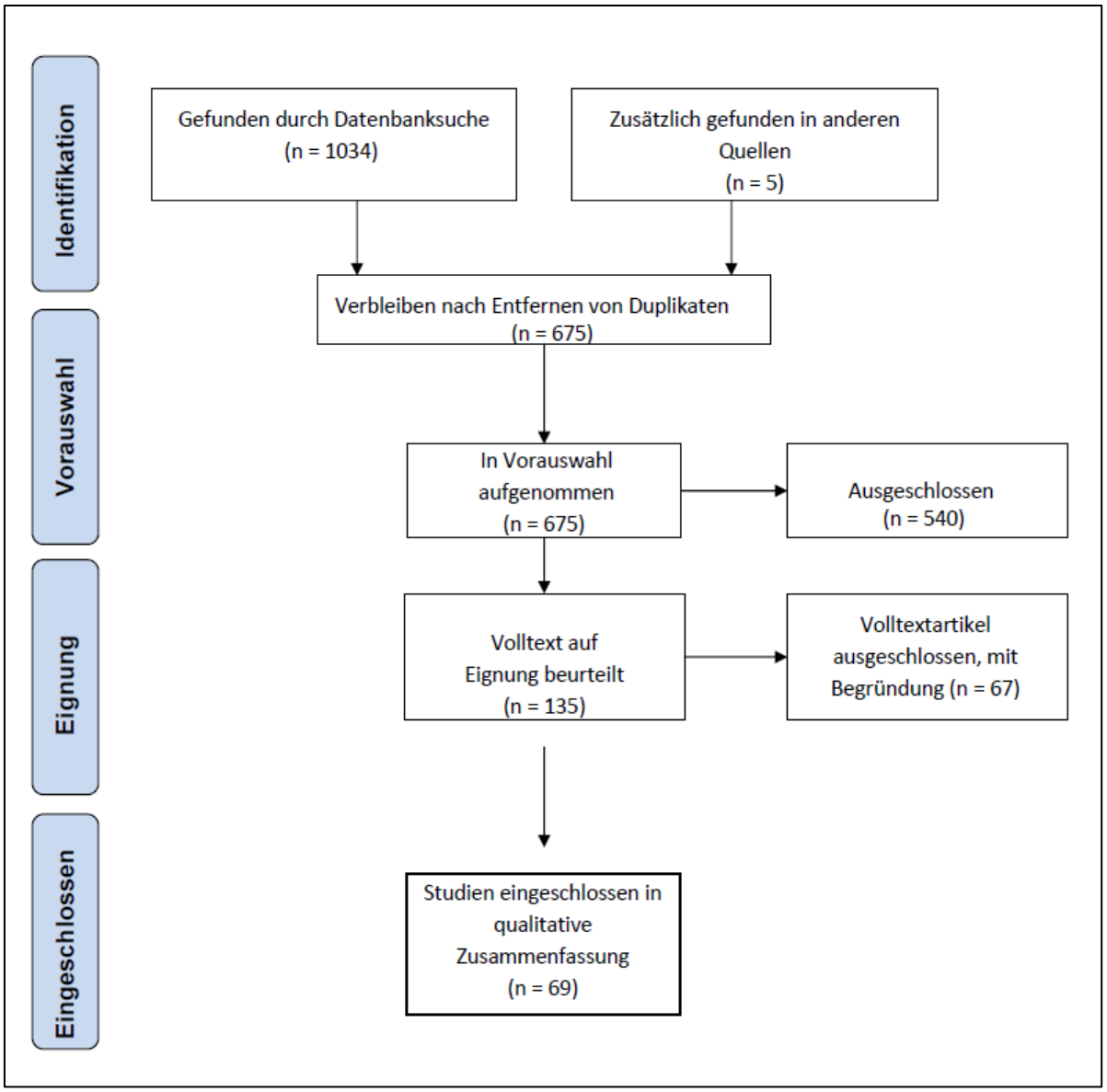


Abbildung 2. Flussdiagramm zur Veranschaulichung der Auswahl der Studien für das *Review* gemäß der PRISMA-Richtlinien (Moher et al., 2009).

3.1.3 Ergebnisse

In 48 der 69 Studien, die in die Auswertung aufgenommen wurden, wurde eine negative Assoziation zwischen Optimismus und mindestens einem Schmerzmaß gefunden. Darunter waren 25 Studien, die ausschließlich einen negativen Zusammenhang, d.h. keine Null- oder positive Assoziation in einem anderen Schmerzmaß festgestellt hatten. Die übrigen 23 Studien

wiesen gemischte Ergebnisse auf. Dies ging entweder darauf zurück, dass unterschiedliche Schmerzparameter (z.B. Schwelle und Intensitätsrating) gemessen wurden, welche unterschiedlich gerichtete Zusammenhänge mit Optimismus aufwiesen, darauf, dass verschiedene Subgruppen der untersuchten Stichprobe (z.B. Männer vs. Frauen) verschiedene Zusammenhänge zeigten, oder darauf, dass statistische Auswertungen vorgenommen wurden, durch die sich der Zusammenhang mit ein und demselben Schmerzparameter veränderte (beispielsweise nach Kontrolle von anderen Variablen oder Hinzufügen komplexerer Auswertungen wie hierarchischen Regressionen). In 21 Studien wurde in keinem Schmerzmaß ein signifikanter Zusammenhang mit Optimismus gefunden.

In mehreren der möglichen moderierenden Faktoren zeigten sich Unterschiede bezüglich des Anteils an Studien mit negativen Schmerz-Optimismus-Assoziationen (Abbildung 3):

Die Anzahl negativer Assoziationen stieg mit zunehmendem durchschnittlichem Alter der Versuchspersonen (Abb. 3a). Binomialtests zeigten, dass in den beiden älteren Gruppen (30-60 und über 60 Jahre) signifikant mehr negative als Null-Assoziationen vorlagen, in der jüngsten Gruppe (unter 30 Jahre) dagegen nicht.

Während sowohl experimentelle als auch klinische Studien einen deutlich größeren Anteil an negativen Optimismus-Schmerz-Assoziationen aufwiesen, wurde diese Tendenz in den experimentellen Designs am deutlichsten (Abb.3b). In diesen sowie in klinischen Längsschnittstudien war der Anteil an negativen Zusammenhängen signifikant höher als unter einer Gleichverteilung, nicht dagegen in klinischen Querschnitten.

Weiterhin wurde eine Unterscheidung zwischen Studien mit dem expliziten, hauptsächlichen Ziel, den Zusammenhang zwischen Schmerz und Optimismus zu messen und Studien, bei denen Optimismus einer von vielen psychologischen Parametern und/oder Schmerz eines von vielen Maßen von Gesundheit war bzw. der Zusammenhang zwischen beiden nur als nebensächliche oder untergeordnete Auswertung erwähnt wurde, vorgenommen. In der Gruppe mit dem Schmerz-Optimismus-Zusammenhang als primärem Untersuchungsziel wurde in 76,5% der Studien und somit signifikant häufiger als unter einer Gleichverteilung eine negative Assoziation gefunden. In der Gruppe mit einem anderen hauptsächlichen Untersuchungsziel dagegen zeigten nur die Hälfte der Studien eine negative Schmerz-Optimismus-Assoziation (Abb. 3c).

Nach Kategorisierung entsprechend dem Qualitätsindex ergaben unsere Analysen einen deutlich höheren Anteil von negativen Schmerz-Optimismus-Assoziationen in den Studien/Publikationen mit hoher Qualität (Abb. 3d). Der Anteil negativer Assoziationen war bei hoher Qualität und mittlerer Qualität signifikant größer als unter einer Gleichverteilung, nicht dagegen bei niedriger Qualität.

Da insgesamt nur acht und damit zu wenige Studien ausschließlich Frauen oder Männer untersuchten oder explizit auf Geschlechtsunterschiede im Optimismus-Schmerz-Zusammenhang testeten, wurden keine Auswertungen bezüglich der möglichen moderierenden Rolle des Geschlechts vorgenommen. Ebenso schien die Anzahl von Studien mit kleiner Stichprobengröße mit vier als zu gering, um aussagekräftige Hinweise auf den Einfluss der Stichprobengröße zu erhalten.

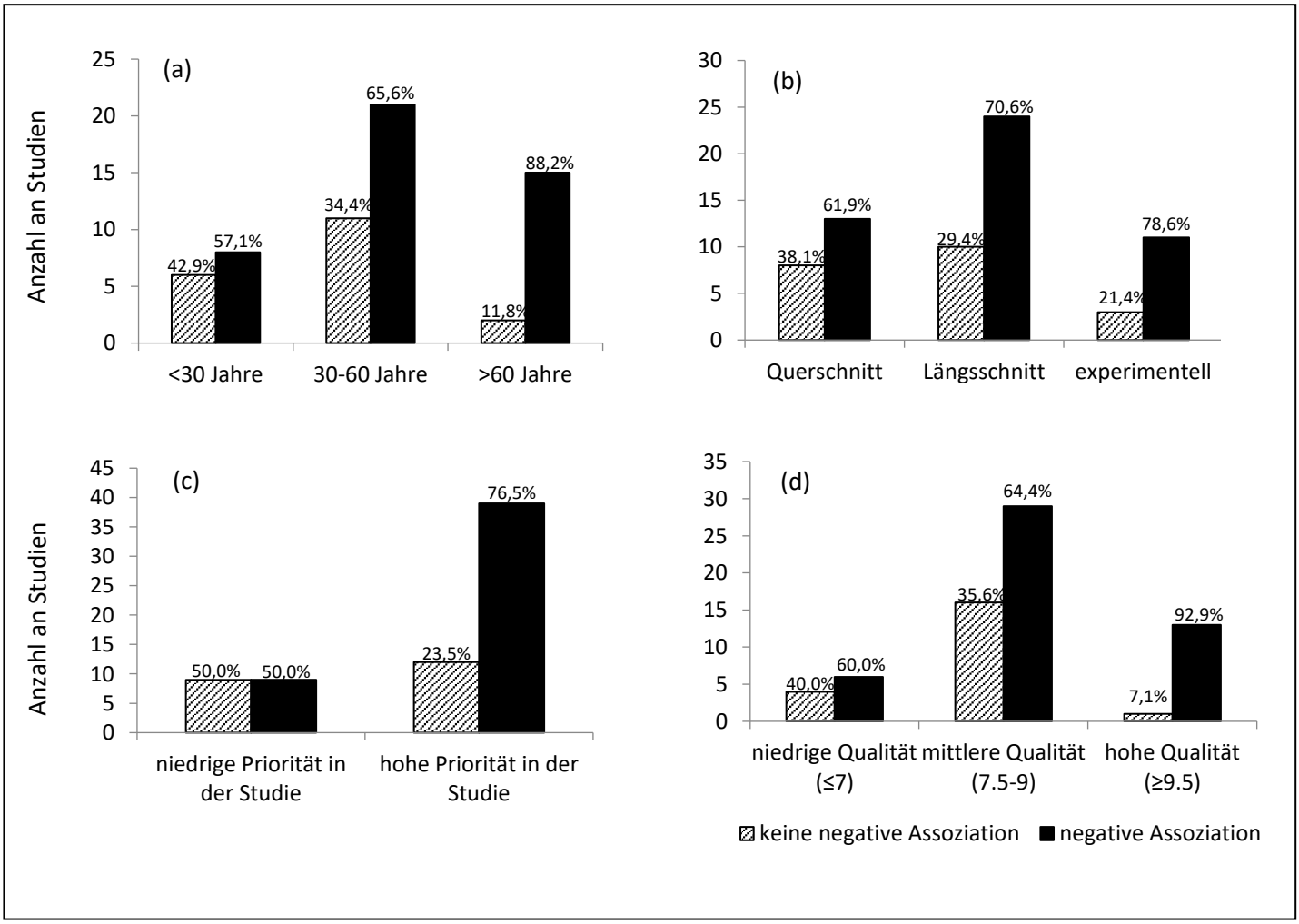


Abbildung 3. Prozentsatz an Studien des *Reviews* mit signifikant negativem vs. positivem oder nicht-signifikantem Zusammenhang zwischen Optimismus und Schmerz, in Abhängigkeit von (a) durchschnittlichem Alter der Probanden/Probandinnen, (b) Studiendesign, (c) Priorität der Optimismus-Schmerz-Assoziation in der Studie und (d) Studienqualität.

3.1.4 Diskussion

Die systematische Gesamtschau von 69 Studien zum Zusammenhang von Optimismus und Schmerz mit einer Vielzahl verschiedener Schmerzarten und -maßen in experimentellen und klinischen Studiendesigns ergab einen negativen Zusammenhang zwischen Optimismus und mindestens einem Schmerzmaß in ca. 70% der Studien. Dies gibt deutliche Hinweise darauf, dass nach aktuellem Forschungsstand davon ausgegangen werden kann, dass Optimismus mit verringertem Schmerz assoziiert sein kann, also einen psychischen Schmerz-Resilienzfaktor darstellt.

Darüber hinaus wurden Faktoren identifiziert, die das Auftreten dieses Zusammenhangs begünstigen oder verstärken, d.h. potenzielle moderierende Variablen. Es ergab sich, dass ein höherer Prozentsatz an negativen Optimismus-Schmerz-Assoziationen in Studien mit einem höheren Durchschnittsalter der Versuchspersonen, in Studien mit experimentellen und klinisch-längsschnittlichen Designs, in Studien mit primärem Ziel, den Zusammenhang zwischen Optimismus und Schmerz zu untersuchen sowie in Studien/Publikationen mit höherer Qualität gefunden wurde. Da sich die letzten drei Variablen (Studiendesign, Priorität in der Studie und Qualität) auf „technische“ Aspekte der Studienplanung, -durchführung und -veröffentlichung beziehen, können aus diesen in gewisser Weise allgemeine Rückschlüsse gezogen werden: Es wurde ein größerer Anteil signifikanter negativer Assoziationen in Studien gefunden, welche eine höhere Wahrscheinlichkeit haben, einen Zusammenhang, der tatsächlich existiert, aufzudecken. Denn es kann vermutet werden, dass Studien von höherer Qualität validere Daten liefern als Studien mit niedrigerer Qualität und dass Studien mit Fokus auf die Optimismus-Schmerz-Relation die beiden betreffenden Variablen akkurater messen und dass in experimentellen und längsschnittlichen Studien konfundierende Variablen mittels experimenteller Variation oder der Erfassung zeitlicher Verläufe besser kontrolliert werden können. Diese Faktenlage bestärkt die getroffene Annahme, dass ein negativer Zusammenhang zwischen Schmerz und Optimismus existiert.

Für den größeren Prozentsatz negativer Schmerz-Optimismus-Assoziationen in Studien mit einem höheren Durchschnittsalter der Versuchspersonen sind mehrere Erklärungen denkbar. Es wäre zum einen möglich, dass, wie von Jylhä et al. (1986) vorgeschlagen, der Einfluss psychologischer Variablen auf die subjektive Bewertung der eigenen Gesundheit mit steigendem Alter zunimmt und somit auch der selbstberichtete Schmerz stärker mit dem Grad an Optimismus der berichtenden Person variiert. Zum anderen könnten in den höheren Altersgruppen verstärkt bestimmten Arten von klinischem Schmerz vertreten sein, welche wiederum besonders zugänglich für einen Einfluss von Optimismus sein könnten. So fanden sich in unseren Auswertungen signifikant negative Optimismus-Schmerz-Zusammenhänge am häufigsten bei post-operativem Schmerz und rheumatischen Erkrankungen. Alle bis auf zwei der Studien mit Altersdurchschnitt über 60 Jahren gehören zu einer der ersten beiden Kategorien.

Aus dem systematischen *Review* lassen sich folgende Ableitungen für weitere Forschung treffen: Die Arbeit gibt bedeutende Hinweise darauf, dass Optimismus unter bestimmten Bedingungen mit weniger Schmerz in Verbindung stehen kann, was die weitere Untersuchung des Zusammenhangs beider Variablen lohnend erscheinen lässt. Neben dieser allgemeinen Bestätigung deckt das *Review* Forschungslücken auf: So machten zum Zeitpunkt der Datensammlung experimentelle Studien mit ca. 20% den deutlich kleineren Anteil an Studien aus. Unter diesen wiederum waren nur zwei, welche eine experimentelle Optimismus-Induktion anwendeten. Angesichts der in 2.1.4 erörterten hohen Bedeutung von systematischer Variation zum Schließen auf Kausalität schien es unabdingbar, weitere Studien durchzuführen, in denen Optimismus experimentell manipuliert wird. Zudem zeigte sich nach systematischer Aufschlüsselung der untersuchten Schmerzvariablen, dass der Fokus bisheriger Forschung auf dem Schmerzselbstbericht lag und, wie in 2.1.5 und 2.3 dargelegt, für andere Schmerzvariablen wie physiologischen Parametern oder dem mimischen Schmerzausdruck noch kaum oder keine Befunde vorliegen. Zuletzt gab das *Review* einige Hinweise für potenzielle Mechanismen des Zusammenhangs von Optimismus und Schmerz, wie etwa die Vermittlung über Schmerzkatastrophisieren. Aus diesem Grund lässt sich aus dem *Review* die Notwendigkeit ableiten, diese Variable näher in ihrer Beziehung zu Optimismus und Schmerz zu untersuchen.

3.2 Experimentelle Studien (Studien 2-4, siehe Anhänge 2-4)

3.2.1 Allgemeiner theoretischer Hintergrund und Überblick

In Einklang mit den Erkenntnissen aus dem systematischen *Review* war das Ziel der experimentellen Studien, den Zusammenhang zwischen Optimismus und Schmerz sowohl bezüglich verschiedener Schmerzparameter als auch bezüglich moderierender oder mediierender Vairablen genauer zu beleuchten. Um im Falle eines signifikanten Zusammenhangs einigermaßen zuverlässige Rückschlüsse auf die Kausalität ziehen zu können, wurde ein experimentelles Design gewählt, bei dem sowohl Schmerz als auch Optimismus experimentell induziert wurden. Mithilfe einer Kontrollgruppe und randomisierter Zuweisung der Versuchspersonen zu einer der beiden Gruppen sollten eindeutige Rückschlüsse auf die Wirkung der Optimismus-Manipulation ermöglicht werden. In Anbetracht der in Kapitel 2.1.6 dargelegten unklaren Wirkung von Optimismus auf den Schmerzausdruck war eines der Hauptziele der ersten experimentellen Studie, den Einfluss der Optimismus-Induktion auf die Schmerzmimik zu untersuchen. Wie oben dargelegt, sollte die Wirkung von Optimismus auf unterschiedliche Komponenten der Schmerzreaktion geprüft werden. Dazu wurden in den experimentellen Studien 2 und 4 mit selbstberichteten Ratings von Intensität und Aversivität, der sympathischen Hautreaktion und ereigniskorrelierten Hirnpotenzialen sowie mimischen Reaktionen eine große Bandbreite an Schmerzparametern erfasst. Studie 3 hatte das Ziel, einen möglichen Mechanismus der Wirkung von Optimismus auf Schmerz zu untersuchen, nämlich die vermittelnde Wirkung von Schmerzkatastrophisieren. Es wurde das situative Schmerzkatastrophisieren während der experimentellen Schmerzstimulation gemessen, um zu analysieren, ob dieses mittels einer Optimismus-Induktion verringert werden kann und ob dabei das dispositionelle Schmerzkatastrophisieren oder der dispositionelle Optimismus eine moderierende Wirkung entfalten, sodass die Optimismus-Manipulation je nach Level an des jeweiligen *Traits* eine unterschiedlich starke Wirkung entfaltet.

Abbildung 4 gibt einen Überblick über den Ablauf der drei experimentellen Studien, bevor sie im Folgenden einzeln im Detail dargestellt werden.

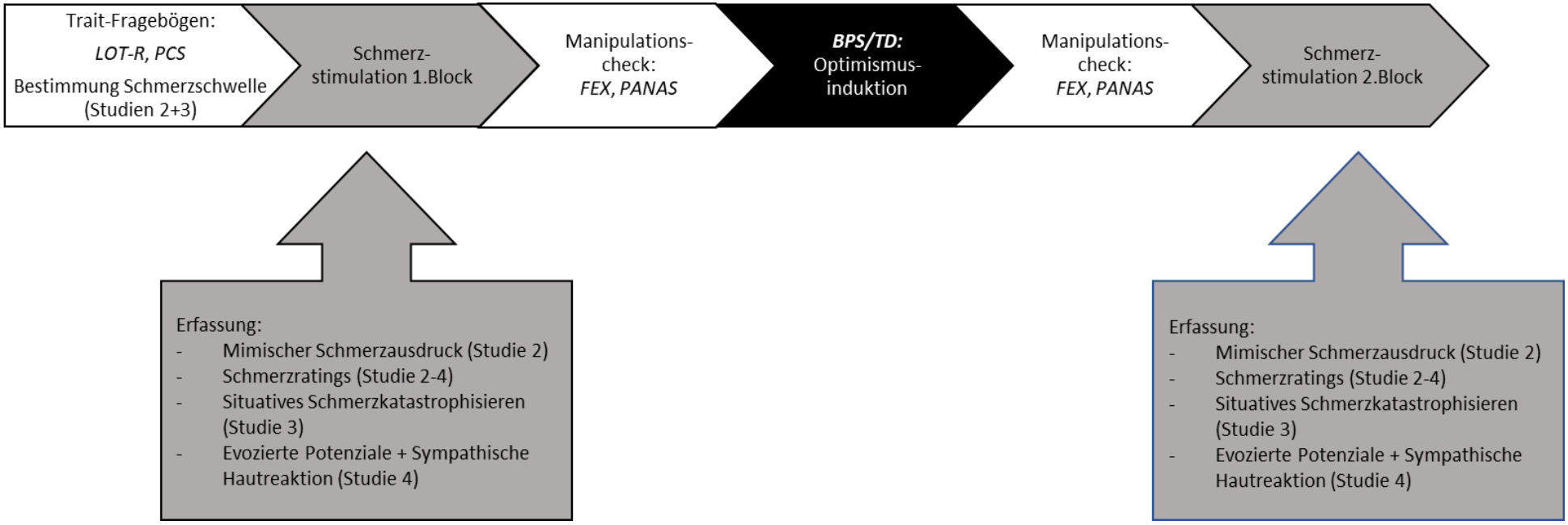


Abbildung 4. Ablaufschema der experimentellen Studien. *LOT-R = Life Orientation Test Revised Version. PCS = Pain Catastrophizing Scale. FEX = Future Expectancies Scale. PANAS = Positive and Negative Affect Schedule. BPS = Best Possible Self. TD = Typical Day*.

3.2.2 Einfluss von induziertem Optimismus auf mimische Aktivität und Schmerzratings (Studie 2, siehe Anhang 2)

Methoden:

Es wurden 40 gesunde Probanden und Probandinnen zwischen 20 und 60 Jahren untersucht. Je die Hälfte der Versuchspersonen wurde randomisiert einer der beiden experimentellen Bedingungen zugewiesen. Beide Gruppen durchliefen zwei Stimulationen mit je 20 Hitzereizen. Dazwischen führte die Experimentalgruppe die *Best-Possible-Self* (*BPS*) Vorstellungs- und Schreibübung nach King (2001) aus, während die Kontrollgruppe über einen alltäglichen Tag dachte und schrieb (*Typical Day*, *TD*).[3] Während der Stimulation, bei der je 10 Hitzereize über und unter der individuellen Schmerzschwelle auf den Unterarm verabreicht wurden, wurden selbstberichtete Ratings von Intensität und Aversivität auf einer 11-stufigen numerischen Ratingskala sowie die mimischen Reaktionen aufgezeichnet (vgl. Abb.4). Die auf Video aufgezeichneten mimischen Reaktionen auf die Schmerzreize wurden in 5s-Segemete (beginnend bei Erreichen der Plateauphase des Stimulus) segmentiert und mithilfe des *Facial Action Coding Systems* (Ekman & Friesen, 1978) entsprechend ihrer Häufigkeit und Intensität kodiert. Entsprechend eines festgelegten Protokolls wurden diejenigen ‚*Action Units*', d.h. auf der Aktivität eines oder mehrerer spezifischer Gesichtsmuskeln basierende Reaktionseinheiten, bestimmt, die in einer Bedingung in mindestens 5% der schmerzhaften Segmente auftraten und signifikant häufiger in den schmerzhaften als in den nicht schmerzhaften Durchgängen vorkamen. Für diese Action Units wurde ein Gesamtwert (*Composite Score*) berechnet (Karmann et al., 2015; Kunz et al., 2007). Zur Kontrolle von Ausgangsunterschieden wurde der dispositionelle Optimismus mit dem *Life Orientation Test Revised Version* (*LOT-R*, Scheier et al., 1994, deutsche Fassung von Glaesmer et al., 1996) erfasst. Als Manipulationscheck wurde mehrfach der situative Optimismus mit der *Future Expectancies Scale* (*FEX*, Hanssen et al., 2013) gemessen.

Um den Effekt der Optimismus-Induktion statistisch zu testen, wurden jeweils der *FACS Composite Score* bzw. die durchschnittlichen Intensitäts- und Aversivitäts-Ratings als

[3] Die Messungen vor bzw. nach dieser experimentellen Manipulation werden künftig als Prä- bzw. Post-Messung bezeichnet.

abhängige Variablen in drei getrennten 2 x 2 ANOVAs mit Messwiederholung genutzt, während die Zugehörigkeit zu BPS- vs. TD-Bedingung als Gruppierungsvariable diente.

Ergebnisse:

Die Varianzanalysen zur Testung der Effekte der experimentellen Optimismus-Manipulation zeigten eine signifikante Interaktion zwischen Messzeitpunkt und Gruppenzugehörigkeit bezüglich der Schmerzmimik: Wie in Abbildung 5 illustriert, nahm die Schmerzmimik von der Prä- zur Postmessung in der *Best Possible Self*-Bedingung stärker zu als in der *Typical Day*-Bedingung.

Im Schmerz-Selbstbericht wirkte sich die Gruppenzugehörigkeit weder auf die Intensitäts- noch für die Aversivitätsratings aus (Abbildung 6).

Die *FEX*-Messungen zeigten eine signifikante Zunahme des situativen Optimismus in der Experimental-, nicht aber in der Kontrollgruppe, was auf den Erfolg der experimentellen Manipulation hindeutet.

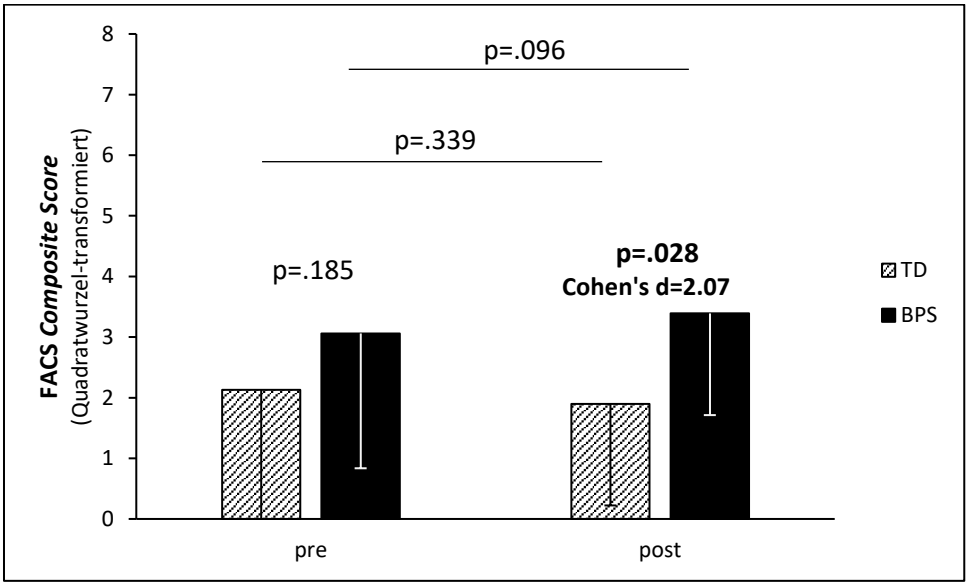


Abbildung 5: Mittlere mimische Aktivität (*FACS Composite Score*) während der Schmerzstimulation. Fehlerbalken: +1 Standardabweichung; *TD = Typical Day, BPS = Best Possible Self*.

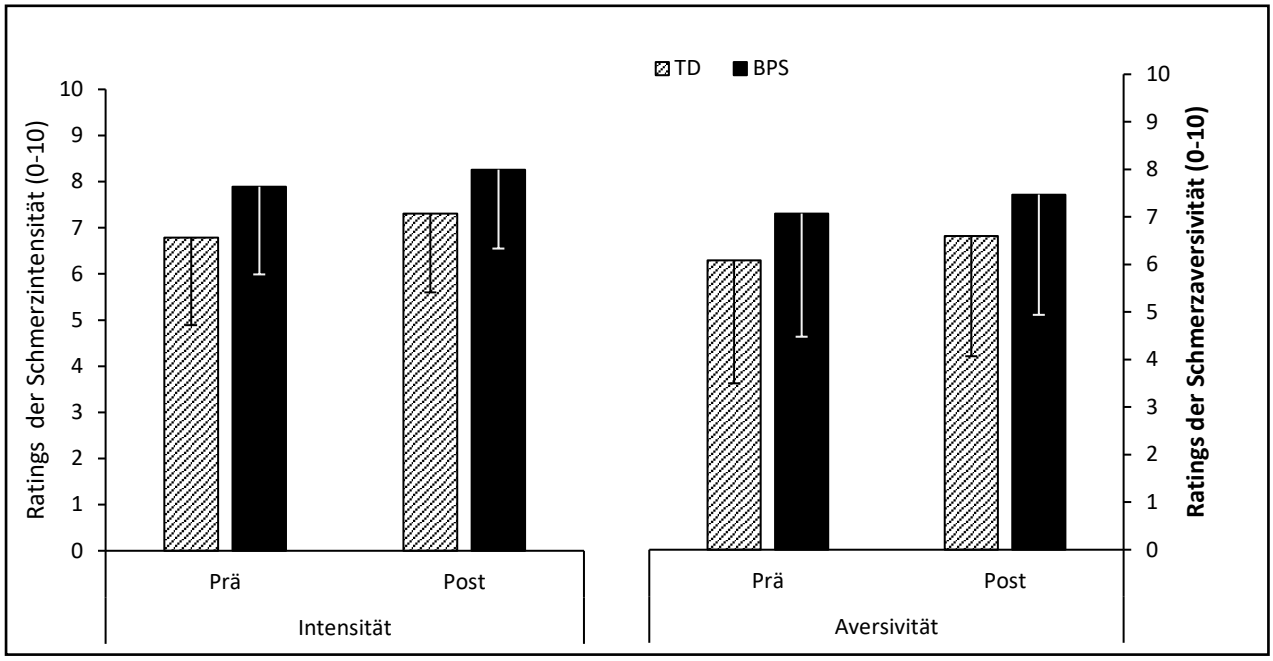


Abbildung 6: Mittlere Ratings der Schmerzintensität (links) und Schmerzaversivität (rechts). Fehlerbalken: - 1 Standardabweichung; *TD = Typical Day*, *BPS = Best Possible Self*.

Diskussion:

Dass keine Effekte der Optimismus-Induktion auf den Schmerzselbstbericht gefunden wurden, ist in Einklang mit einigen (Traxler et al., 2019; Boselie et al., 2014), aber auch in Widerspruch zu einer anderen experimentellen Studie (Hanssen et al., 2013), welche einen schmerzdämpfenden Effekt der *BPS*-Technik gefunden hatte. Es ist daher einerseits denkbar, dass der Effekt von Optimismus auf Schmerz grundsätzlich eher klein ist, sodass signifikante Ergebnisse wenig reliabel sind. Andererseits könnten auch die Art und Länge der Schmerzstimuli eine wichtige Rolle spielen. Die Studie von Hanssen et al. (2013), welche einen signifikanten positiven Effekt fand, nutzte einen *Cold Pressor Task* von zwei Minuten Dauer für die Schmerzstimulation. Möglicherweise wirkt Optimismus über komplexere kognitive Prozesse, sodass sich diese Wirkung während der von uns verwendeten Stimuli von 5s Dauer noch nicht entfalten konnte.

Der verstärkende Effekt der Optimismus-Induktion auf die Schmerzmimik ist vor dem Hintergrund des Schmerzselbstberichts so zu interpretieren, dass in der vorliegenden Studie bei gleichbleibendem subjektivem Schmerzempfinden situativer Optimismus zu einer höheren Neigung zur Expression dieses Schmerzes geführt hat. Dies ließe sich, wie unter 2.1.6

dargelegt, aus früheren Studien damit erklären, dass Optimismus das Vertrauen in die Umgebung und die Erwartung stärkt, vom sozialen Umfeld in einer Situation eigener Schwäche eher Hilfe als Ablehnung oder Ausnutzung dieser Schwäche zu erfahren. Um dieser Annahme nachzugehen, könnte in Anlehnung an die Studie von Karmann et al. (2014) zukünftige experimentelle Forschung explizit untersuchen, ob es Unterschiede in der Optimismuswirkung gibt, je nachdem, ob die Versuchsperson während der Schmerzstimulation allein, mit einer unbekannten oder mit einer vertrauten anderen Person im Raum ist.

3.2.3 Einfluss von induziertem Optimismus auf situatives Schmerzkatastrophisieren (Studie 3, siehe Anhang 3)

Methoden:

Für die dritte Studie wurden Daten der Probanden/Probandinnen aus Studie 2 aus derselben Testung verwendet. Der experimentelle Ablauf war damit in weiten Teilen wie unter 3.2.2 beschrieben. Zusammen mit dem *Trait*-Optimismus (*LOT-R*) wurde zu Beginn der Sitzung das *Trait*-Schmerzkatastrophisieren über die *Pain Catastrophizing Scale* (*PCS*, siehe 2.1.2) erfasst. Die beiden Schmerzblöcke dienten neben der Messung der unter 3.2.2 genannten Schmerzparameter gleichzeitig dazu, eine standardisierte Schmerzreferenz zu erzeugen, bezüglich der situatives Schmerzkatastrophisieren erfasst werden kann. Zur Messung von letzterem erhielten die Versuchspersonen jeweils direkt nach der Prä- und Post-Schmerzstimulation den *Situational Catastrophizing Questionnaire* (*SCQ*, siehe 3.1.2; vgl. Abb.4). Um die Wirkung der Optimismus-Induktion auf das situative Schmerzkatastrophisieren zu erfassen, wurde in einer 2 x 2 ANOVA mit Messwiederholung auf einen Messzeitpunkt*Bedingungs-Effekt getestet. Zur Testung der moderierenden Wirkung von *Trait*-Optimismus und *Trait*-Schmerzkatastrophisieren wurden zwei getrennte ANCOVAs mit dem *LOT-R*- bzw. *PCS*-Wert als Kovariate durchgeführt. Damit sollte getestet werden, ob sich die Optimismusinduktion in Abhängigkeit von der individuellen Disposition zu Optimismus bzw. zu Schmerzkatastrophisieren unterschiedlich stark auf das situative Katastrophisieren auswirkt.

Ergebnisse:

Entgegen der Hypothese zeigten sich keine Unterschiede im situativen Schmerzkatastrophisieren zwischen der *BPS*- und der *TD*-Gruppe (Abbildung 7).

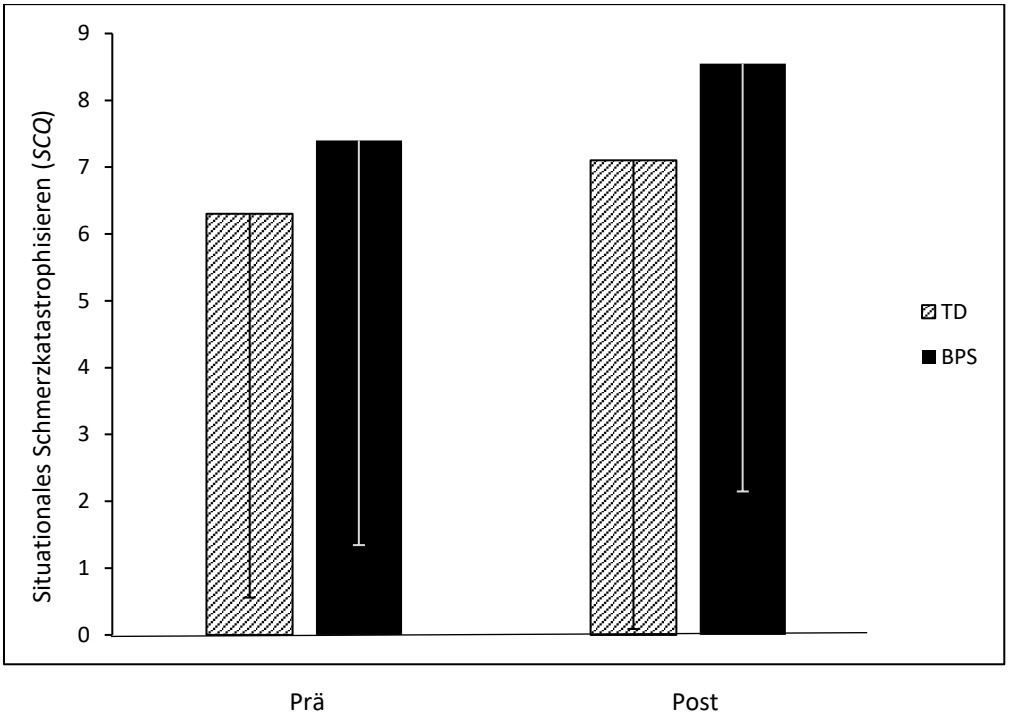


Abbildung 7: Mittleres situatives Schmerzkatastrophisieren in Abhängigkeit von experimenteller Bedingung (*BPS* vs. *TD*) und Messzeitpunkt (Prä vs. Post). Fehlerbalken = -1 Standardabweichung. *TD* = *Typical Day*, *BPS* = *Best Possible Self*. *SCQ* = *Situational Catastrophizing Scale*.

Es wurde hingegen eine signifikante Interaktion mit *Trait*-Schmerzkatastrophisieren gefunden. Diese Interaktion wird in Abbildung 8 durch eine Regression der SCQ-Prä-Post-Veränderungswerte auf den PCS-Wert, getrennt nach experimenteller Bedingung, veranschaulicht: Hohe PCS-Werte (hier für zwei Standardabweichungen über dem Durchschnitt illustriert) sagen eine Zunahme des situativen Katastrophisierens in der TD-Gruppe vorher, während die Differenz in der BPS-Gruppe nur wenige Zehntel von Null abweicht, also die Prä- und Post-Werte ungefähr gleich sind. Bei niedrigen dispositionellen Schmerzkatastrophisierern (niedrige PCS-Werte) liegt ein umgekehrtes Muster vor: In der

BPS-Gruppe findet sich eine Zunahme des situativen Katastrophisierens, in der TD-Gruppe bleibt der Wert ungefähr konstant (Post-minus-Prä-Differenz <1). Insgesamt nahm das situative Schmerzkatastrophisieren von der Prä- zur Post-Messung im Durchschnitt in allen Gruppen zu. Diese Zunahme war bei den hohen *Trait*-Katastrophisierern in der Kontrollgruppe stärker ausgeprägt als in der Experimentalgruppe, während umgekehrt bei den niedrigen *Trait*-Katastrophisierern ein stärkerer Zuwachs in der Experimental- als in der Kontrollgruppe zu verzeichnen war.

Für den dispositionellen Optimismus (Wert im *LOT-R*) wurde kein moderierender Einfluss gefunden.

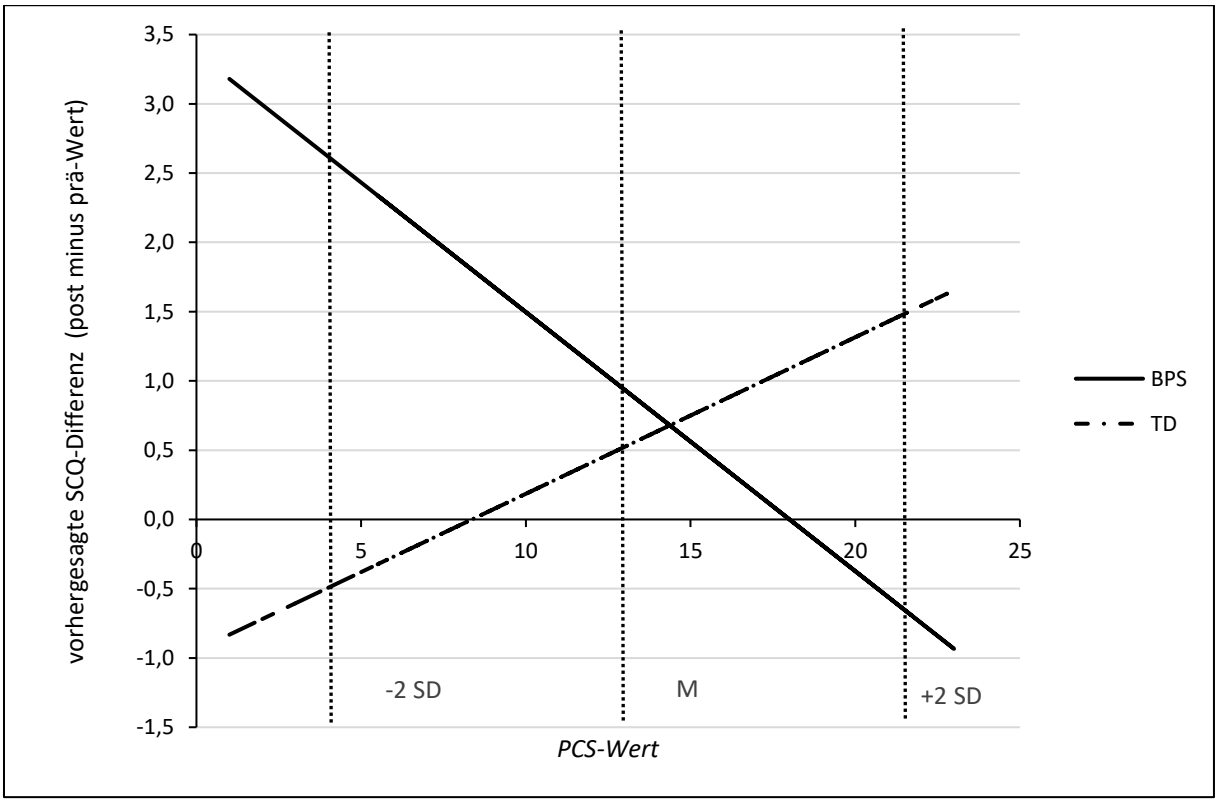


Abbildung 8: Regression der Veränderung im situatives Schmerzkatastrophisieren (SCQ post minus SCQ prä-Wert) auf dispositionelles Schmerzkatastrophisieren (PCS-Wert). Geschätzte SCQ-Werte beim Mittelwert (M) sowie bei plus/minus zwei Standardabweichungen (+/-2SD) der PCS-Werte sind mit vertikalen Linien gekennzeichnet. Positive Werte zeigen einen SCQ-Anstieg von Prä zu Post an, negative Werte eine Abnahme. *BPS = Best Possible Self. TD = Typical Day. SCQ = Situational Catastrophizing Questionnaire. PCS = Pain Catastrophizing Scale.*

Diskussion:

Entgegen früheren Befunden wurde in der 3. Studie keine allgemeine Reduktion des situativen Schmerzkatastrophisierens durch eine experimentelle Optimismus-Induktion festgestellt. Dieser Befund steht im Gegensatz zu einigen Studien, die einen negativen Zusammenhang zwischen Optimismus und Schmerzkatastrophisieren feststellten. Zwei dieser Studien (Goodin, Glover et al., 2013; Hood et al., 2012) scheinen wenig Vergleichbarkeit zu bieten, da sie lediglich Fragebögen ohne eine experimentelle Manipulation von Optimismus und ohne ein situatives Maß für Schmerzkatastrophisieren verwendeten. Hier ist hervorzuheben, dass auch in der vorliegenden Stichprobe eine negative, in der Experimentalgruppe hohe und signifikante, Korrelation zwischen den Trait-Werten (LOT-R und PCS) vorlag. Eine dritte Studie (Hanssen et al., 2013), die bereits oben vorgestellt wurde und die den angesprochenen Zusammenhang zwischen den situativen Variablen fand, könnte, wie oben argumentiert, aufgrund der längeren, tonischen Schmerzstimulation mehr Zeit für optimistische Bewertungsprozesse und eine Gegenregulation zu katastrophisierenden Kognitionen gelassen haben. Darüber hinaus könnte die Analyse von moderierenden Variablen oder von Subgruppen aufschlussreich sein, deren Ergebnisse im Folgenden diskutiert werden.

Der signifikante Interaktionseffekt mit dispositionalem Schmerzkatastrophisieren weist darauf hin, dass in der vorliegenden Studie die Assoziation des *Trait*- mit dem *State*-Schmerzkatastrophisieren in Abhängigkeit von der experimentellen Bedingung und des Messzeitpunkts variierte. Die Korrelationen zeigen, dass in der BPS-Gruppe eine signifikante, hohe Korrelation zwischen den *PCS*- und den *SCQ*-Scores in der Prä-Messung bestand, welche in der Post-Messung nicht mehr vorlag. Die Kontrollgruppe wies zu beiden Messzeitpunkten signifikante, starke Korrelationen auf. Dieser Befund legt nahe, dass die Wirkung des *Trait*-Katastrophisierens durch die Optimismus-Induktion abgeschwächt wurde, der induzierte Optimismus also der Manifestation des *Traits* in der konkreten Schmerzsituation entgegenwirkte (Tett & Gutterman, 2000). Folglich könnten dispositionelle Schmerzkatastrophisierer stärker von der Optimismus-Induktion profitiert haben als Personen mit niedrigen *PCS*-Leveln, welche auch ohne Optimismus-Induktion schon niedriges State-Katastrophisieren gezeigt hätten. Diese Ergebnisse unterstützen somit Resilienzmodelle, welche protektive Faktoren wie Optimismus als „Puffer“ gegen Risikofaktoren wie z.B. Schmerzkatastrophisieren konzipieren (z.B. Catalano et al., 2011). Die Besonderheit von

Studie 3 liegt somit in der Berücksichtigung differenzieller Aspekte, d.h. relativ stabiler Persönlichkeitsmerkmale, welche eine Rolle für die individuelle Resilienz spielen.

Sowohl Optimismus als auch Schmerzkatastrophisieren wird eine kommunikative, interpersonelle Funktion zugeschrieben (Brissette et al., 2002; Dougall et al., 2001). Das „C*ommunal Coping Model*" des Schmerzkatastrophisierens sieht das Katastrophisieren als eine Coping-Strategie, die darauf abziele, durch verstärktes Schmerzerleben Nähe, Unterstützung und Empathie der sozialen Umwelt zu maximieren (Sullivan 2001, 2004; Keefe et al., 2000). Vor diesem Hintergrund ist es denkbar, dass Optimisten eher auf eine derartige Strategie verzichten können, weil schon ihr Optimismus zu größerer wahrgenommener sozialer Unterstützung und potenziell stärkerem Vertrauen in die soziale Umwelt führt (Brissette et al., 2002; Dougall et al., 2001), was bereits an sich, wie in Studie 2 bezüglich des mimischen Schmerzausdrucks dargelegt, zu einer verstärkten Schmerexpression führen könnte.

3.2.4 Einfluss von induziertem Optimismus auf schmerzevozierte Potentiale und die sympathische Hautreaktion (Studie 4, siehe Anhang 4)

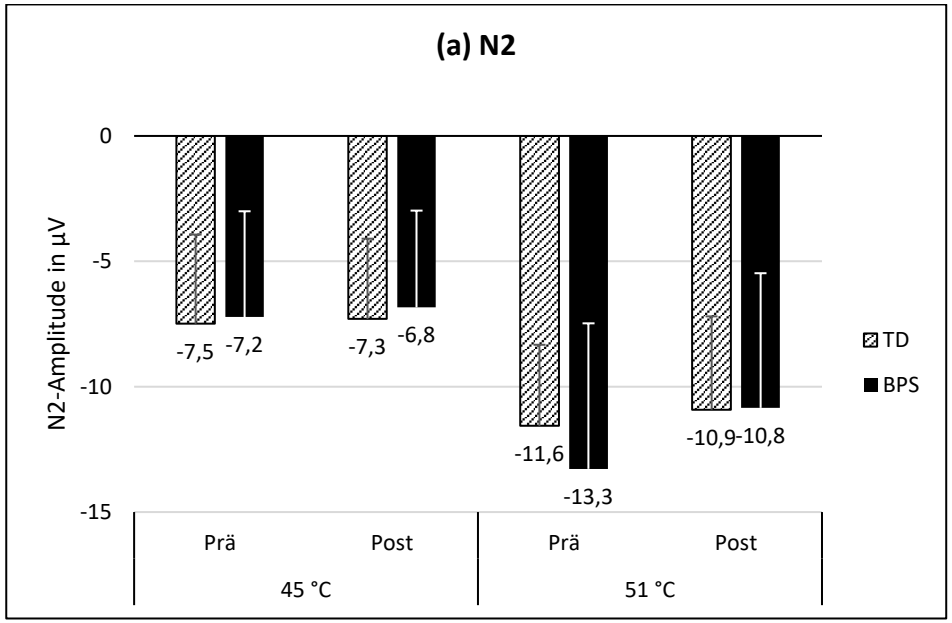
Methoden (vgl. Abb.3):

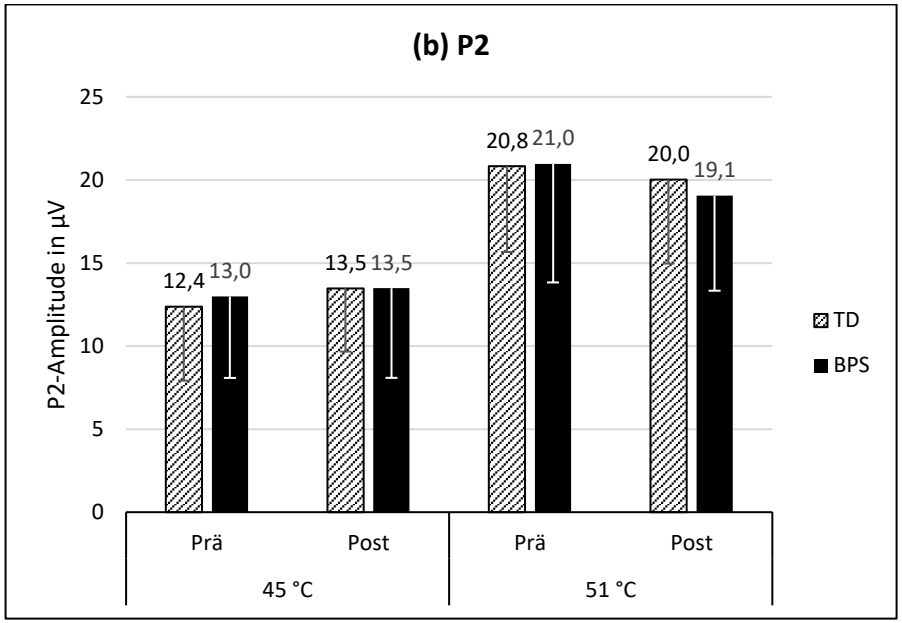
47 gesunde Probanden/Probandinnen durchliefen ein ca. zweistündiges Experiment, in dem zwei Blöcke von Schmerzstimulationen mit je 40 Hitzereizen (Dauer 10ms, Temperatur 45 °C und 51 °C in randomisierter Reihenfolge) durchgeführt wurden. Zwischen den Blöcken wurde wie in Studie 2 bei der Experimentalgruppe die *BPS*-Übung zur Optimismus-Induktion, bei der Kontrollgruppe die *TD*-Aufgabe durchgeführt. Mittels EEG wurden schmerzevozierte Potenziale aufgezeichnet – die Komponenten N2 und P2, definiert als zweiter negativer und zweiter positiver Peak nach Stimulusbeginn, sowie die N2P2 als Differenz beider Peaks. Zur Messung der sympathischen Hautreaktion (*SSR*) wurde über Elektroden die elektrodermale Aktivität am Daumenballen abgeleitet und die schmerzrelevante Komponente N1P1, definiert als Differenz zwischen erstem negativem und erstem positivem Peak, berechnet. Wie in den Studien 2 und 3 wurden auch Schmerzratings während der Hitzestimulation gemessen. Über Fragebögen wurden dispositioneller Optimismus (*LOT-R*) und dispositionelles Schmerzkatastrophisieren (*PCS*) als Kontrollvariablen erfasst. Die statistische Auswertung

erfolgte mittels Testung auf einen Temperatur*Messzeitpunkt*Bedingungs-Interaktionseffekt in 2 x 2 x 2 ANOVAs mit Messwiederholung. Auf diese Weise sollte geprüft werden, welche Wirkung die Optimismusinduktion bei schmerzhaften Reizen auf die genannten abhängigen Variablen (evozierte Potenziale, SSR, Ratings) hat.

Ergebnisse:

Die signifikante Abnahme der situativen negativen Zukunftserwartungen und die signifikante Zunahme im positiven Affekt nach der BPS-Übung weisen darauf hin, dass die experimentelle Manipulation erfolgreich war. Die statistischen Tests ergaben für keinen der Schmerzparameter einen signifikanten Effekt der Optimismusinduktion (Abbildungen 9-11). Die Optimismus-Induktion scheint somit weder eine Auswirkung auf die schmerzevozierten Potentiale noch auf die sympathische Hautreaktion oder die Intensitätsratings gehabt zu haben.





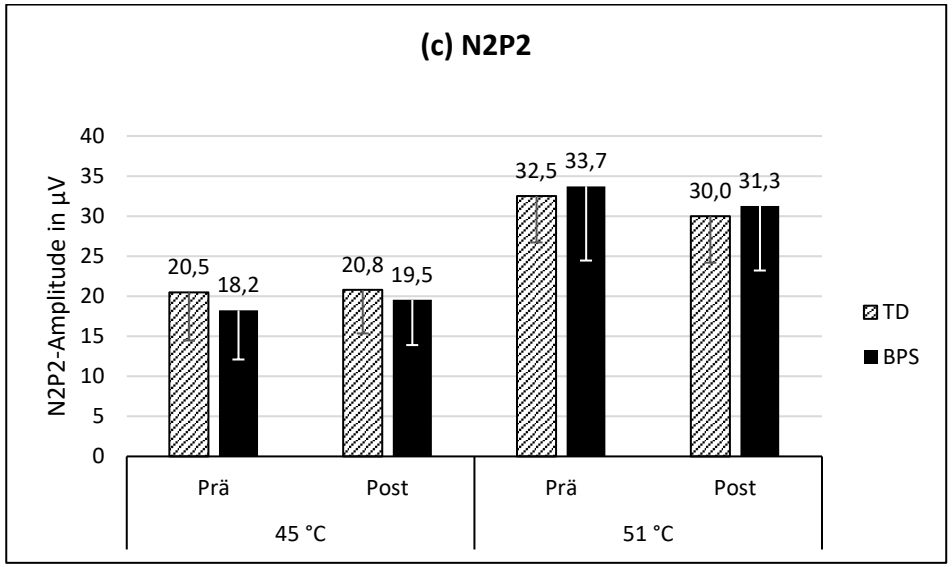


Abbildung 9. Mittlere Amplitude der schmerzevozierten Potentiale (a) N2, (b) P2 und (c) N2P2 in Abhängigkeit von Reizintensität (45 °C vs. 51 °C) und experimenteller Bedingung (BPS vs. TD). Fehlerbalken = -1 Standardabweichung. *BPS= Best Possible Self. TD= Typical Day.*

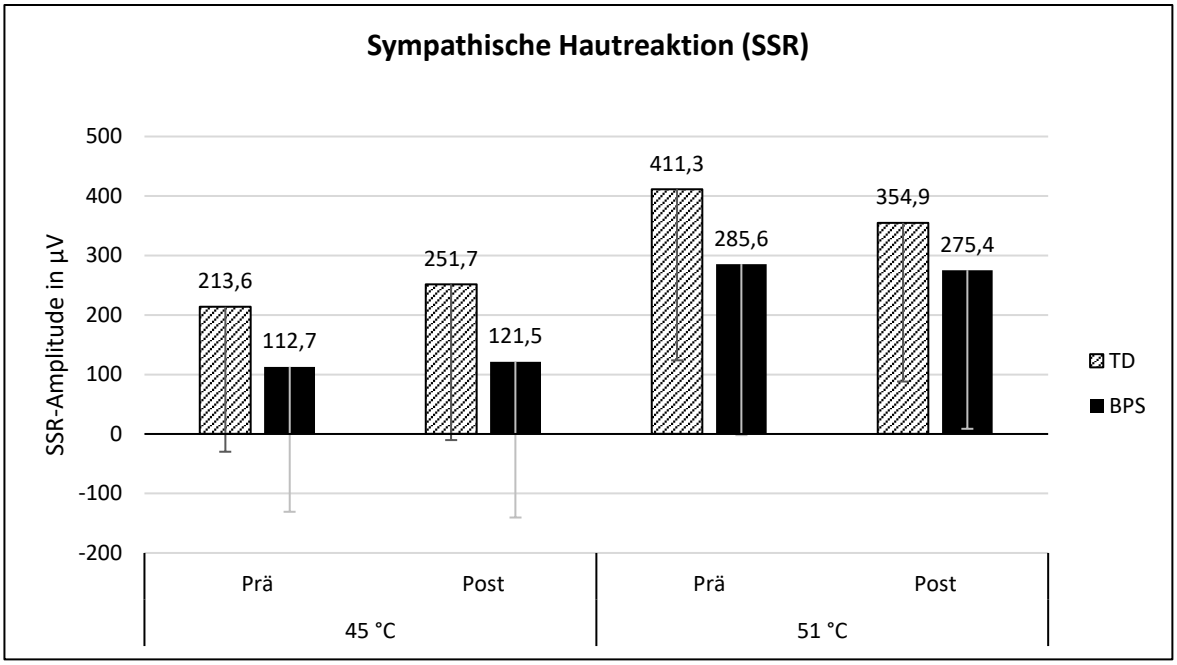


Abbildung 10. Durchschnittliche Amplitude der sympathischen Hautreaktion in Abhängigkeit von Reizintensität (45 °C vs. 51 °C) und experimenteller Bedingung (*BPS* vs. *TD*). Fehlerbalken = - 1 SD. *BPS* = *Best Possible Self. TD* = *Typical Day.*

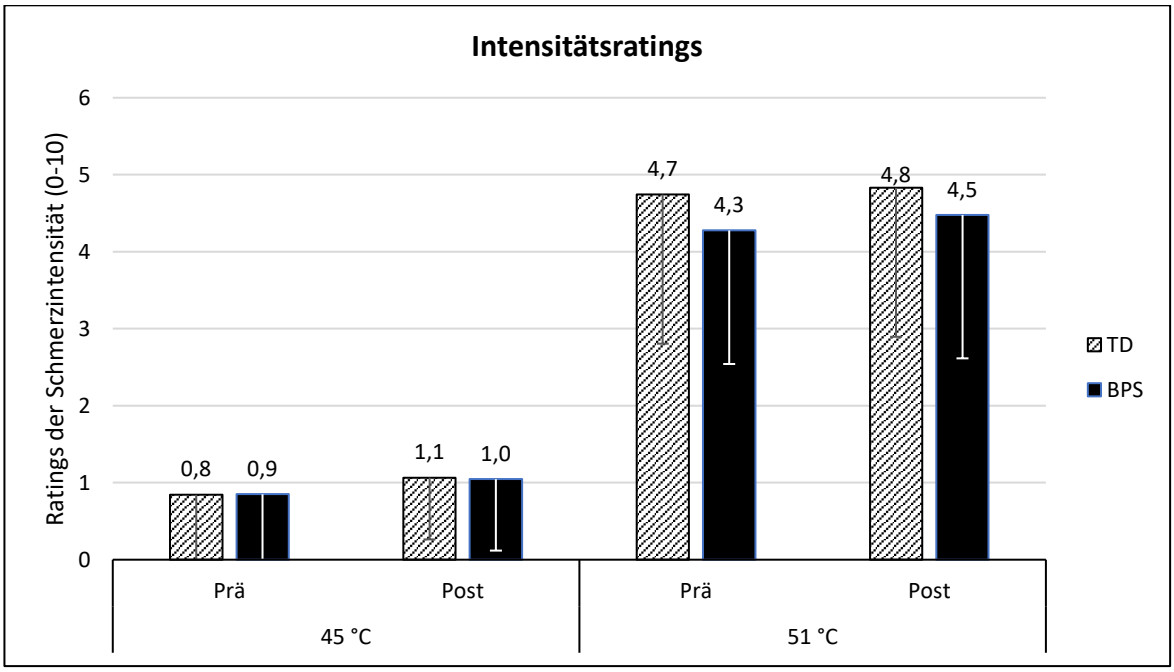


Abbildung 11. Mittlere Intensitätsratings im Schmerz-Selbstbericht in Abhängigkeit von Reizintensität (45 °C vs. 51 °C) und experimenteller Bedingung (BPS vs. TD). Fehlerbalken = - 1 Standardabweichung. *BPS* = *Best Possible Self. TD* = *Typical Day.*

Diskussion:

Die Optimismus-Induktion hatte keine Auswirkungen auf die untersuchten Schmerzparameter. Bezüglich der Ratings werden somit die Befunde der Studien 2 und 3 bestätigt. Die entscheidende Neuerung der Studie liegt darin, dass mit den schmerzevozierten Potenzialen und der sympathischen Hautreaktion erstmals Komponenten aus zeitlich sehr frühen Phasen in der Schmerzverarbeitung – im Millisekundenbereich nach Onset des Schmerzreizes – als abhängige Variablen untersucht wurden. Nach dem etwa von Price (1988) und Wade et al. (1992) vorgeschlagenen 4-Stufen-Modell entspricht das der sensorisch-diskriminativen Dimension der Schmerzverarbeitung und der „*immediate pain unpleasantness*" (Price & Bushnell, 2004; Wade et al., 1996). Beide Dimensionen werden nicht oder kaum von Persönlichkeitsmerkmalen, Einstellungen, Erwartungen und Bewertungen oder anderen höheren kognitiven Prozessen beeinflusst (Harkins et al., 1989; Wade et al., 1992; Wager et al., 2006; Wager et al., 2004; Zaslansky et al., 1996), was unsere Befunde eines fehlenden Einflusses von Optimismus stützt. Die Wirkung psychischer Faktoren scheint also frühestens erst nach der basalen Nozizeption einzusetzen. Da Optimismus über Bewertungs- und Coping-Prozesse auf das Schmerzerleben wirkt (Chang et al., 1998; Geers et al., 2008; Solberg Nes et al., 2006), ist anzunehmen, dass ein potenzieller Einfluss dieser elaborierten, höheren kognitiven Prozesse erst in späteren Stadien der Schmerzverarbeitung zum Tragen kommen würde.

Mit der Messung kortikaler und vegetativer Schmerzkomponenten wird der für Verzerrungen anfälligere Schmerzselbstbericht um Maße von höchster Objektivität ergänzt, was die Befunde, dass frühe Schmerzmaße im Millisekunden- bis Sekundenbereich nicht von Optimismus beeinflusst werden, weiter validiert.

4 Übergreifende Diskussion

4.1 Zusammenfassung der Ergebnisse

Das systematische *Review* (Studie 1) ergab einen großen Prozentsatz qualitativ hochwertiger, großenteils klinischer, Studien, welche einen negativen Zusammenhang zwischen Optimismus und Schmerz fanden. Zudem konnte ein Überblick über bekannte oder vermutete Mechanismen, Moderatorvariablen und Forschungsdesiderate geschaffen werden. Letztere wurden in den eigenen experimentellen Studien adressiert, indem erstens durch die Optimismus-Manipulation die Basis für kausale Schlüsse gelegt wurde, indem zweitens neben dem subjektiven Schmerzbericht mehrere bisher unberücksichtigte Schmerzparameter (Schmerzmimik, ereigniskorrelierte Potentiale, sympathische Hautreaktion) herangezogen wurden und auf diese Weise erstmals auch sehr frühe Schmerzkomponenten erhoben wurden und indem drittens durch den Einbezug der Variable Schmerzkatastrophisieren ein möglicher Mechanismus der Optimismus-Schmerz-Relation detailliert unter die Lupe genommen wurde.

Die drei experimentellen Arbeiten zeigten weder einen Einfluss auf den Schmerz-Selbstbericht noch auf autonome oder frühe kortikale Komponenten der Schmerzreaktion. Der mimische Schmerzausdruck hingegen wurde durch die Optimismus-Induktion signifikant verstärkt. Induzierter Optimismus führte nicht generell zu weniger Schmerzkatastrophisieren, jedoch profitierten Personen mit einer hohen Neigung zu schmerzkatastrophisierenden Gedanken bezüglich ihres tatsächlichen *State* Katastrophisierens während des Experiments stärker von der Optimismus-Induktion als Personen mit einer niedrigen Neigung zu Schmerzkatastrophisieren.

Die Befunde der Arbeit ergeben zusammenfassend (Abbildung 12) folgendes Bild:

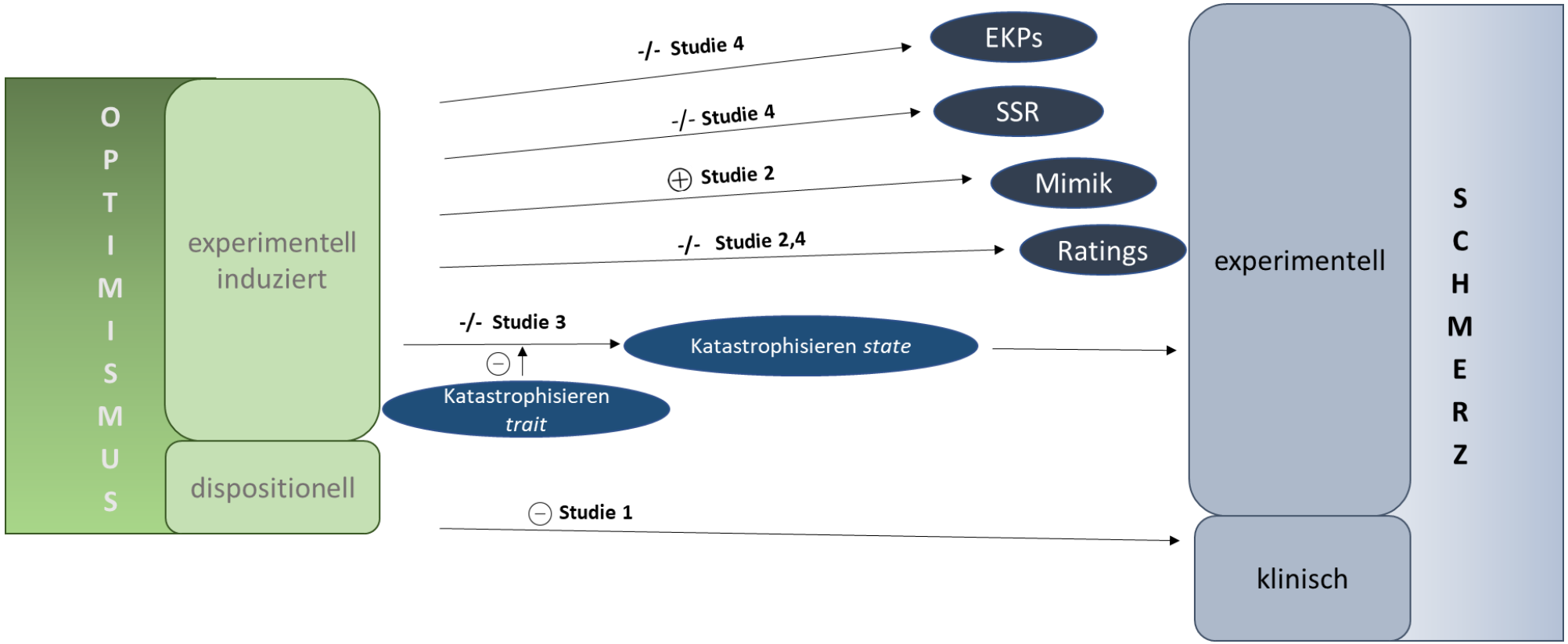


Abbildung 12. Zusammenfassende schematische Darstellung der Ergebnisse der Dissertation.

-/-: Nullbefund (kein statistisch signifikanter Effekt). ⊖: Negative Optimismus-Schmerz-Assoziation. ⊕: Positiver Effekt von Optimismus auf Schmerz.

4.2 Wirkung von Optimismus auf die Schmerzverarbeitung

Es ergibt sich aus den Befunden der experimentellen Studien folglich das Bild, dass mit Ausnahme der mimischen Reaktionen keiner der erfassten frühen Schmerzparameter von der Optimismus-Manipulation beeinflusst wurde. In Zusammenschau mit der Vielzahl der im *Review* gefundenen schmerzdämpfenden Effekte von Optimismus liegt die Vermutung nahe, dass die kognitive Optimismus-Intervention keinen messbaren Einfluss auf die basale Nozizeption hat, sondern ihre stärkste Wirkung erst zu einem späteren Zeitpunkt der Schmerzverarbeitung entfaltet, wenn die kognitive Verarbeitung, z.B. in Form von Bewertungen oder Selbstinstruktionen, zum Tragen kommt. Die Länge der verwendeten Schmerzstimuli bzw. der zeitliche Abstand der Schmerzmessung zum Stimulusbeginn wären somit entscheidende Faktoren für das Auffinden oder Nicht-Auffinden eines Effekts. Dasselbe gilt für klinische Studien, wobei anzunehmen ist, dass klinischer Schmerz tendenziell ohnehin eine deutlich längere Dauer hat als experimenteller.
Um die Vermutung zu überprüfen, dass die mit Optimismus in Verbindung stehenden *Appraisal*-Prozesse eine zu lange Zeit in Anspruch nehmen, als dass sie während der kurzen Hitzereize und der unmittelbaren Reaktionsmessung ablaufen oder gemessen werden könnten, müssten weitere Studien mit tonischen Stimuli bzw. dem expliziten Vergleich von phasischen und tonischen Stimuli unternommen werden. Die in 3.2.2 ausgeführte Tatsache, dass in der Studie von Hanssen et al. (2013) die stärksten Unterschiede zwischen der *BPS*- und der *TD*-Gruppe in der letzten von mehreren Messungen während des zweiminütigen *Cold Pressor Task* gefunden wurden, unterstützt diese Überlegung.

4.3 Wirkung von Optimismus auf die Schmerzexpression

Im Gegensatz zu den übrigen Schmerzparametern wurde hinsichtlich der Schmerzexpression eine Verstärkung des mimischen Schmerzausdrucks durch die Optimismus-Induktion festgestellt. Obgleich dieser erstmalige Befund mit Vorsicht zu behandeln ist, da er weiterer Replikationen bedarf, besteht eine theoretische Basis zur Erklärung der Zusammenhänge. Da keine parallelen Zunahmen der Schmerzratings gefunden wurden, scheint es unwahrscheinlich, dass ein Kontrasteffekt vorliegt, dass also die Versuchspersonen nach Durchführung einer angenehmen Optimismus-Übung die folgenden Schmerzen als im Vergleich umso stärker empfunden haben. Vielmehr scheinen sie bei gleichbleibendem

Schmerzempfinden eine höhere Bereitschaft gehabt zu haben, ihren Schmerz offen auszudrücken. Dies könnte, wie in 3.2.2 ausgeführt, auf ein höheres Vertrauen in die Umgebung und mehr Erwartung von Empathie infolge der Optimismus-Induktion zurückgehen. Auf Basis des verwendeten Studiendesigns lassen sich keine Aussagen darüber treffen, ob der Effekt unabhängig von der Anwesenheit einer anderen Person auftritt, also auf Mechanismen basiert, die eine *potenzielle* Kommunikation vorbereiten, oder ob er nur in einer tatsächlich als solcher aufgefassten Kommunikationssituation beobachtbar ist. Zwar saß die Versuchsleiterin während der Schmerzstimulationen schräg hinter den Versuchspersonen, sodass deren Gesicht nicht direkt einsehbar war. Allerdings ist zu vermuten, dass durch die Aufzeichnung über eine Kamera und durch die Tatsache, dass die die Mimik begleitenden Schmerzlaute von der Versuchsleiterin hörbar waren, trotzdem das Gefühl, unter Beobachtung zu stehen, entstanden ist. Um die Bedeutung einer realen Kommunikationssituation zu ergründen, scheint es notwendig, in zukünftigen Studien eine soziale Manipulation einzubauen, d.h. eine Bedingung mit Sichtbarkeit durch den Versuchsleiter vs. kompletter Abwesenheit des Versuchsleiters hinzuzunehmen, ähnlich wie sie in der Studie von Karmann et al. (2014) durch die Variation zwischen Anwesenheit einer vertrauten vs. nicht vertrauten Person vorgenommen wurde.

Folgt man der Argumentation, dass Schmerzreaktionen im Sekundenbereich nach Onset des Schmerzstimulus zu früh für einen statistisch bedeutsamen Effekt von Optimismus sein dürften, stellt sich die Frage, warum in der Schmerzmimik ein Optimismus-Effekt gefunden wurde, obwohl diese ebenfalls im 5-Sekunden-Intervall nach Beginn des Schmerzstimulus aufgezeichnet wurde. Eine mögliche Erklärung für diese Diskrepanz wäre, dass die Verstärkung des Schmerzausdrucks zumindest in Teilen eine vom konkreten Stimulus unabhängige, die gesamte Situation überspannende behaviorale Disinhibition einer optimistischeren Versuchsperson widerspiegelt. Der optimistische Zustand würde somit zu einem höheren Gefühl von Wohlbefinden und Sicherheit führen, welches die Reflexunterdrückung verringern und dann unmittelbar in einem spontaneren und stärkeren reflektorischen Ausdruck der empfundenen Schmerzen resultieren würde (Radell et al., 2016; Oskarsson et al., 2012; Hirsh et al., 2011).

4.4 Wirkung von Optimismus auf das Schmerzkatastrophisieren

Im Gegensatz zur Vorläuferstudie von Hanssen et al. (2013) wurde in der vorliegenden Arbeit keine allgemeine Senkung des situativen Schmerzkatastrophisierens durch induzierten Optimismus gefunden. Dies stellt auch die postulierte Mediatorrolle des Schmerzkatastrophisierens zwischen Optimismus und Schmerzempfinden in Frage, welche in der vorliegenden Arbeit mangels signifikanter Zusammenhänge zwischen Optimismus und Schmerz nicht untersucht werden konnte. Vor diesem Hintergrund erhält die Suche nach moderierenden Variablen eine besondere Bedeutung. Mit dem Indiz, dass Personen mit höherem dispositionellen Schmerzkatastrophisieren von der Optimismus-Induktion bezüglich ihres situationalen Katastrophisierens stärker profitieren könnten als Personen mit geringerer Neigung zum Katastrophisieren und dem Befund, dass sich derartige Zusammenhänge für dispositionellen Optimismus nicht finden ließen, liefert die vorliegende Arbeit erste Antworten auf diese Frage. Es lässt sich daraus ableiten, dass eine differenzialpsychologische Herangehensweise für die Resilienzforschung zu zusätzlichem Erkenntnisgewinn führen dürfte und weiterverfolgt werden sollte.

4.5 Limitationen, klinische Implikationen und Ausblick

Wie oben erwähnt bleibt zu berücksichtigen, dass in beiden im Rahmen dieser Arbeit durchgeführten experimentellen Schmerzstimulationen phasische Hitzereize von kurzer Dauer verwendet wurden. Um die hier gefundenen Ergebnisse verallgemeinern oder aber differenzielle Aussagen treffen zu können, sind Studien mit anderen Schmerzmodalitäten und vor allem auch – vor dem Hintergrund der vermuteten Wirkung von Optimismus über komplexere kognitive Prozesse – Schmerzreize von noch längerer, über den Sekundenbereich hinausgehender, Dauer vonnöten. Möglicherweise ließe sich auf diese Weise die Divergenz zwischen den vorliegenden Studien und dem Experiment von Hanssen et al. (2013) erklären. Angesichts der vermuteten Wirkung von Optimismus über komplexe kognitive Prozesse dürften insbesondere Studien, die sich explizit mit Schmerzkognitionen beschäftigen, aufschlussreich sein.

Es ist ebenfalls erneut daran zu erinnern, dass bei experimentell erzeugtem Schmerz, welcher sich bezüglich Intensität, Kontrollierbarkeit und Auswirkungen auf das alltägliche Leben in der

Regel stark von klinischem Schmerz unterscheidet, andere Mechanismen in der Schmerz-Optimismus-Relation involviert sein könnten als bei klinischem Schmerz. So scheint eine gesonderte Untersuchung klinischer Stichproben – etwa Personen mit chronischen Schmerzerkrankungen oder mit Depression, zu deren Kernsymptomen eine pessimistische Weltsicht zählt – sinnvoll, wobei Variablen wie Coping, Funktionalität und Beeinträchtigung sowie der Erhalt von Lebensqualität trotz Schmerzen mit einbezogen werden sollten.

Ferner ist zu überlegen, welche Folgen ein verstärkter Schmerzausdruck im klinischen Kontext haben könnte. Da vor allem bei chronischen Schmerzen negative Folgen gesteigerten Schmerzverhaltens bekannt sind, die längerfristig einerseits zu einer Abwendung der Bezugspersonen, andererseits auch zu einer Verstärkung der Schmerzen führen können (Bastian et al., 2014; Cano, 2004), stellt sich die Frage, ob dieselben Mechanismen bei Optimisten greifen oder ob, wie in 2.2.2 beschrieben, in Abhängigkeit der Umstände eine flexible Anpassung an die Situation erfolgt und der Schmerzausdruck möglicherweise auf längere Sicht wieder reduziert würde. Zudem ließe sich aus den Befunden der vorliegenden Studie die Vermutung ableiten, dass ein verstärkter Schmerzausdruck im Verlaufe der Behandlung einerseits Ausdruck tatsächlich gestiegener subjektiver Schmerzen sein könnte, andererseits aber auch lediglich auf eine Zunahme der Vertrautheit und des Vertrauens gegenüber dem Behandlungsteam und damit einhergehend einer höheren Bereitschaft, die eigenen Schmerzen zu kommunizieren, zurückgehen könnte. Beide Varianten könnten unter Umständen sehr unterschiedliche praktische Implikationen für die Behandlung haben und sollten somit den Behandelnden bewusst sein und, falls möglich, von ihnen unterschieden werden.

Die genannten Prozesse sind auch beim klinischen Einsatz von (längerfristigen) Optimismus fördernden Interventionen zu berücksichtigen, zu denen vielversprechende erste Befunde vorliegen (Meevissen et al., 2011; Flink et al., 2015; Peters et al., 2017). Nachdem nach Erkenntnissen der vorliegenden Arbeit die Wirkung von Optimismus als Schmerz-Resilienzfaktor nicht auf die basale Nozizeption, sondern auf spätere Phasen der Schmerzverarbeitung wirkt, sollte auch Faktoren wie Krankheitsbewältigung, Funktionalität und Aufrechterhaltung der Lebensqualität trotz Schmerzen, für deren Zusammenhang mit Optimismus bereits Evidenz besteht (Achat et al., 2000; Wrosch & Scheier, 2003; Balck et al., 2016), künftig ein besonderes Augenmerk gelten.

Angesichts der vermuteten differenziellen Pufferwirkung von Optimismus auf den Risikofaktor Schmerzkatastrophisieren wäre im Sinne einer individualisierten bzw. personalisierten Medizin zu empfehlen, klinische Interventionen zur Resilienzförderung gezielt auf das jeweilige individuelle Risikoprofil der Patientin oder des Patienten abzustimmen.

4.6 Fazit

Die vorliegende Dissertation gibt breite Einblicke in die Wirkung von Optimismus als Resilienzfaktor. Anhand empirischer Studien wurde die Wirkung von induziertem Optimismus auf eine große Bandbreite an Schmerzparametern erforscht, welche mehrheitlich noch nicht in diesem Zusammenhang untersucht worden waren. Die Arbeit gibt Hinweise darauf, dass eine experimentelle Optimismus-Induktion keine frühen Effekte auf selbstberichtete Schmerzintensität und -aversivität, auf die sympathische Hautreaktion, auf schmerzevozierte Potenziale und situatives Schmerzkatastrophisieren während phasischer Hitzereize hat, während der mimische Schmerzausdruck verstärkt wird. Die Arbeit legt nahe, dass Personen mit einer hohen Neigung zu Schmerzkatastrophisieren im Hinblick auf ihre katastrophisierenden Gedanken in einer konkreten Schmerzsituation stärker von einer vorausgehenden Optimismus fördernden Übung profitieren und Optimismus somit eine puffernde Rolle für negative Auswirkungen von Schmerz hat.

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Danksagung

An dieser Stelle möchte ich mich von ganzem Herzen bei allen Personen bedanken, die meine Promotion möglich gemacht und unterstützt haben: An erster Stelle meinem Betreuer Herrn Prof. Stefan Lautenbacher für seine jahrelange fachliche und persönliche Unterstützung.

Weiterhin dem Evangelischen Studienwerk für die ideelle und materielle Förderung, hier insbesondere der Studienleiterin Frau Dr. Almuth Hattenbach und ihrem Nachfolger Herrn PD Falk Müller; ebenso allen beteiligten Professorinnen und Professoren und Stipendiaten des Promotionsschwerpunktes „Resilienzfaktoren in der Schmerzverarbeitung“ für die interdisziplinäre Einbettung und den wertvollen Austausch.

Weiterer Dank gilt allen Kolleginnen und Kollegen der letzten Jahre und allen Beteiligten am Doktorandenprogramm „Biopsychology of Pain and Emotions“ für ihr Feedback, ihre Inspiration und die gegenseitige Unterstützung. Besonders hervorheben möchte ich hierbei Eva Capito und Cindy Strömel-Scheder für ihr unablässiges Engagement für den Zusammenhalt im Team.

Zudem bedanke ich mich bei den Kooperationspartnerinnen Frau Prof. Madelon Peters und Frau Prof. Miriam Kunz für ihre wertvolle inhaltliche Beratung bezüglich Optimismus bzw. Mimik und die Unterstützung bei den Manuskripten.

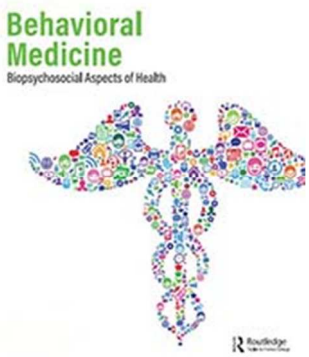
Abschließend gilt ein besonderer Dank meinem Partner Tobias für seine Unterstützung, sowie ihm, meinen Eltern und meinen Schwiegereltern, ohne deren zuverlässige Kinderbetreuung bei Workshops und Kongressen das Promovieren nicht in dieser Form und Intensität möglich gewesen wäre.

Anhang 1

Dokument-Version: akzeptiertes Manuskript (Postprint)

Quelle für veröffentlichte Version:

Basten-Guenther, J., Peters, M., & Lautenbacher, S. (2019). Optimism and the experience of pain: A systematic review. *Behavioral Medicine*, *45*(4), 323-339. Doi: 10.1080/08964289.2018.1517242



Optimism and the experience of pain – a systematic review

Journal:	*Behavioral Medicine*
Manuscript ID	40-17-104-SR.R2
Manuscript Type:	Systematic Review
Keywords:	pain, optimism, resilience, chronic pain, positive psychology

Optimism and the experience of pain – a systematic review

Abstract

A growing body of literature provides evidence of the health-promoting effects of optimism, including its protective role in acute and chronic pain. Optimists are characterized by positive expectations concerning the future. These positive outcome expectancies lead to more and longer goal-directed efforts and the use of approach coping strategies. No systematic review on the effects of optimism on the experience of pain has so far been conducted. A search in the databases PubMed, Web of Science and PsycInfo and the scanning of reference lists identified 69 eligible studies. These were categorized according to sample size, participants' age and sex, design, optimism-pain relation as primary vs. secondary study objective and level of study/publication quality. Overall percentages of positive, zero and negative associations between optimism and pain as well as relative frequencies of these associations in the different categories were analyzed. About 70% of the studies showed a positive, i.e. beneficial association between optimism and at least one pain outcome. A larger percentage of beneficial associations was found in studies with experimental designs, in studies with the optimism-pain relation as primary objective, in high quality studies/publications and in studies including participants with a higher average age. The review suggests that optimism is associated with less acute and chronic pain, especially since a higher percentage of beneficial associations was found with high study/publication quality and with the primary focus on this relationship. For the moderating role of age, different explanations are proposed. Further research on causal relationships and on optimism-fostering clinical interventions is needed.

Introduction

For decades, pain research has been dominated by the examination of risk factors. Only recently, in the wake of Antonovsky's *salutogenic model*[1] and Martin Seligman's work in positive psychology[2], this traditional focus has been extended to the search for resilience factors, i.e. factors which can dampen acute pain experience, promote adaptation to chronic pain or protect against developing chronic pain. Self-efficacy, hope and positive affect are among these characteristics that have been shown to promote pain resilience[3,4].

As stated in the fear-avoidance model of musculoskeletal pain[5], chronic pain can be a result of a dysfunctional psychological reaction to an acute pain experience. People who tend to engage in catastrophizing thoughts concerning their pain are likely to get caught in a vicious circle of fear of pain, avoidance and hypervigilance, disuse and disability and in turn increased pain. Optimism seems to protect against the development of this vicious circle leading to chronic pain in that it stops catastrophizing and hypervigilance to negative information, as will be described below. Originally defined by Scheier and Carver as "generalized positive outcome expectancies"[6] in the context of their theory of self-regulation[7], optimism describes the tendency of individuals to expect positive things to happen to them in the future. As optimists subjectively evaluate the probability of success higher, they are more likely to engage and persist in goal-directed efforts (as opposed to the "why-bother"-attitude of pessimists[8]), which in turn increases their chance to effectively cope with stressors[9]. This is in line with traditional *expectancy x value*-theories of motivation (for example, Atkinson[10)], which emphasize the role of expectations in motivation and motivated behavior.

There is evidence of a wide range of health-promoting effects of optimism (for a comprehensive overview, see Carver et al.[11]; for a recent mini review concerning chronic

diseases, see Avvenuti et al.[12]). Although the association of optimism with *pain* has been examined in numerous studies, no systematic review or meta-analysis has to our knowledge been published on this topic.

Apart from several overviews covering related topics such as the relationship between pain and positive traits[3] or between optimism and coping[13], there have been two publications on the topic of optimism and the experience of pain: Garofalo's review on perceived optimism and chronic pain, covering the literature until 2000[8], and Goodin and Bulls' review on optimism and the experience of pain incorporating research from 2000 to 2013[9]. Although being valuable sources of information, the two publications lack the methodic and scrupulous approach of *systematic* reviews.

Garofalo[8], limiting his review to chronic pain conditions, concluded that the body of literature available at that time was too scant for definite conclusions, but tentatively suggested positive effects of optimism on chronic pain. Goodin and Bulls[9], who were able to make inferences from a significantly larger number of studies, confirmed these findings, extending them to experimental pain conditions. They also listed several cognitive and behavioral mediators that are associated with less severe pain reports and therefore might explain the underlying mechanisms of the optimism-pain relationship: optimists tend to show lower pain catastrophizing (see Pulvers & Hood[3], for an overview), higher hopefulness and pain acceptance and more effective coping strategies.

The present overview adds to and extends this previous work in that it uses a research algorithm in order to systematically retrieve all relevant studies on the optimism-pain relationship, covering experimental and clinical pain as well as dispositional and situational optimism. It is thus the first to give a comprehensive account of the current state of research. Additionally, in order to propose explanations for divergent results, we seek to

identify variables which influence whether a study finds a significant association or not, i.e. moderating factors of the optimism-pain relation. In the pain context, sex and age have been shown to be among the most important moderating variables[14,15]. Accordingly, for men and women differential relations between optimism and various health-related variables like, for example, stress symptoms have been reported[6,16].Similarly, there is evidence of age effects in the prediction of self-rated health by several psychological variables such as positive affect or depressive symptoms (for example, Spuling et al., Benyamini et al., French et al.[17,18,19]). In these studies, the influence of psychological as compared to physiological variables augmented with increasing age. It can therefore be speculated that likewise optimism's association with pain might be bigger in older individuals. For this reason, age will be analyzed as another possible moderating variable. The probability that an existing association between optimism and pain is statistically detected also depends on parameters of study design. Studies with large sample sizes have more statistical power. In experimental studies, confounding variables can more easily be ruled out. Studies focusing on optimism and pain as their primary aim can be supposed to be tailored to more accurately measure the two variables of interest. Therefore, these technical variables as well as an overall measure of study/publication quality are included in the set of variables possibly influencing the optimism-pain relation.

So far, optimism has largely been conceptualized as a personality disposition measured by trait questionnaires, especially the *Life Orientation Test* (*LOT*)[6] and its revised version (*LOT-R*)[20], which offer both a composite optimism score and separate scores on optimism and pessimism subscales.

Only recently, attempts have been made to experimentally induce an optimistic state for a short while. Fosnaugh et al. describe significant positive changes in a dispositional (*LOT-R*)

and a comparative optimism measure both after a future thinking manipulation and after a semantic optimism-priming task[21]. Peters et al.[22] as well as Hanssen et al.[23] report positive evidence obtained by a different manipulation, the *Best-Possible-Self*-task (BPS)[24]. During this exercise, participants imagine and write about themselves in the future, when they envision to have reached all their goals and when all their dreams have become true (for the exact instructions, see supplement 2)[25]. The BPS was shown to be successful in bringing about an increase in participants' situational optimism, which was recorded by the *Questionnaire for Future Expectations (FEX)*, an adaptation of the *Subjective Probability Task*[26].

In the present work, both studies using experimental pain and studies of clinical pain are reviewed. As the theoretical framework on optimism claims that optimism has a trait (dispositional) as well as a state (situational) component[27], we will consider trait as well as state measures of optimism – which are known to be highly correlated[28] – and include induced (experimentally or through clinical interventions) as well as spontaneous (non-induced) optimism. As implied by Carver and Scheier's definition[6], optimism concerns *generalized* outcome expectations, which is why specific expectations (e.g. health-related beliefs) are not considered here as a measure of optimism.

Since there are many different pain-related variables, it seems reasonable to focus first on pain experience in the narrow sense, which comprises reports of pain intensity, frequency or unpleasantness, the measurement of pain thresholds, pain tolerance thresholds and psycho-physiological parameters like evoked potentials or heart rate responses. Also considered are parameters which can be derived from the first group of parameters such as habituation, temporal summation, conditioned pain modulation or placebo/nocebo effects. Due to the growing number of methodological approaches to assess pain and its various dimensions, it

is not possible to incorporate all different pain outcome variables into one review. Thus, it seemed reasonable to focus only on the basic variables of pain experience in this first overview. Secondary pain outcomes such as fear of pain, pain-related disability, functional impairment, coping with pain or adjustment to pain conditions are not included here, but may be considered in further reviews.

It is, in summary, our aim to provide an overview of a topic of high clinical relevance, the association of optimism with pain experience. We set out for the first time to systematically review research on the optimism-pain-relation in order to propose answers to the following questions: is optimism associated with less pain and, if yes, under which conditions is this association observed?

Methods

The present article is based on the recommendations of the PRISMA guidelines for the creation of systematic reviews and meta-analyses.[29] The studies included in this review were identified through a computerized search in the databases *PubMed, Web of Science* and *PsycInfo,* which cover a large part of research articles in the field of psychology and medicine and have been used in previous reviews on similar or related topics (for example [3,30]). A search algorithm combining keywords referring to pain (such as “pain”, “clinical pain”, “experimental pain”, “pain intensity”, “pain threshold” etc.) with keywords referring to optimism (such as “optimism”, “dispositional optimism”, “situational optimism”) was employed. Due to the known differences of pain perception between adults and children[31] we decided to exclude pain in children and focus on adult humans. Therefore, “children”, as well as “animals”, were applied as NOT-terms (for the exact syntax used for the search, see

supplement 1). There were no restrictions concerning years of publication. Five additional relevant studies from other sources, e.g. scanning of reference lists, were added (see figure 1). Titles and abstracts of the 675 studies retrieved via this systematic search were screened. Five hundred forty records had to be excluded because they were either not related to the topic of pain and optimism or they were records in a language other than English, reviews or no peer-reviewed journal articles. Of the 135 articles assessed in full-text for eligibility by two reviewers, only those were included in our synthesis which fulfilled the following three conditions: 1) involving the exact variables of interests, i.e. pain and optimism rather than related constructs such as hope; 2) providing distinct measures of both optimism and pain (within the same person, thus precluding studies treating concepts like "caregiver optimism") in order extract the specific values of these two constructs; 3) reporting some form of statistical measure of the relation between both constructs (e.g., correlation, effect size in ANOVA or regression; regressions of optimism on pain were excluded on the basis of our research question).

For a methodological study/publication description, the 69 studies meeting all inclusion criteria (see table 1) were assessed using an index of quality, inspired by assessment tools for studies in meta-analyses such as the *Newcastle-Ottawa scale*[32], which provide an operationalized score for each study. Lower levels of quality in the respective categories (for example no clear description of measures, missing documentation of comorbidity) are awarded fewer points (see table 2). The quality of each study/publication could range from a minimum of 1.5 points to a maximum of 11 points.Based on our theoretical assumptions on potential moderating variables described in the introduction, we classified all studies according to age of subjects (following Erikson's[33] categorization), sex of subjects, sample size, design (clinical-cross-sectional vs. clinical-longitudinal vs. experimental), importance of

the optimism-pain relation within the study (among the primary objectives of the study or not) and the above-mentioned quality index. The included pain measures reflect different dimensions (e.g., pain intensity, unpleasantness, threshold, tolerance, duration) and can therefore not sensibly be aggregated. For this reason, it was not possible to perform a meta-analysis incorporating the whole sample of studies.

We analyzed for each moderating variable the percentage of studies with positive (i.e. significant beneficial association between optimism and pain)[1] vs. not positive results in the different classes of this variable (e.g., different age groups). Due to the numerous cell frequencies of n<5 in the resulting multi-field panels, we did not perform chi² tests, but instead tested for significant deviations from an equal distribution with binominal tests.

Results

Descriptive statistics (cf. tables 1 and 3):

Of the 69 studies included in the review, 55 dealt with clinical pain[34-88], 12 with experimental pain[23,89-99] and two[100,101] with both of them.

Clinical studies: Most studies concerning clinical conditions had participants with either musculoskeletal pain (k=10)[2], arthritis (k=10) or post-operative pain (k=17). Another seven articles dealt with different forms of cancer pain, the remaining eleven studies with various other clinical conditions, which are listed in detail in table 1. To assess pain, the clinical studies used questionnaires – mostly the *SF-36* (k=7), the *MPQ* and its short form

[1] In order to avoid confusions of the term "positive result" which could be interpreted as either a positive correlation between optimism and pain or as a protective association (i.e. a negative correlation) between optimism and pain, the term "beneficial association of optimism with pain" (referring to a negative statistical correlation) will be used throughout the text.

[2] In the following, numbers of studies are referred to by the *k* common in meta-analyses while numbers of persons are designated by *n*.

(k=5), the *BPI(-SF)* (k=7) or illness-specific questionnaires (k=12) as, for example, the *RADAR* – and/or rating scales (k= 24).

Experimental studies: In experimental settings, the majority of the 14 studies used the cold pressor task (k=8). Three studies applied laser (k=1) or thermode-induced (k=3) heat pain. The remaining three studies used thermode-induced cold pain (k=1), chemical (k=1) and ischemic (k=1) pain. Pain experience was determined by recording reports of intensity (k=11) and unpleasantness (k=4), pain thresholds (k=4) or pain tolerance thresholds (k=6). From these, some studies computed markers of inhibitory or facilitatory processes (conditioned pain modulation or temporal summation, k=2), habituation (k=1) and placebo analgesia (k=2). As only three articles included psycho-physiological and stress parameters (blood pressure and heart rate[92,93] and the pro-inflammatory cytokine interleukin-6[100]), we did not perform any separate analyses with these outcome measures.

Optimism measure: All but nine studies (k=60) fully or partly employed the same optimism measure, namely the *LOT* or *LOT-R*. In five studies, measurement of optimism was limited to a single item, which in one case was taken from the *LOT*. One study took two items from the *LOT*, the remaining three studies used other scales (*PAS*, *EMS* and *MMPI*). All of the measures concerned dispositional optimism. The two studies which conducted an experimental induction of optimism[23,89] additionally recorded situational optimism (measured by the *FEX*).

Sample size: Sample sizes ranged from 27 to 5696.

Sex: The majority of the studies (k=62) included both sexes; five studies had only female and two studies only male participants.

Age: As several reports (k=5) did not specify participants' age, no exact indication of the average or range of age can be made. Of the studies where age was reported, about half

(k=33) had an average between 30 and 60 years, 22% (k=14) below 30 years and 27% (k=17) above 60 years. In experimental studies, the average age seems to be below 30 years (27.9 in studies that reported average age); in clinical studies, the mean of specified age averages was 53.6 years.

Study/publication quality: Quality according to the index we applied (see table 2) ranged from 6 to 11 points in the present studies. Only one article[94] scored the maximum of 11 quality points.

(Co)morbidity: In more than half of the studies (k=36), morbidity or comorbidity was not reported. Most experimental designs excluded illnesses that are known to influence pain perception. In at least 10 clinical studies, a part of the participants was affected by major illnesses such as depression or diabetes.

Optimism-pain relation:

In total, 48 of the 69 studies (69.6%) found a significant beneficial association between optimism and at least one pain outcome. Of those, 25 studies (36.2% of all 69 studies) revealed an exclusively beneficial i.e. no additional zero or negative association. The remaining 23 studies (33.3% of all 69 studies) showed mixed results which means that they report two or more outcome measures with diverging results (see table 1). These different results partly stem from different statistical analyses of the same data: in some cases, for example, simple correlations or univariate regressions were significantly positive, while the association disappeared in more complex models such as hierarchical regressions or multivariate models[82,83,86]. Apart from that, "mixed results" also refers to diverging results for subgroups of the sample (e.g. men vs. women[49], different experimental conditions[93], clinical population vs. healthy controls[100]), for different optimism parameters (e.g. subscales of the LOT[75]), for different pain outcomes (e.g. pain intensity vs. pain tolerance or pain

threshold[78,95]; clinical vs. experimental pain[101]; different types of clinical pain[57,65,66]) or for different times of measurement (first vs. second experimental session[97]; baseline vs. follow-up[50,73,87]).

Twenty-one studies (30.4% of all 69 studies) did not detect any association; one study[84] reports a negative association for one subgroup of the sample (patients with established rheumatoid arthritis), beneficial associations for the other two subgroups (early and intermediate rheumatoid arthritis) and no association between optimism and pain in the overall correlation.

Moderating variables:

Sample size: 72.3% (k=47 of 65) of studies with medium (n= 50-100) or large (n>100) sample sizes report a beneficial association between optimism and at least one pain outcome. Since there were only a few studies with small sample sizes (k=4), we are not able to draw any general conclusions about the impact of sample size on the likelihood of positive findings.

Age: As shown in figure 2, the proportion of studies showing beneficial associations increases with higher age. Thus, 88.2% (k=15 of 17) of studies with an average age above 60 years revealed significantly beneficial associations, compared to 65.6% (k=21 of 32) and 57.1% (k=8 of 14) in the age groups of 30-60 years and under 30 years, respectively. Binominal tests showed that there were significantly more beneficial than zero associations in the two older age groups (30-60 years: $p=.03$; above 60: $p<.005$), but not in the youngest one ($p=.18$).

Sex: Due to the too small number of studies including either exclusively women or men or explicitly testing for sex differences (k=8), no conclusions can be derived concerning the moderating role of sex.

Design: While both experimental and clinical studies show a clear majority of beneficial over zero associations, this tendency becomes more apparent in experimental designs, where beneficial associations are reported in 78.6% (k=11 of 14) of studies, compared to 70.6% (k=24 of 34) in clinical-longitudinal and 61.9% (k=13 of 21) in clinical-cross-sectional studies (see figure 2). The proportion of beneficial associations was significantly larger than an equal distribution in the former two (experimental: *p=.02*; clinical-longitudinal: *p=.01*), but not in clinical-cross-sectional designs (*p=.10*).

Optimism as primary objective: As there were studies whose major focus was set on examining the relationship between optimism and pain experience as opposed to others in which optimism was one of a multitude of psychological variables measured and pain one of health-related outcomes, we analyzed separately those studies that treated the optimism-pain relation as primary vs. secondary objective. While in the latter group, only half of the studies (k=9 of 18; *p=0.19*) found a positive optimism-pain association, studies focusing on optimism and pain yielded beneficial associations at 76.5% (k=39 of 51; *p<0.005*) and thus significantly more often than expected under an equal distribution (see figure 2).

Study/publication quality: Eventually, regarding quality of study and publication as a possible moderating factor, our analysis showed a markedly higher percentage of beneficial associations with high study/publication quality (quality index ≥9.5): as shown in figure 2, 92.9% of the studies in this group (k=13 of 14) report a beneficial association between optimism and at least one pain outcome, compared to 60% (k=6 of 10) of records with low study/publication quality (≤7 points) and 64.4% (k=29 of 45) of records with medium study/publication quality (7.5-9 points). The proportion of beneficial associations was significantly bigger than expected under an equal distribution in the medium (*p=.02*) and high quality group (*p<.005*), but not in the low quality group (*p=.20*).

Discussion

The present systematic review on studies investigating the relation between optimism and the experience of pain is the first of its kind. Optimism was defined as generalized expectations concerning the future, including trait and state measures. Pain experience according to our definition included reports of pain intensity, frequency or unpleasantness, the measurement of pain thresholds, pain tolerance thresholds and psycho-physiological parameters as well as higher-ordered pain processes like habituation, temporal summation, conditioned pain modulation or placebo/nocebo effects.

Of the 69 eligible articles comprising experimental and clinical studies with a variety of different types and measures of pain, about 70% (k=48) showed a beneficial association regarding at least one pain outcome measure. A significantly bigger proportion of beneficial associations than expected under an equal distribution of was found in experimental and clinical-longitudinal studies, studies with the major focus on the optimism-pain relation, studies with high study/publication quality as well as studies with a higher average age of the participants. All in all, the present state of research suggests that optimism can indeed be considered a psychological factor which is associated with a diminished experience of pain.

Moderating variables:

In order to determine why some studies found significant beneficial associations while others did not, we examined several moderating factors of the optimism-pain relation.

Experimental and clinical-longitudinal designs, studies with the optimism-pain relation as primary objective and studies with a higher study/publication quality were shown to produce a significantly larger percentage of beneficial associations than expected under an equal distribution. This seems to further corroborate our assumption of a beneficial

optimism-pain relationship, since these are studies which are more likely to detect an association if it does exist: studies with high study/publicationquality presumably yield more valid data than studies with low study/publication quality. Studies primarily focusing on optimism and pain can be supposed to more accurately measure the two variables of interest. In experimental and clinical-longitudinal designs, confounding variables can be better controlled by context manipulation or recording temporal relationships.

The higher percentage of beneficial associations with increasing age of participants may be explained by a model proposed by Jylhä et al.[102]. The authors assume that self-rated health results from an evaluation process, incorporating both physical health factors and additional factors such as chronological age or health expectations. Furthermore, according to the model, the relative importance of these evaluation criteria changes with age. Self-rated health in older people could reflect to a higher degree psychological adaptation to decreasing health than in younger people[103]. Similar processes might be at work in pain reports. In higher age, the relative importance of psychological processes such as appraisal or social comparison (for example, “It is normal to have pain at this age”, “Given my high age, my pain is relatively low”, etc.) – which are in turn influenced by optimism – could become bigger compared to that of actual physical symptoms in predicting pain reports. These assumptions gain great plausibility because very similar phenomena have been repeatedly found for the prediction of self-rated health[17-19].

65 of the 69 studies of this review were published after 2000 i.e. within a relatively short time span. Therefore, we cannot rule out that the age effect we found is in fact a cohort effect, i.e. not caused by the age of participants, but by differences between earlier and later-born cohorts, for example as regards lifestyle, environmental conditions, values or health/disease definitions[17]. Apart from that, the age effect we found could, as far as clinical

studies are concerned, simply result from either a different pain duration or from different clinical conditions represented in the respective age groups: in our analysis, significant relations were most likely found with post-operative pain (beneficial associations in 80% of the respective studies) and rheumatoid diseases (75%, compared to 71% in cancer pain and 60% in musculoskeletal pain); all but two studies with an average age of above 60 years (k=15 of 17) belong to either one of these two categories. Another possible explanation is that if individuals experience little pain from early on, this could in turn diminish their expectations of future harm and thus increase their optimism, which again would lead to even less pain experience. Over decades, these reciprocally intensifying effects could cumulate and stabilize the benefits of optimism at a high level. However, the fact that experimental studies revealed a higher percentage of significant beneficial associations even though their participants were younger than those in clinical studies (76.9% of laboratory studies had an age average below 30 years, compared to only 8% of clinical studies) casts some doubt on this assumption.

While previous research supports the moderating role of sex in that a stronger protective effect of optimism on health-related variables was found for men in general (for example in mortality, see Giltay et al., Peterson et al.[104,105]), only one of the 69 studies included in the present review[49] explicitly investigated sex differences of the optimism-pain relation: they detected a beneficial association for women and no association for men. Future studies should test for sex as a moderator variable.

Mechanisms of the optimism-pain relation:

Geers et al.[93] propose the explanation that optimists are not generally less reactive to pain stimuli, which indeed could be highly dysfunctional in certain situations when detecting and monitoring pain is crucial. They assume that instead optimists are more flexible in coping

with pain than pessimists: they might be generally inclined to focus their attention on the positive aspects of a situation. Whenever it becomes apparent that certain stimuli (e.g., pain cues) are of relevance for their well-being and require their action, however, they could switch to an "approach mode" of problem-focused coping and face the pain, as described in Garofalo's[8] model for chronic pain.

It is thus conceivable that two different mechanisms are at work in experimental vs. clinical studies: healthy optimists who are confronted with an experimental pain induction are aware that the noxious stimuli are not harmful and will be over soon. It is likely that they therefore divert their attention from these negative features of the situation and subsequently report less pain. Corroborating this assumption, Peters et al.[106] found in an eye-tracker study that optimists tended to turn away from angry faces and gazed longer at joyful faces. Facing a serious threat to their well-being, on the contrary, such as an operation or cancer, the same optimists *focus* on pain and its context instead of withdrawing from it. They take steps to tackle the problem (cf. Luo et al.[107] for a study on optimism and skin cancer information) in the sense of the approach-style coping as described above[9]. Unlike pessimists they still expect there are things they can do to improve their condition.

However, this problem-focused coping, based on the optimistic expectations that by trying hard pain will decrease, might not be unconditionally functional in people confronted with a *chronic* or malignant illness that holds little or no improvement over the years. When there is not much one can do about one's condition, strategies like acceptance and distraction are more suitable to maintain a high quality of life[108]. Indeed, in another study by Saariaho et al.[71] optimism was associated with active coping, which in turn had positive effects on chronic pain, impairment and functioning. Active coping is conceptually different from the above-mentioned approach or problem-focused coping in that it does not aim at eliminating

the problem (in this case, the pain or pain-related illness) but instead – much like acceptance strategies – aims at staying active and maintaining activities and well-being *despite* the pain. Furthermore, optimists have been reported to have the highly adaptive flexibility to switch to emotion-focused coping (including acceptance, seeking emotional support or positive reinterpretation) as soon as it becomes clear that the situation cannot be changed[13]. Thus, in chronic pain conditions, optimism may not be helpful anymore to lower pain, but it can still be of benefit for functioning and well-being.

Limitations:

There are some limitations as to the generalizability of our conclusions and thus to the informative value of this review.

As mentioned above, comorbidity and pain medication – two factors that strongly influence pain experience – have not been sufficiently documented and accounted for in a large part of the studies on patients. If they differ between optimists and pessimists, results could be distorted.

Besides, despite the high percentage of beneficial associations, one must consider that within the same study, the significance of these associations often tended to disappear as soon as more complex statistical models such as multivariate or hierarchical linear regression analyses were computed. This might partly be due to the reduced statistical power of complex models integrating several different variables. It is also conceivable, though, that optimism accounts for less incremental variance as soon as correlated variables are added to the model i.e. that there is no significant unique contribution of optimism in predicting pain. While there is evidence that the association of optimism with pain is independent of affect[39] and social desirability[93], several other factors are possibly correlated with optimism. In some studies[50,52,83], optimism reached significance when entered alone or

early in the model, but did not explain significant additional variance as soon as other variables (e.g. control and benefit appraisals, self-efficacy, social support) were entered simultaneously or even before. It remains unclear whether any of these variables are mediators of the optimism-pain relation i.e. whether optimism works through these mechanisms, or only moderators. In our descriptive analysis, we could not account for these possibilities and each result was weighted equally, independent of the statistical approach which was employed.

One must also take into account that our descriptive analysis was based on the percentage of significant effects. As we do not have detailed information on the power and robustness of the statistical tests employed in most studies, it is likely that both alpha and beta errors are contained in our sample of studies. We therefore recommend to especially consider effect sizes in future quantitative reviews.

Similarly, the percentage of significant associations between optimism and pain might be over-estimated if - due to publication bias - non-significant results were less likely to be published.

Even if optimism is measured at an earlier time than the pain experience (e.g. pre-operatively), and even in studies with adequate control groups, one cannot be entirely sure about the causality of the optimism-pain relation: it is also conceivable that a general preparedness for experiencing and coping with pain – be it due to biological or psychological predispositions or due to a sufficient "immunization" by gradual exposure and subsequent adaptation to pain in the past – has, over the years, resulted in a high level of dispositional optimism, which in turn will dampen future pain experiences. Thus, a reversed causality from little pain to high optimism cannot be ruled out. In consequence, lower levels of optimism in clinical pain cohorts[8,109] could either arise from the fact that less optimistic

individuals are more likely to develop pain or from the tendency of patients' optimism to be dampened as a result of their increased pain vulnerability, existing already before the development of the clinical pain condition. Only some studies preclude this latter possibility by controlling for baseline symptoms or, as far as experimental designs are concerned, by manipulating optimism. Lastly, there could be third variables which substantially influence both pain and optimism reports, as for example response biases like a tendency towards positive statements. In consequence, we cannot derive definitive conclusions regarding causality from this review. The findings should cautiously be interpreted in terms of correlation.

While the focus of this review was on pain *experience*, one must keep in mind that especially in chronic pain this is not the only relevant pain outcome factor. Even when optimism does not positively affect pain intensity in itself, optimists could still benefit in other respects, as for example in adjustment to pain[110], mood or goal-directed efforts[111].

Given the heterogeneity of the retrieved studies in terms of design and measures (especially pain measures[112]), it was not possible to perform quantitative analyses including all of them. The present work may, however, be useful as a basis for future meta-analytic evaluations as it provides an overview of the variety of approaches and variables, which might be used to derive and answer more specific research questions.

Lastly, while we were obliged to focus on those moderating variables for which sufficient data were provided, it would be interesting to examine the role of further demographic and clinical variables such as, for example, ethnic background or pain duration, as soon as a critical number of studies will have become available.

Outlook and clinical implications:

The review provides suggestions for plausible mechanisms of the optimism-pain relation and likely moderating variables. These require explicit testing in future studies.

The manipulation of optimism – by means of future thinking exercises or semantic priming as, for example, in Fosnaugh et al.[21] – is a chance to explain causality and to develop clinical interventions. So far, the *Best-Possible-Self*-technique seems to be the only one to have been applied in the pain context.

Although in some subdomains studies are still missing (for example, clinical studies applying an optimism manipulation), given the retrieved material and the number of studies with sufficiently homogenous outcome measures, we propose that the time is ripe for a meta-analysis. It seems reasonable that if a significant association of optimism with pain exists, this association is more likely to be detected in studies with high study/publication quality, which is why future research should be especially concerned with the mentioned quality criteria.

Furthermore, while our review was necessarily limited on pain *experience* in the narrow sense, we recommend to enlarge future research to the above-mentioned other pain-related outcomes such as cognitive or emotional adjustment to pain or functional disability. These might reveal differential relations with optimism and thus provide further interesting insights into the optimism-pain research.

As shown in this review, optimism might be a powerful resilience factor against pain. Therefore, enhancing optimism could help in reducing acute pain experience as well as in preventing the transition to chronic pain. A recent meta-analysis[113] indicates that optimism can indeed be increased by psychological interventions in both clinical and healthy samples.

Effect sizes were bigger when applying the BPS compared to other optimism interventions (for example cognitive-behavioral techniques) and when interventions were provided in person instead of online. While therapeutic short-term effects have been shown to be very likely,evidence for long-term effects is still scarce. Therefore, clinical research should focus on how to preserve and stabilize the short-term optimism effect for longer action. Meevissen et al.[114] recently succeeded in creating longer-term changes in optimism in healthy individuals through an intensive optimism-fostering intervention. Another three studies[115,116,117], which trained optimism by combining the above-mentioned *Best-Possible-Self* imagery and writing technique with other positive psychology-exercises, found increased optimism for up to six months and promising results on well-being in chronic pain patients. This gives reason to hope that similar interventions may in future be used as part of the treatment of pain, possibly selectively in individuals "at risk", i.e. low in dispositional optimism.

Conclusion

The present analysis gives reason for assuming a beneficial association of optimism with pain experience. Studies with a presumed higher validity provided a higher percentage of beneficial associations. Significant associations between optimism and pain were more frequently found in older participants. Further research is needed to illuminate causal relations and to suggest evidence-based clinical applications of optimism-fostering interventions.

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Table 1: Studies comprised in the review

	Authors (year)	sample size	age			type of pain (pain-causing method/event/medical condition)		optimism measure	design			result (type of association)			quality points	among primary objectives
			Ø <30	Ø 30-60	Ø >60	*experimental*	*clinical*		*cross- sectional*	*longitudinal*	*experimental*	*beneficial*	*zero*	*non-beneficial*		
*34	Achat et al. (2000)	659	?	?	?	-	x	LOT	x	-	-	x	-	-	6.5	x
35	Airila et al. (2014)	360		x		-	multiside musculoskeletal pain	single item	-	x	-	-	x	-	7	?
36	Allison et al. (2000)	88		x		-	head and neck cancer	LOT	-	x	-	x	-	-	8	x
37	Bediako et al. (2011)	83		x		-	sickle-cell disease	LOT-R	x	-	-	x	-	-	8	-
38	Bentsen et al. (2008)	101		x		-	chronic low back pain after spinal fusion	single item	x	-	-	x	-	-	7.5	x
39	Benyamini (2005)	120			x	-	osteoarthritis	LOT	-	x	-	x	-	-	9	-
40	Booth-Kewley et al. (2014)	134	x			-	musculoskeletal injuries	LOT-R	-	x	-	-	x	-	9	x
89	Boselie et al. (2014)**	74	x			cold pressor task	-	LOT-R; FEX	-	-	x	-	x	-	8	-
41	Brewer et al. (2007)	91	x			-	anterior cruciate ligament reconstruction	LOT-R	-	x	-	-	x	-	8	x
42	Bruce et al. (2012)	338		x		-	breast cancer surgery	LOT SF	-	x	-	x	-	-	8	x
43	Bruce et al. (2014)	338		x		-	breast cancer surgery	LOT SF	-	x	-	x	x	-	8	x
44	Callahan (2000)	163		x		-	temporomandibular disorders	LOT	x	-	-	x	-	-	7.5	x
45	Chamberlain et al. (1992)	57			x	-	surgery for joint replacement	LOT	-	x	-	x	x	-	8	x
46	Chrisler et al. (2006)	92	x			-	menstrual pain	LOT	x	-	-	x	-	-	7	-
47	Coronado (2017)	63		*x*		-	shoulder pain	LOT-R	-	*x*	-	-	*x*	-	8.5	*x*
90	Corsi et al. (2017)	46	*x*			heat pain	-	LOT-R	-	-	*x*	-	*x*	-	9.5	*x*
100	Costello et al. (2002)	48	x			ischemic pain	temporomandibular disorders	LOT	-	-	x	x	x	-	9.5	x
91	Dimova et al. (2015)	110	?	?	?	capsaicin	-	LOT-R	-	-	x	x	-	-	10.5	x
48	Ferreira et al. (2007)	72			x	-	osteoarthritis	LOT-R	x	-	-	x	-	-	7.5	x
49	Fishbain et al. (2001)	637	?	?	?	-	myofascial pain syndrome	PAS	x	-	-	x	x	-	7	-
50	Fitzgerald et al. (1993)	49			x	-	coronary artery bypass surgery	LOT	-	x	-	x	x	-	7	x
92	Geers et al. (2010)	116	x			cold pressor task	-	LOT-R	-	-	x	x	-	-	9	x
93	Geers et al. (2008)	72	x			cold pressor task	-	LOT-R	-	-	x	x	x	-	9	x
101	Goodin et al. (2013) a)	100		x		heat	knee osteoarthritis	LOT-R	-	-	x	x	x	-	10	x
94	Goodin et al. (2013) b)	149	x			cold pressor task	-	LOT-R	-	-	x	x	x	-	11	x
51	Gramke et al. (2009)	648	?	?	?	-	day-case surgery	LOT	-	x	-	-	x	-	9	x
23	Hanssen et al. (2013)**	79	x			cold pressor task	-	LOT-R; FEX	-	-	x	x	-	-	8	x
95	Hanssen et al. (2014)	60	x			cold pressor task	-	LOT-R	-	-	x	x	x	-	8.5	x
52	Hetmann et al. (2015)	106			x	-	thoracotomy	LOT-R	-	x	-	x	-	-	9.5	x
96	Hood et al. (2012)	114		x		cold pressor task	-	LOT-R	-	-	x	x	-	-	9.5	x
53	Hoofwijk et al. (2015)	908		x		-	outpatient surgery	4 items of LOT	-	x	-	x	-	-	9.5	x
54	Katz et al. (2016)	164		x		-	inflammatory bowel disease	LOT-R	x	-	-	-	x	-	9	-
55	Kurtz et al. (2008)	214		x		-	during chemotherapy	LOT	-	x	-	x	-	-	8	x
56	Lam et al. (2012)	253		x		-	nasopharynegeal cancer	single item	-	x	-	-	x	-	7	-
57	Langbach et al. (2016)	265		x		-	hernia and hernia repair	LOT-R	-	x	-	x	x	-	9.5	x
58	Lau et al. (2008)	5163		x		-	x	1 item of LOT	-	x	-	x	-	-	7.5	x
59	Long et al. (1993)	200			x	-	rheumatoid arthritis/ osteoarthritis	LOT	x	-	-	-	x	-	8.5	-
60	Mahler et al. (2000)	215			x	-	coronary bypass surgery	LOT	-	x	-	x	-	-	10	x
97	Morton et al. (2009)	62	x			laser heat	-	LOT-R	-	-	x	x	x	-	8.5	x
61	Mueller et al. (2003)	148		x		-	fibromyalgia	4 items	x	-	-	-	x	-	7	-
62	Pence et al. (2007)	27	x			-	sickle-cell disease	LOT-R	-	x	-	-	x	-	8.5	-
63	Peters et al. (2007)	625		x		-	surgery	LOT	x	-	-	-	x	-	8	x
64	Peters et al. (2010)	401		x		-	elective surgery	LOT	-	x	-	-	x	-	9	x
65	Pinto et al. (2015)	252		x		-	hysterectomy/ joint arthroplasty	LOT-R	-	x	-	x	x	-	7	x
66	Pinto et al. (2017)	124			x	-	hip and knee arthroplasty	LOT-R	-	x	-	x	x	-	9.5	x
67	Pinto et al. (2014)	110			x	-	major joint arthroplasty	LOT-R	-	x	-	x	-	-	10	-
68	Pinto et al. (2013)	124			x	-	primary total hip/ knee arthroplasty	LOT-R	-	x	-	x	-	-	9	x

69	Powell et al. (2012)	135			x	-	inguinal hernia repair surgery	2 items of LOT	-	x	-	x	-	-	7.5	x
70	Pulgar et al. (2015)	69	?	?	?	-	hematological cancer	LOT	x	-	-	-	x	-	7	x
71	Ramírez-Maestre et al. (2012)	98		x		-	chronic pain	LOT	x	-	-	-	x	-	7.5	x
72	Ronaldson et al. (2014)	197			x	-	coronary artery bypass graft surgery	LOT-R	-	x	-	x	x	-	9	x
73	Rosenberger et al. (2009)	180		x		-	arthroscopic knee surgery	LOT-R	-	x	-	x	x	-	9.5	x
74	Saariaho et al. (2011)	602		x		-	chronic pain	EMS	x	-	-	x	-	-	8	x
75	Sherman et al. (2013)	160			x	-	osteoarthritis	LOT-R	x	-	-	x	x	-	8	-
76	Singh et al. (2010)	1449			x	-	knee replacement	MMPI	-	x	-	x	-	-	8	x
77	Sipilä et al. (2009)	5696	?	?	?	-	temporomandibular disorders	LOT-R	x	-	-	x	-	-	8	x
78	Smith et al. (2008)	170			x	-	rheumatoid arthritis/ osteoarthritis	LOT-R	-	x	-	-	x	-	8	-
98	Smith et al. (2009)	47		x		heat and cold	-	LOT	-	-	x	x	x	-	8.5	x
99	Snyder et al. (2005)	116	x			cold pressor task	-	LOT-R	-	-	x	-	x	-	8.5	x
79	Söderlund et al. (1999)	104		x		-	whiplash associated disorders	LOT	x	-	-	-	x	-	7.5	x
80	Sorbi et al. (2006)	80		x		-	chronic pain	single item	-	x	-	x	-	-	8.5	x
81	Stessel et al. (2017)	1118		x		-	day surgery	4 items of LOT-R	-	*x*	-	*x*	-	-	9.5	-
82	Su et al. (2017)	320		x		-	temporomandibular disorders	LOT-R	x	-	-	x	x	-	7.5	*x*
83	Tennen et al. (1992)	54		x		-	rheumatoid arthritis	LOT	-	x	-	x	x	-	7.5	-
84	Treharne et al. (2005)	154		x		-	rheumatoid arthritis	LOT	-	x	-	x	x	x	8.5	x
85	Tsakogia et al. (2011)	96		x		-	chronic musculoskeletal pain	LOT-R	x	-	-	x	-	-	8	x
86	Wiesmann et al. (2014)	387			x	-	x	LOT	x	-	-	x	x	-	8	x
87	Wong et al. (2007)	334			x	-	lung cancer	single item	-	x	-	x	x	-	7	x
88	Wright et al. (2011)	89		x		-	chronic musculoskeletal pain	LOT-R	x	-	-	-	x	-	8	x

*numbers are identical to those by which the studies are designated in the text; **experimental optimism induction

Table 2: Quality index applied for the selected studies

category		*points*
sample size	small (n<50)	0.5
	medium (n= 50-100)	1
	large (n>100)	1.5
sex	not reported	0
	one sex only	0.5
	both sexes, not well-balanced	1
	well-balanced ratio (max. 40:60)	1.5
age	not well documented	0
	moderately well documented (e.g. range OR average)	0.5
	well documented	1
type of pain	unclear description	0
	sufficiently clear description	1
description of pain measure	unclear description	0
	sufficiently clear description	1
type of pain measure	health measure including a pain-item	0.5
	specific pain measure	1
measure of optimism	single item	0
	more than one item out of validated questionnaire	0.5
	validated questionnaire	1
medication	not reported	0
	moderately well specified	0.5
	precisely described	1
comorbidity	not reported	0
	moderately well specified	0.5
	precisely described	1
design	cross-sectional	0.5
	longitudinal/experimental	1

Table 3: Summary of types of pain and pain measures in the 69 reviewed studies

	clinical pain	*k*	**experimental pain**	*k*
type of pain	musculoskeletal pain	10	cold pressor task	8
	arthritis pain	10	laser heat pain	1
	post-operative pain	17	thermode heat pain	3
	cancer pain	7	chemical pain	1
	other	11	ischemic pain	1
pain measure	questionnaires		rating of intensity	11
	• SF-36	7	rating of unpleasantness	4
	• MPQ(-SF)	5	pain threshold	4
	• BPI(-SF)	7	tolerance threshold	6
	• illness-specific (f.ex. RADAR)	12	CPM & TS	2
	rating scales	24	habituation	1
			placebo analgesia	2

Figure 1: Flow chart illustrating the selection of studies for the review according to the PRISMA guidelines

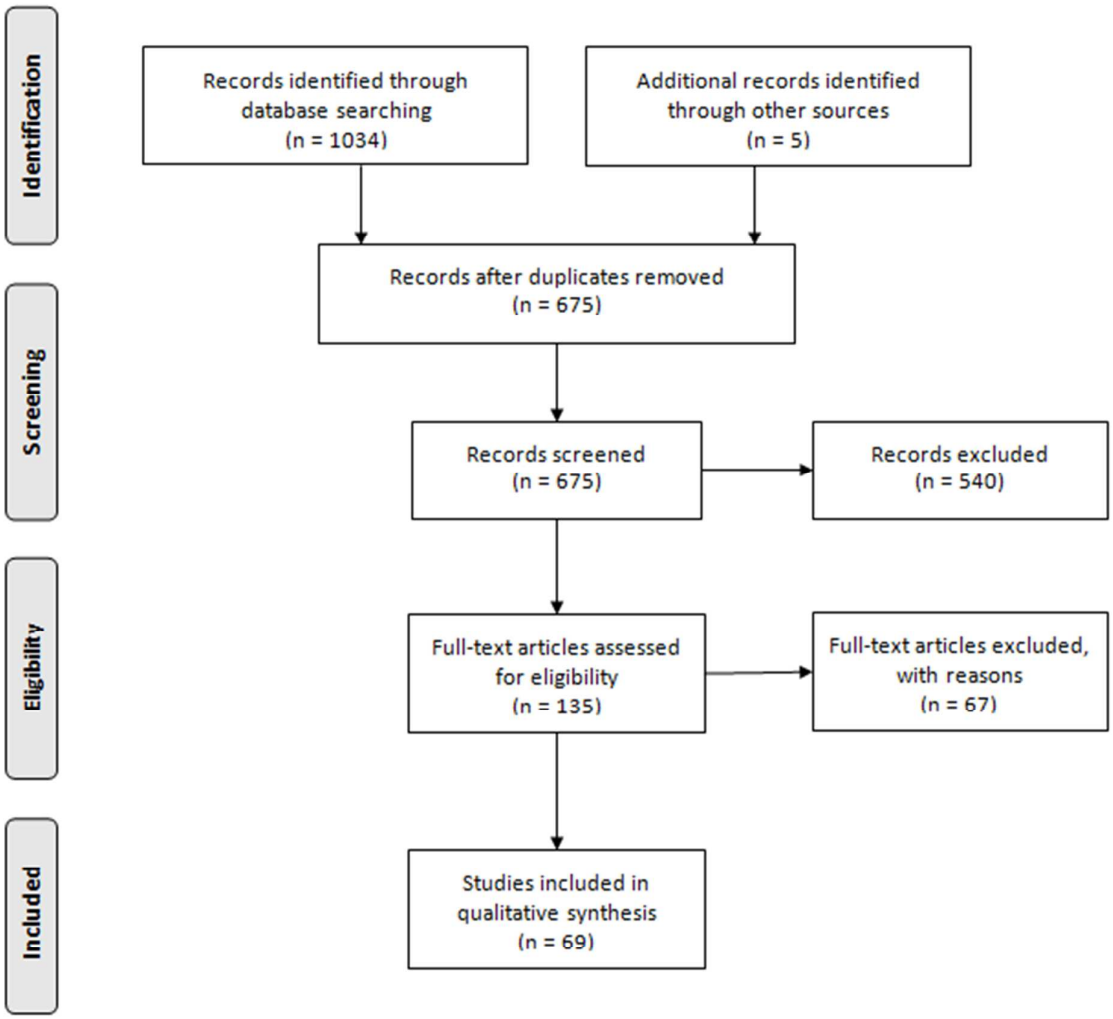
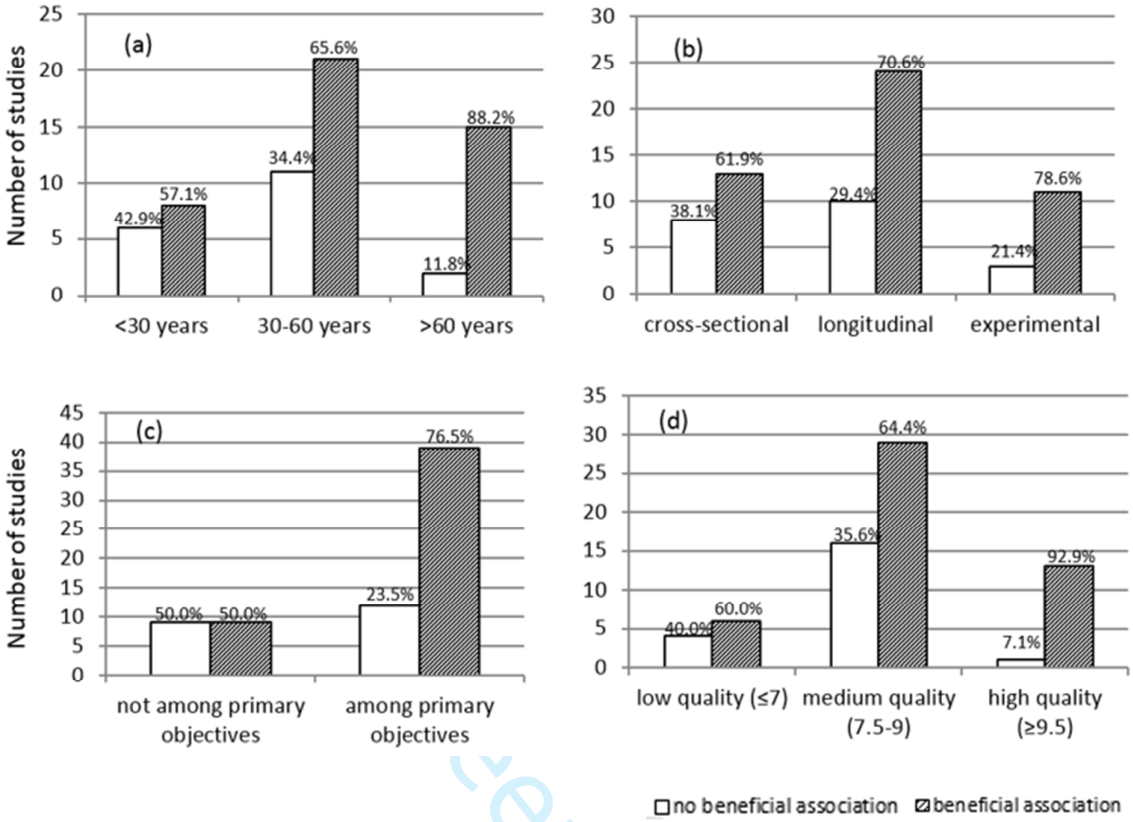

Identification
Screening
Eligibility
Included
Records identified through database searching (n = 1034)
Additional records identified through other sources (n = 5)
Records after duplicates removed (n = 675)
Records screened (n = 675)
Records excluded (n = 540)
Full-text articles assessed for eligibility (n = 135)
Full-text articles excluded, with reasons (n = 67)
Studies included in qualitative synthesis (n = 69)

Figure 2: Possible moderating variables of the optimism-pain relationship: age (a), type of design (b), level of quality (c), relevance of the relation within the study (d)



Supplement 1: Algorithm applied for the database-search (conducted in May, 2016)

(pain OR pain perception OR pain unpleasantness OR pain experience OR pain threshold OR pain sensitivity OR pain intensity OR noxious OR noxious stimulus OR noxious stimuli OR noxious stimulation OR placebo analgesia OR endogenous pain processing OR endogenous pain inhibition OR temporal pain summation OR Conditioned pain modulation OR clinical pain OR chronic pain OR experimental pain OR pain rating OR nocebo OR endogenous analgesia OR DNIC) AND (optimism OR induced optimism OR optimistic OR dispositional optimism OR situational optimism OR pessimism) NOT (animals OR non-humans OR children)

Supplement 2: Instructions for the *Best-Possible-Self (BPS)* optimism induction and for the *Typical-Day (TD)* control condition

- BPS condition:

  Thinking about your best possible self means that you imagine yourself in the future, after everything has gone as well as it possibly could. You have worked hard and succeeded at accomplishing all the goals of your life. Think of this as the realization of your dreams, and that you have reached your full potential.

- TD condition:

  Thinking about your typical day means that you take notice of ordinary details of your day that you usually don't think of. These might include particular classes or meetings you attend to, people you meet, things you do, typical thoughts you have during the day. Think of this as moving through your typical day, hour after hour.

Anhang 2

Basten-Günther, J., Kunz, M., Peters, M., & Lautenbacher, S. (2021). The effect of optimism on the facial expression of pain: Implications for pain communication. *European Journal of Pain*, *25*(4), 817-830. Doi: 10.1002/ejp.1712

DOI: 10.1002/ejp.1712

ORIGINAL ARTICLE

EJP European Journal of Pain

The effect of optimism on the facial expression of pain: Implications for pain communication

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Abstract

Background: There is a broad range of evidence on optimism dampening the pain experience, as assessed by subjective self-report. Facial expression of pain conveys supplementary information about the pain experience, is an integral part of pain communication and assists psychosocial pain coping. Nevertheless, the effect of induced optimism on facial activity during pain has to our knowledge not been examined.

Methods: In our experiment, 40 healthy participants underwent two blocks of thermal stimulation containing phasic non-painful and painful stimuli. Between the two blocks, the *Best Possible Self* imagery and writing task was performed to induce situational optimism, while a control group wrote about their typical day. Facial activity and self-report ratings of intensity and unpleasantness were recorded. Facial activity was analysed using the Facial Action Coding System.

Results: The optimism manipulation was successful in increasing state optimism. It did not affect self-report ratings, but resulted in a stronger facial expression of pain, caused especially by increases in Action Units 4 (furrowed brows) and 6_7 (narrowed eyes).

Conclusions: All Action Units, which were affected by the optimism induction, are known to be prevalent during pain stimulation. The increase in facial expression might reflect reduced inhibition of pain communication in temporarily optimistic participants. Optimism might lead to expecting positive and helpful reactions from others and, by that, to great readiness to elicit these reactions by non-verbal social behaviour.

Significance: This study is the first to indicate that state optimism increases the facial expression of pain as a social signal for help and empathy without concomitant changes in the subjective pain experience.

1 | INTRODUCTION

Optimism is commonly defined as positive expectancies concerning the future (Scheier & Carver, 1985). Positive effects of optimism on various health-related outcomes have been demonstrated (e.g. well-being, cancer progression, cardiovascular and immune functioning, mortality; for overviews, see Avvenuti et al., 2016; Carver et al., 2010; Forgeard & Seligman, 2012; Rozanski et al., 2019; Scheier & Carver, 2018). There are numerous reports of optimism's dampening effect both on experimental and on clinical pain as well as on pain-related distress (Basten-Günther et al., 2019; Garofalo,

2000; Geers et al., 2008; Goodin & Bulls, 2013). The underlying mechanisms of this relationship are not yet fully clear. There are hints that optimism leads to lower pain catastrophising, which in turn decreases pain reports (cf. Pulvers & Hood, 2013). Furthermore, optimism might be associated with adaptive coping (problem- or emotion-focused coping, cf. Solberg Nes & Segerstrom, 2006) and in turn, diminish pain experience. Alternatively, optimists could tend to divert their attention from the negative aspects of a situation (Peters et al., 2016) and subsequently report less pain.

While a large part of previous studies has investigated the association between dispositional i.e. trait optimism and pain, there are more recent attempts to manipulate state optimism both experimentally and as a clinical intervention. These approaches might be helpful to demonstrate causality in the optimism-pain relation (Hanssen et al., 2013). One of the techniques to foster state optimism is the *Best-Possible-Self* task (*BPS*; King, 2001), an imagery and writing exercise which has proven successful in increasing optimism temporarily (Hanssen et al., 2013; Peters et al., 2010). Two previous studies have investigated the effect of the *BPS* task on experimental pain. One showed decreased pain ratings after the optimism induction (Hanssen et al., 2013), the other did not find an effect on self-reported pain intensity and conditioned pain modulation (Traxler et al., 2019).

Studying facial reactions during pain could provide new insights into the optimism-pain relationship. Facial reactions can be seen as an independent source of information as their intensities have been shown to be only weakly to moderately correlate with subjective pain ratings (Kunz et al., 2004). Several experimental studies have revealed that facial reactions to pain can be influenced by cognitive and affective factors such as fear of pain or pain catastrophising (Vervoort et al., 2008; Vlaeyen et al., 2009). Their function is the nonverbal communication of pain in order to warn the interaction partner or appeal for help and compassion as a way of psychosocial coping (Hadjistavropoulos et al., 2011; Sullivan et al., 2001). Consequently, facial expressions of pain also vary with the social context, i.e. they are enhanced in the presence of the partner and reduced in the presence of an unfamiliar person or in situations of social threat (Karmann et al., 2014; Karos et al., 2019). This might be one mechanism of action of optimism because optimism has been associated with more social support seeking and a greater real or perceived availability of social support (Brissette et al., 2002; Dougall et al., 2001). Accordingly, the facial expression of pain might be influenced by optimism independently from and additionally to the subjective experience of pain.

The effect of optimism on the facial expression of pain may be twofold. On the one hand, the facial expression of pain might be weakened after the induction of state optimism as a consequence of a decreased pain experience. On the other hand, since situational optimism is likely associated with increased trust in the social environment, readying individuals to manifest otherwise hidden signs of weakness and appeals for help, optimism may in contrast lead to the opposite, namely stronger facial expressions of pain. Thus, the aim of the present study was to decide which of the two theoretically derived, contrary effects of situational optimism on the facial expression of pain prevails.

2 | METHODS

2.1 | Participants

A total of 40 healthy, pain-free individuals (20 men and 20 women, ten from each decade between 20 and 60); mean [± *SD*] age 39.9 ± 13.5 years) participated in the current study. The participants were recruited via advertisements in the local newspaper (Bamberg, Germany). Exclusion criteria were current experience of acute or chronic pain, psychological or physical illnesses, pregnancy or pain-influencing medication. Participants were asked not to take alcohol or analgesic and psychotropic drugs on the day of the experiment and to postpone the appointment if pain occurred or if any pain influencing substances had to be taken on that day. All participants provided informed consent and received monetary compensation. The study protocol was approved by the ethics committee of the University of Bamberg (Bamberg, Germany).

2.2 | Procedure

2.2.1 | Design and general protocol

We conducted a randomized controlled trial. In a mixed-design, an experimental group receiving an optimism manipulation and a control group performing a neutral task (between-subject factor) were compared across two timepoints which acted as pre- and post-induction measurements (within-subject factor). Group assignment was randomized, and the two groups were balanced regarding age, sex, phase of the menstrual cycle and time of day of the session.

The experiment consisted of one session taking place at 1.30 p.m. for half of the participants and at 3.30 p.m. for the other half. After providing informed consent and filling out several questionnaires (Life Orientation Test-Revised: *LOT-R*; Future Expectancies Scale: *FEX*; Positive and Negative Affect Schedule: *PANAS*), participants underwent two identical blocks of thermal stimulation during which their facial activity, heart rate (results not reported here) and self-report ratings were recorded (Figure 1). During the pain blocks, the experimenter sat behind the subject and was not visible. In between the two pain blocks of stimulation, the experimental manipulation (optimism versus neutral imagery and writing

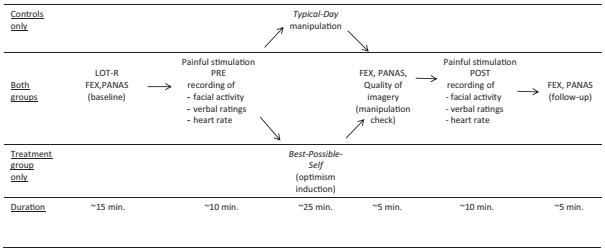

FIGURE 1 Overview of the general protocol of the experiment

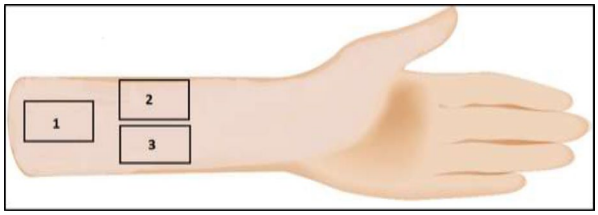

FIGURE 2 Positions of thermode during (1) threshold determination, (2) first block of stimulation (pre-measurement), (3) second block of stimulation (post-measurement). The upper edge of thermode at position 1 is located 1 cm distal from the elbow pit. Thermode at positions 2 (lateral) and 3 (medial) is located 1 cm distal from the lower edge of thermode at position 1. Illustration adapted from Mücke et al. (2014).

task) was executed (independent variable). The state questionnaires *FEX* and *PANAS*, which served as a manipulation check, were filled out three times in order to record changes in affect and situational optimism: before the first pain block (baseline), immediately after the BPS/TD intervention and after the second pain block (follow-up). After roughly 2 hr, the participants were thanked and debriefed and the session was concluded.

2.2.2 | Painful stimulation

Thermal stimulation was applied to three designated sites on the left volar forearm (see Figure 2) by a Peltier-based contact stimulation device (TSA-2001, Medoc, Israel) with a 30 mm × 30 mm contact thermode. To ensure that temperature intensities were perceived as painful but not too painful in all participants (to prevent floor as well as ceiling effects), temperature intensities were tailored to the individual pain threshold. Thus, heat pain thresholds were determined first, using the method of adjustment. Participants were asked to adjust a temperature starting from 35°C, using heating and cooling buttons, until they obtained a level that was barely painful. A constant press of the buttons produced a heating or cooling rate of 0.5°C/s. Following a familiarisation trial, there were four trials and the average of these four trials was used to constitute the threshold estimate. Following the assessment of pain thresholds, phasic heat stimuli (trapezoid form, 5 s [plateau]; rate of change: 4°C/s; baseline temperature: 38°C; inter-stimulus intervals of 15 s) were applied to the volar forearm (different sites for the determination of threshold and the two blocks of stimulation, respectively). Two different stimulus intensities were applied; namely, painful (+3°C above the pain threshold) and non-painful (−1°C below the pain threshold) intensities. Including non-painful intensities and comparing non-painful and painful intensities allowed for the determination of which types of facial responses are specific for painful experiences. After three familiarisation stimuli (intensities: threshold, threshold +1°C, threshold −2°C), participants received two blocks of stimulation (one before and one after the experimental manipulation), which each consisted of 10 painful and 10 non-painful stimuli in the same random order.

2.2.3 | Optimism manipulation

In between the two blocks of heat stimulation, the experimental optimism induction was performed. Optimism was induced by BPS manipulation, a positive future thinking technique based on work by King (2001). The BPS task has been proven effective in increasing positive affect and positive future expectancies (Peters et al., 2010). Participants were instructed to carry out a writing and imagery exercise. Half of the participants were assigned to the BPS condition ($n = 20$), which required them to write about their life in the future where everything has turned out for the best. The other half of the participants were assigned to the control condition ($n = 20$), whose task consisted of writing about a typical day (TD). The instructions for BPS and TD were as follows (cf. Sheldon & Lyubomirsky, 2006).

- BPS condition:

Thinking about your best possible self means that you imagine yourself in the future, after everything has gone as well as it possibly could. You have worked hard and succeeded at accomplishing all the goals of your life. Think of this as the realization of your dreams, and that you have reached your full potential.

- TD condition:

Thinking about your typical day means that you take notice of ordinary details of your day that you usually don't think of. These might include particular classes or meetings you attend to, people you meet, things you do, typical thoughts you have during the day. Think of this as moving through your typical day, hour after hour.

Both manipulations had the same procedural format: participants were requested to think for 1 min about what to write, then to write uninterrupted for 15 min, followed by 5 min of imagining the story they had just been writing. Instructions were given both verbally and in writing. The manipulation check followed immediately by asking the participants to complete the FEX and PANAS a second time and to answer a questionnaire about the quality of their writing and imaginations (*Quality of imagery*, Peters et al., 2010).

2.2.4 | Questionnaires

Trait questionnaires

The validated German version (Krohne et al., 1996) of the *Life Orientation Test-Revised* (*LOT-R*; Scheier et al., 1994) was used to assess the level of dispositional optimism. The LOT-R has 10 items that are rated on a 5-point Likert scale, ranging from 0 ('strongly disagree') to 4 ('strongly agree'). There are three positively phrased items (optimism subscale), three negatively phrased items (pessimism subscale) and four filler items. A total trait optimism score is calculated over the six items with either positive or negative content after reversing the negatively phrased items. Internal consistency as measured by Cronbach's alpha was $\alpha = 0.76$.

State questionnaires

The *Future Expectancies Scale* (*FEX*; Hanssen et al., 2013) was administered to assess state optimism. A German translation of the questionnaire was used which has been translated in a standard 'forward-backward' procedure and used in a prior study by the authors (Peters et al., 2016). The FEX consists of 10 statements describing a positive future event and 10 statements describing a negative future event. Participants rated the likelihood that they will experience each specific event on a 7-point Likert scale, ranging from 1 ('not at all likely to occur') to 7 ('extremely likely to occur'). The FEX has previously been demonstrated to be responsive to optimism manipulations (Boselie et al., 2014; Hanssen et al., 2013). The subscores FEX positive and FEX negative were used for further analyses. Internal consistency at the three assessment times ranged from Cronbach's $\alpha = 0.89$ to $\alpha = 0.91$ for the subscale FEX positive and from $\alpha = 0.83$ to $\alpha = 0.87$ for the subscale FEX negative.

Mood was assessed with the *Positive and Negative Affect Schedule* (*PANAS*; Watson et al., 1988). The PANAS consists of 20 items measuring positive (10 items) and negative (10 items) affect. Participants indicate the degree to which a certain feeling is present at that moment on a 5-point Likert scale ranging from 1 ('not at all') to 5 ('extremely'). The subscores PANAS positive (PANAS_PA) and PANAS negative (PANAS_NA) were used for further analyses. For the PANAS, a validated German version was available (Glaesmer et al., 2008). Internal consistency at the three assessment times ranged from Cronbach's $\alpha = 0.86$ to $\alpha = 0.93$ for PANAS_PA and from $\alpha = 0.66$ to $\alpha = 0.83$ for PANAS_NA.

Quality of imagery

Two visual analogue scales (Peters et al., 2010) were used to rule out qualitative (in contrast to content-related) differences in participants' imagery between the BPS and the TD group. Participants were asked two questions which have been used in previous studies (Hanssen et al., 2013): 'How well could you imagine yourself in the situation you described in your writing' (not at all – extremely well) and 'How vivid were the pictures you imagined?' (not vivid at all – very vivid). A third VAS was administered to determine whether imagery in the BPS group was more positive than in the TD group: 'How negative or positive were your imaginations?' (very negative – very positive). This third question was meant to serve as an additional manipulation check as we wanted to rule out that imaginations and writing content were equally positive in the TD group as in the BPS group.

2.2.5 | Pain-related parameters

Facial activity

Participants' faces were videotaped throughout the heat stimulation. The camera was located approximately 1.5 m in front of the participant to allow for a frontal view. To prevent effects of social desirability on facial expressions, participants were told that the main focus of interest was heart rate measurement whereas video recordings served only for the control documentation of the regular procedure. To enable the offline segmentation of the videos, an LED light visible to the camera, but not to the participant, was lit concurrently with the 5 s heat stimuli, beginning when the target temperature was reached. To ensure that the face would always be upright and in a frontal view during stimulation, participants were asked to avoid movements and to look at the fixation cross on the computer screen in front of them which appeared during each plateau phase of heat stimulation. Participants were also instructed not to talk during heat stimulation. Facial expressions were coded from the video recordings using the Facial Action Coding System (FACS) (Ekman & Friesen, 1978), which is based on an anatomical analysis of facial movements and distinguishes 44 different 'action units' (AUs) produced by single muscles or combinations of muscles. A certified FACS coder (qualified by passing an examination given by the developers of the system) who was blind to the experimental conditions identified the frequency and the intensity (five-point scale) of the different AUs. Software designed for the analysis of observational data (Observer Video-Pro; Noldus Information Technology,

Netherlands) was used to segment the videos and to enter the FACS codes into a time-related database. Time segments of 5 s beginning just after the stimulus had reached the target temperature (time period during which the LED was lit) were selected for scoring. In total, 2 × 20 segments of heat stimulation (10 non-painful and 10 painful segments in both the first (pre, i.e. prior to the optimism manipulation) and the second (post, i.e. after the optimism manipulation) block) were analysed for each participant. For the purpose of necessary data reduction, AUs that represent similar facial movements were combined, as has been performed in previous studies without any loss of information (Kunz et al., 2008, 2012). Those combinations include AUs 1_2, 6_7, 9_10 and 25_26_27. In order to determine interrater reliability, five percent of the video segments, taken from both the experimental and the control group, including facial responses to both painful and non-painful stimuli during pre- and post-measurement were coded by a second certified observer also blind to the experimental conditions. Interrater reliability was calculated using the Ekman–Friesen formula (Ekman & Friesen, 1978; number of AUs agreed upon ×2 and divided by the overall amount of AUs coded). Interrater reliability was 0.83, which compares favourably with other research in the FACS literature (e.g. Karmann et al., 2019; Priebe et al., 2015).

Pain-relevant AUs were selected similar to the procedures developed in previous studies (e.g. Karmann et al., 2019; Kunz et al., 2007, 2008) using the following steps (see also Table 1): (a) AUs had to occur in more than 5% of the painful trials in at least one of the two groups during at least one of the two stimulation periods (pre and post) and (b) AUs had to be substantially more frequent during painful than during non-painful trials (Cohen's *d* effect size of $d \geq 0.5$ for this frequency difference; the effect sizes fulfilling this criterion are marked in bold in Table 1) in at least one of the two groups during at least one of the two stimulation periods. The resulting subset of pain-relevant AUs is consistent with previous findings regarding facial responses to pain (Kunz et al., 2019) and consists of the following AUs: AU 1_2 (raised eyebrows), AU 4 (furrowed brows), AU 6_7 (narrowed eyes), AU 9_10 (wrinkled nose and raise of the upper lip), AU 14 (dimpler) and AU 25_26_27 (opened mouth and jaw drop). Then mean AU-frequency and mean AU-intensity values were combined by multiplication (product terms) and averaged across all selected AUs to form a composite score. These composite scores were not distributed normally in any of the four experimental conditions (TD group: Kolmogorov–Smirnov $Z = 0.307$ (pre), $Z = 0.243$ (post); BPS group: $Z = 0.242$ (pre), $Z = 0.203$ (post); all $p < 0.05$). To avoid losing power by switching to non-parametric tests, we used square root transformed composite scores for all further analyses as has also been performed in previous studies (Karmann et al., 2014; Karmann et al., 2019; Kunz et al., 2012). These transformed data were normally distributed (TD group: Kolmogorov-Smirnov $Z = 0.169$ (pre), $Z = 0.138$ (post); BPS group: $Z = 0.128$ (pre), $Z = 0.128$ (post); all $p > 0.12$). In case of significant effects for the composite scores, analyses of the underlying single AUs were also conducted on the basis of square root transformed values.

TABLE 1 Facial Action Units (AUs) with a critical frequency of occurrence of more than 5% in painful segments

	Pre		Post		Pre		Post	
	%[a]	*d*	%	*d*	%	*d*	%	*d*
AU **1_2** (raised eyebrows)	24	**0.7**	19	**0.6**	20	0.4	26	**0.5**
AU **4** (furrowed brows)	28	**1.0**	15	**0.5**	48	**1.2**	52	**1.1**
AU **6_7** (narrowed eyes)	73	**0.9**	54	**1.9**	98	**1**	129	**1.2**
AU **9_10** (wrinkled nose and raise of the upper lip)	3	**0.5**	20	**1.6**	41	**1.1**	49	**0.8**
AU **25_26_27** (opened mouth and jaw drop)	21	**0.8**	21	**0.9**	49	**0.8**	59	**0.9**
AU **14** (dimpler)	10	0.4	9	0.1	11	**0.6**	11	−0.3

Note: Effect sizes for frequency differences between "non-painful" and "painful" trials are given. Medium and strong effect sizes ($d \geq 0.5$) are marked in bold. TD = typical day (control group), BPS = Best Possible Self (treatment group).

[a]% denotes the percentage of occurrence in the painful trials given separately for each group (BPS/TD) and each point in time (pre/post).

Self-report ratings

Participants were asked to provide self-report ratings of pain intensity (sensation scale) and pain unpleasantness (affect scale) of the thermal stimuli using two eleven-point electronic scales (0–10), which appeared horizontally on a computer screen after each stimulus. The endpoints of the scales were labelled with German adaptations of the designations proposed by Price et al. (1983): 'no sensation' and 'the most intense sensation imaginable' for the sensation scale, 'not bad at all' and 'the most intense bad feeling possible for me' for the affect scale. Participants were asked to rate stimulus intensity and stimulus unpleasantness proportionately (e.g. a number twice as big for intensity or unpleasantness twice as strong) by clicking with the mouse on 1 of the 11 numbered buttons. Ratings had to be given within 15 s after stimulus offset.

Heart rate

During the two blocks of heat stimulation, participants' heart rate was recorded continuously (recording device: SIGMA Plpro/Type Databox DB 36). Two electrodes were fixed on the upper and lower end of the patients' sternum, the ground electrode was placed on the hip. Data were not analysed and are not reported here because heart rate recording mainly served as a 'cover story' to disengage the subject's interest from the videotaping of facial responses.

2.2.6 | Statistical analyses

Sample description: In order to assess differences in demographic or baseline variables between the BPS and the TD group, independent samples *t* tests comparing the two groups were applied. Means with standard deviations were given for basic description.

Manipulation check: To control whether the optimism induction was successful, four separate 2 × 2 (time × group) repeated measures ANOVAs were computed, with either the PANAS or the FEX sub-scales as the dependent variable, experimental condition as fixed factor and time (pre-post) as within-subject factor. Independent samples t tests were used to investigate group differences as regards the quality of writing and visualisation.

Hypotheses testing: In order to examine the effect of the optimism induction on the pain parameters, we tested for a time × group interaction effect in separate 2 × 2 repeated measures ANCOVAs for the two dependent variables (self-report ratings and composite score of facial activity). Experimental condition was entered as fixed factor. All analyses were repeated with the LOT_R optimism sub-score as a covariate because it differed prior treatment between the BPS and TD groups (see the results). This did not change the results. In case of significance, post-hoc testing with *t* tests for dependent or independent samples was applied. For the description of the potential influence of trait optimism, correlational analyses between the *LOT-R* score and pain-related variables were conducted. In case of significant results for the composite score of facial activity, the underlying AUs were tested for their single contributions by *t* tests on changes from pre- to post-measurements (Δpost-pre; before and after optimism treatment).

Analyses were conducted with SPSS 24 and the alpha-level was 0.05 throughout.

3 | RESULTS

3.1 | Descriptive statistics

Means and standard deviations for demographic variables, heat pain threshold and dispositional optimism (*LOT-R*) are shown in Table 2. The LOT-R mean score is exactly the same as the population-based norm recently reported by Schou-Bredal et al. (2017). The heat pain threshold is very similar to the scores found in prior studies (for example, Horn-Hoffmann & Lautenbacher, 2015; Karmann et al., 2014).

	TD, *n* = 20	**BPS, *n* = 20**			
Sex, male	**10 (50%)**	**10 (50%)**	***t*-test for independent samples (TD versus BPS)**		
	Mean (*SD*)	**Mean (*SD*)**	***t*(38)**	***P***	***d***
Age (years)	40.50 (11.69)	40.20 (12.60)	0.08	0.94	0.03
Pain treshold (°C)	46.09 (2.53)	45.45 (1.83)	0.93	0.36	0.29
LOT-R	16.40 (3.17)	18.05 (4.06)	1.43	0.16	0.45
LOT-R optimism subscale	9.70 (1.98)	8.40 (2.09)	2.02	0.05*	0.64
LOT-R pessimism subscale	4.00 (1.69)	3.65 (2.75)	0.48	0.63	0.15

TABLE 2 Demographics, heat pain threshold and trait optimism.
BPS = best possible self (treatment group); TD = typical day (control group)

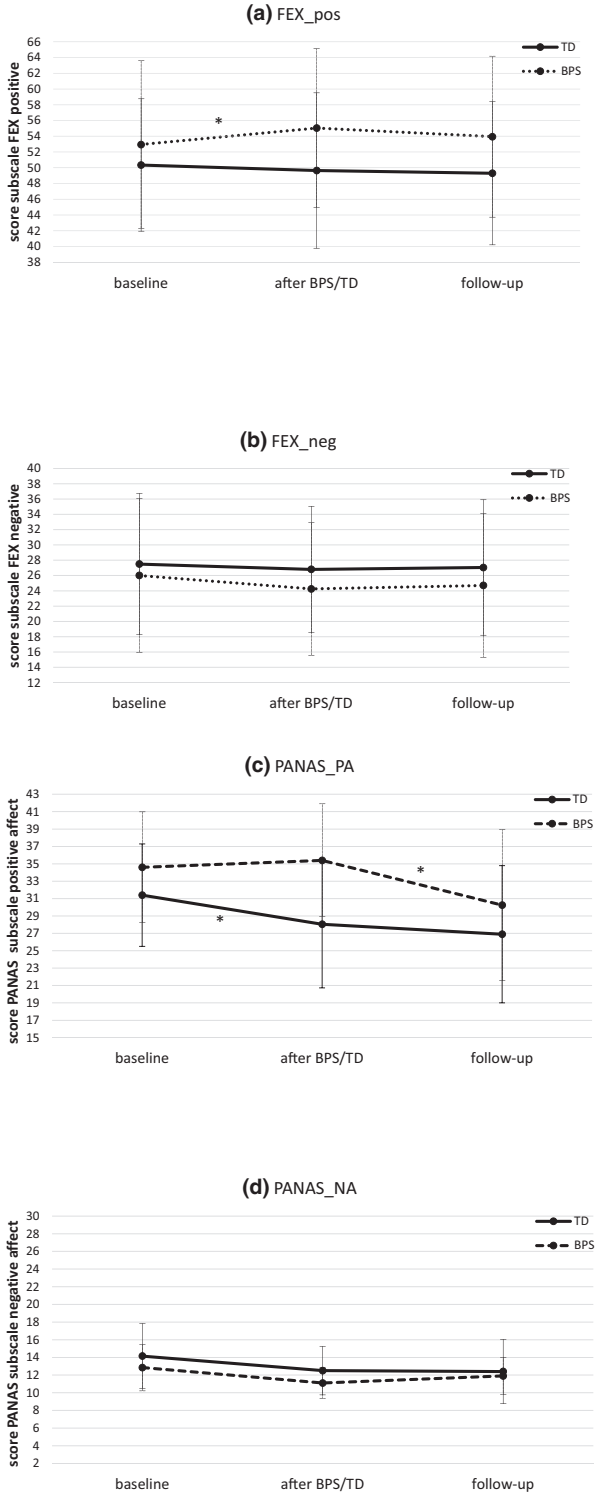

FIGURE 3 Mean values for state optimism (FEX_pos (a) and FEX_neg (b)) and positive/negative affect (PANAS_PA (c) and PANAS_NA (d)) at baseline, after the experimental manipulation and at follow-up at the end of the experiment. Error bars represent standard deviations. TD = Typical day, BPS = Best Possible Self. *significant contrast ($p \leq .05$) between the respective times of assessment in within-condition repeated measures ANOVA

The BPS and TD groups did neither significantly differ in their pain threshold nor in any demographic, trait or baseline state variable except for the optimism subscale of the *LOT-R*, where the TD group scored significantly higher (medium effect size).

Of the 20 female participants, five took oral contraceptives, five were post-menopausal and one participant had undergone hysterectomy. Of the remaining nine, three were in the follicular, three in the periovulatory and three in the luteal phase of their menstrual cycle at the time of the experiment. There were no significant differences between BPS and TD groups regarding the intake of contraceptives or the distribution of menstrual phases

3.2 | Influence of optimism induction

3.2.1 | Effects on mood and cognition (manipulation checking)

There was a significant, medium-sized, time x group interaction effect for PANAS_PA (subscale positive affect; $F(2,76) = 3.89$, $p = 0.03$, $\eta p^2 = 0.09$) and FEX_pos (subscale positive future expectancies; $F(2,76) = 3.07$, $p = 0.05$, $\eta p^2 = 0.08$). Within-condition analyses of repeated measurements with planned contrasts were performed to compare changes in these scales between the pre-manipulation (baseline) and the post-manipulation assessment and between the pre-manipulation and the follow-up assessment at the end of the experiment. As illustrated in Figure 3, results indicated that in the BPS condition (optimism induction), FEX_pos was significantly larger at the post-manipulation assessment ($F(1,19) = 6.5$, $p = 0.02$, $\eta p^2 = 0.255$; large effect size) but not at the follow-up assessment at the end of the experiment ($F(1,19) = 1.7$, $p = 0.20$, $\eta p^2 = 0.083$) compared to the pre-manipulation (baseline) assessment, respectively. In the TD group, there were no differences between the three assessments. Corresponding analyses for the PANAS_PA scale showed a significant decrease of positive affect in the TD group at the post-manipulation and follow-up assessments compared to baseline (post-manipulation: $F(1,19) = 7.6$, $p = 0.01$, $\eta p^2 = 0.287$; follow-up: $F(1,19) = 14.2$, $p = 0.001$, $\eta p^2 = 0.427$; both large effect sizes) whereas positive affect in the BPS group remained stable directly after the manipulation but was only significantly lower compared to baseline at the follow-up assessment (post-manipulation: $F(1,19) = 1.2$, $p = 0.29$, $\eta p^2 = 0.058$; follow-up: $F(1,19) = 10.1$, $p = 0.005$, $\eta p^2 = 0.348$, large effect). There were no significant differences between the three assessment times in the negative subscales of FEX and PANAS (cf. Figure 3).

Given the relative increases in situational optimism and positive affect directly after the BPS treatment, leading in each case to large effects, we can assume that the optimism manipulation was successful.

The BPS and the TD groups did not significantly differ in the VAS (0-100mm) about the quality and the vividness of their imaginations ('how well could you imagine yourself in the situation you described in your writing': BPS: $M = 77.35$, $SD = 15.09$, TD: $M = 74.05$, $SD = 21.75$; $t(38) = 0.56$; $p = 0.58$; $d = 0.18$ and 'how vivid were the pictures you imagined?': BPS: $M = 77.15$, $SD = 22.73$, TD: $M = 69.25$, $SD = 22.09$; $t(38) = 1.12$; $p = 0.27$; $d = 0.35$). This is in accordance with prior research (Hanssen et al., 2013). On the third question asking the emotional valence ('how negative or positive were your imaginations?'), the BPS group scored as expected significantly higher than the TD group (BPS: $M = 86.60$, $SD = 14.73$, TD: $M = 61.15$, $SD = 25.09$; $t(38) = 3.91$, $p < 0.005$, $d = 1.24$, *large effect size*).

3.2.2 | Effects on pain (hypotheses testing)

Ratings of painful stimuli

As shown in Table 3, the 2 × 2 repeated measures ANCOVAs did not show any significant effects on ratings, neither on ratings for stimulus intensity nor on ratings for stimulus unpleasantness. This means that there was no effect of induced optimism on subjective pain experience (Figure 4).

3.2.3 | Facial activity

As regards the composite score, the 2 × 2 repeated measures ANCOVA showed that the time × group interaction effect reached significance (see Table 3). The square root transformed composite scores did not significantly differ between BPS and TD group in the pre-measurement ($t(38) = 1.35$, $p = 0.185$, $d = 0.25$; *small effect*) but indicated significantly more facial activity in the BPS group than in the TD group in the post-measurement ($t(38) = 2.28$, $p = 0.028$, $d = 0.68$; *medium to large effect*) (see Figure 5). These findings suggest a relative augmentation of pain-related facial activity after the optimism induction.

In order to find out which of the pain-relevant AUs contributed to the augmentation in facial activity indicated by the composite score, we computed, separately for each of the six underlying Action Units (using square root transformed values), change scores (Δpost-pre) and conducted *t* test for independent samples to compare the difference in changes between the BPS and TD groups. As can be seen in Figure 6, facial responses decreased during the post-testing in the TD group (this was especially apparent for AU 4). In contrast, the BPS group showed more stable facial responses to pain in the pre- and post-measurements, with one exception, namely AU 6_7 which

TABLE 3 Results of the ANCOVAs with the factors "condition" (between-subjects, levels: BPS and TD), "time" (within-subject, levels: pre and post) and the covariate "dispositional optimism (*LOT-R*)" for all pain-related variables

	Condition	Time	LOT-R	Condition x time	Time x LOT-R
Stimulus intensity	$F(1,37) = 2.935$; $p = 0.095$; $\eta p^2 = 0.073$	$F(1,37) = 0.535$; $p = 0.469$; $\eta p^2 = 0.014$	$F(1,37) = 0.056$; $p = 0.814$; $\eta p^2 = 0.002$	$F(1,37) = 0.007$; $p = 0.936$; $\eta p^2 = 0.000$	$F(1,37) = 2.431$; $p = 0.127$; $\eta p^2 = 0.062$
Stimulus unpleasantness	$F(1,37) = 1.671$; $p = 0.204$; $\eta p^2 = 0.043$	$F(1,37) = 0.778$; $p = 0.383$; $\eta p^2 = 0.021$	$F(1,37) = 0.456$; $p = 0.503$; $\eta p^2 = 0.012$	$F(1,37) = 0.026$; $p = 0.873$; $\eta p^2 = 0.001$	$F(1,37) = 2.480$; $p = 0.124$; $\eta p^2 = 0.063$
FACS composite score	$F(1,37) = 3.734$; $p = 0.061$; $\eta p^2 = 0.092$	$F(1,37) = 1.715$; $p = 0.198$; $\eta p^2 = 0.044$	$F(1,37) = 1.260$; $p = 0.269$; $\eta p^2 = 0.010$	$F(1,37) = 4.941$; $p = \mathbf{0.032}$, $\eta p^2 = 0.118$	$F(1,37) = 1.986$; $p = 0.167$; $\eta p^2 = 0.051$

Note: Significant effects ($p \leq 0.05$) are marked by bold text and gray-shaded background.

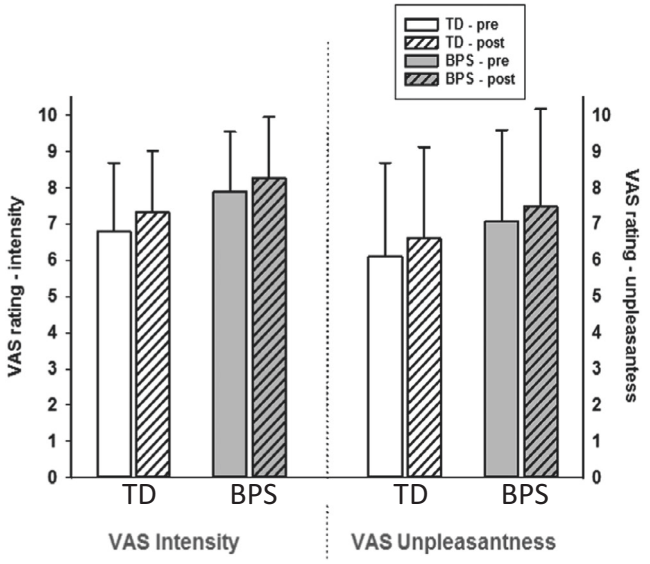

FIGURE 4 Mean self-report ratings of stimulus intensity (a) and stimulus unpleasantness (b). Error bars: standard deviation; TD = Typical day, BPS = Best Possible Self.

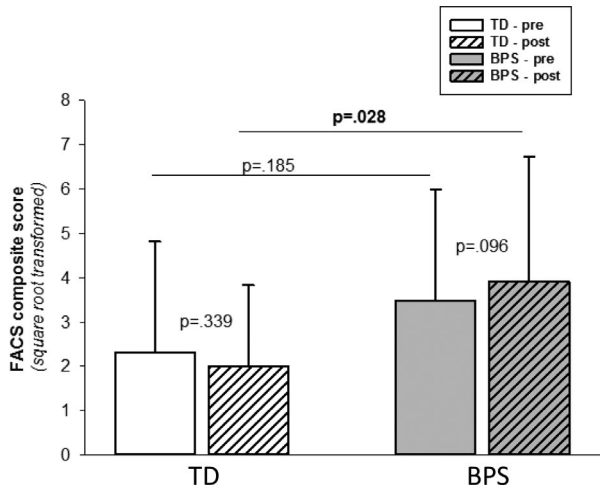

FIGURE 5 Mean facial activity (FACS composite score) during painful stimulation. Error bars: standard deviation; TD = Typical day, BPS = Best Possible Self.

showed a strong increase after optimism induction. Not surprising, only the change scores for AU4 ($t(38) = -2.92$; $p = 0.006$) and AU 6_7 ($t(38) = -2.87$; $p = 0.007$) were significantly different between the two groups ($p > 0.463$ *for all other 4 AUs*). Thus, the overall divergence in the composite score of facial responses between BPS and TD groups was mostly driven by optimism induced changes in AU 4 and especially in AU 6_7.

3.2.4 | Intercorrelations between pain-relevant variables

As shown in Table 4a, absolute values of ratings and facial activity (averages of pre- and post- measurements) were correlated

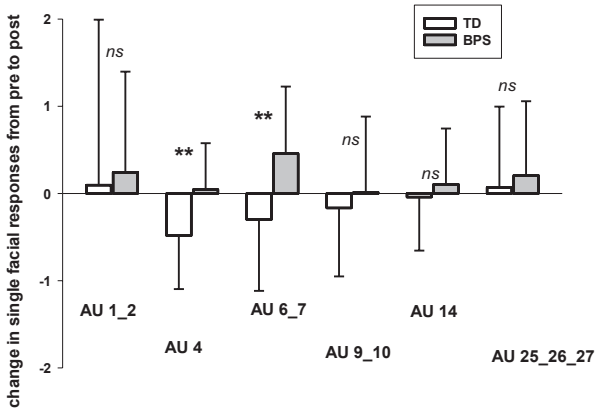

FIGURE 6 Mean chance scores in facial activity pre- and post-treatment (Δpost-pre for the AUs underlying the composite score). Error bars: standard deviation; TD = Typical day, BPS = Best Possible Self.

moderately for the whole sample and for the TD group: higher ratings were associated with more facial activity as measured by the FACS composite score (square root transformed values). In the BPS group, pain ratings were not significantly and only weakly correlated with the facial responses to pain. These findings replicate the well-known only weak-to-moderate associations of these two pain indicators. In Table 4b, correlations between pre-post-change scores (Δpost-pre) are shown. They reveal a similar pattern to the correlations between absolute values. In the whole sample and the TD, change scores of pain ratings and facial responses were moderately correlated, whereas, in the BPS group, correlations were only weak and not significant. This clearly points to the independent effects of BPS on pain ratings and facial activity.

4 | DISCUSSION

The aim of the present study was to compare the effects of an experimental optimism induction (*Best Possible Self [BPS] treatment*) on subjective and facial responses to painful heat stimulation. The effects of optimism on the facial expression of pain are described here for the first time. While there was no effect of the BPS treatment on subjective pain ratings following painful stimuli, the facial expression of pain was significantly stronger in the BPS group compared to the control (*Typical Day [TD]*) group after the optimism induction.

4.1 | Facial activity

It is of note that optimism mainly affected Action Units which are part of the known facial pain response (Kunz et al., 2019), while not activating other facial muscles that might express other affective states like joy. Thus, the facial encoding of pain was not qualitatively altered as one might expect when

TABLE 4 Intercorrelations between pain parameters (self-report ratings of stimulus intensity and stimulus unpleasantness, facial activity). Correlations between (a) absolute values, (b) change scores

(a)	Whole sample		TD		BPS	
	Stimulus unpleasant-ness	FACS score	Stimulus unpleasant-ness	FACS score	Stimulus unpleasant-ness	FACS score
Stimulus intensity	0.83**	0.35*	0.93**	0.46*	0.73**	0.18
Stimulus unpleasantness	–	0.39*	–	0.44*	–	0.32
(b)	**whole sample**		**TD**		**BPS**	
	Stimulus unpleasant-ness	**FACS score**	**Stimulus unpleasant-ness**	**FACS score**	**Stimulus unpleasant-ness**	**FACS score**
Stimulus intensity	0.84**	0.39*	0.88**	0.54*	0.74**	0.22
Stimulus unpleasantness	–	0.40*	–	0.47*	–	0.36

Note: Significant effects ($p \leq 0.05$) are marked by asterisk and gray-shaded background.
Abbreviations: BPS, best possible self; TD, typical day.

the induction would lead to a melting of pain with positive emotions. Instead, optimism appeared to only quantitatively change the facial expression of pain. It may be that optimism releases the brake that normally retains part of the facial expression of pain. These results are similar to earlier findings from our laboratory on the influence of feeling socially familiar (Karmann et al., 2014). The authors found changes in facial responses to pain to be dependent on the presence of other persons. Facial responses were significantly stronger in the presence of the partner compared to the conditions where either the experimenter or no one was present during painful stimulation. Self-report ratings were unchanged across the three social conditions. It seems that a stronger feeling of being safe—as produced by the presence of one's partner—leads to less inhibition of facial responses and thus an increased display of facial responses to pain. Similarly, a recent study showed that social threat (thus, a reduced feeling of being safe) led to a select reduction in facial expressions of pain whereas self-report ratings increased compared to a low threat condition (Karos et al., 2019). These findings strongly resemble those obtained in the present study in which temporarily optimistic individuals showed more facial expressions of pain though pain ratings did not mirror this increase.

It has been argued that individuals are more likely to communicate their vulnerability towards a familiar other such as the partner (Karmann et al., 2014) or a child's parent (Vervoort et al., 2008, 2011), from whom empathy and help can be expected. Optimism may thus lead to greater communicative openness as expectations regarding the social context become more positive. Being in a state of optimism, one may be inclined to expect empathy and help instead of rejection or abuse of one's weakness from others and therefore be more willing to express one's pain via facial responses. (As a methodological reminder, the experimenter was in the room but not visible to the subject during pain stimulation in the present study). This would also be in accordance with prior research, which reports that optimists show more social support seeking and a greater real or perceived availability of social support (Brissette et al., 2002; Dougall et al., 2001). Future studies should combine the optimism induction with an above-mentioned social manipulation (alone versus with a (un)familiar other) to further clarify our findings.

The consequence of increased state optimism was thus hypothesized to be twofold and unfold contrary actions on facial responses to pain. Optimism may lower the experience of pain, (Basten-Günther et al., 2019) but may also increase the expressiveness of pain. The latter should not be misinterpreted as an augmentation of pain but should be interpreted as an enhanced readiness to non-verbally signalling one's pain. Persons engaged in pain management have to be informed that improving the social context of treatment or the attitudes towards this context could even result in more behavioural signs of pain. The optimism-driven increase in

facial expression of pain does not appear to differ qualitatively from the regular facial expressions of pain. Still, given the fact that pain catastrophising also leads to increased communication of pain (Sullivan et al., 2006), it would be interesting to explore whether there are qualitative differences in pain behaviour between high optimists and high pain catastrophizers—particularly since optimism has been proposed to act on pain via reduced pain catastrophising.

A finding worth being discussed is that the increase in facial expression of pain in consequence of temporarily induced optimism is mainly due to two AUs, namely AU 4 (furrowed brows) and especially AU 6_7 (narrowed eyes). The two AUs belong both to the sensory and the affective signals of pain encoded by the facial expression (Kunz, Lautenbacher, et al., 2012). Thus, optimism may strengthen both behavioural indicators of pain intensity and pain unpleasantness and improve the full presentation of the problem. Furthermore, the two AUs are very likely those facial means most commonly used to express pain (Kunz & Lautenbacher, 2014; Kunz et al., 2019; Prkachin, 1992; Prkachin & Solomon, 2008) and also those being sensitive to the familiarity of other people being present (Karmann et al., 2014). Thus, optimism does not act on rare facial expressions but on the frequent facial signals with social function.

It remains open why only induced (state) and not dispositional (trait) optimism was significantly associated with facial responses to pain. Potentially, our experiment represented an unambiguous situation where induced states played a bigger role than latent traits which would more likely manifest themselves under conditions providing more ambiguous situational characteristics (Fleeson & Gallagher, 2009).

4.2 | Ratings of painful stimuli

Pain ratings of intensity and unpleasantness were not influenced by the optimism induction. Prior studies using comparable experimental designs reveal mixed results: Hanssen et al. (2013) report pain-dampening effects of the BPS task, while another study (Traxler al., 2019) did not show changes in pain reports. We can only speculate why no pain-dampening effect of optimism was found in our study. To begin with, the temporary effect of our optimism manipulation may have been too weak to result in any detectable changes in pain ratings. However, given the significant effect of the optimism induction on facial responses and given prior significant effects in a study using the BPS procedure with the same efficacy (Hanssen et al., 2013), this explanation does not seem very likely. It appears more plausible that the effect of optimism on pain ratings is in general rather small, making significant results not reliable.

In a situation like this, pain modality and stimulus length might play a crucial role. The study by Hanssen et al. (2013) found lower pain reports after the BPS task applied pain by use of the cold pressor task and pain ratings were obtained at 20, 40 and 60 s during the 1 min immersion of the hand into cold water. The differences between the BPS and the TD group augmented continually and were highest at the last rating. We can, therefore, speculate that cognitions associated with optimism take a while to act—-e.g. mediated by cognitive appraisal processes—and that our 5 s heat stimuli were too short to see any optimism effect in the ratings.

Divergences between subjective pain ratings and facial expression of pain have already previously been reported (Karos et al., 2019; Kunz et al., 2007, 2015; Priebe et al., 2015) and do, therefore, not constitute a major challenge in understanding the zero results as regards the pain ratings in face of positive findings as regards the facial responses to pain. The two variables represent largely independent sources of information about pain, as also shown by our correlation analyses.

4.3 | Efficacy of optimism induction by the BPS treatment

Considering the increases in situational optimism (scale FEX positive) and positive affect (scale PANAS-PA) directly after the induction of optimism by the BPS treatment, we can assume that the optimism manipulation was successful. This is in accordance with prior studies using the same paradigm (Carrillo et al., 2019; Hanssen et al., 2013; Peters et al., 2010, 2016). As expected, the BPS exercise creates only short-lasting changes in optimism: at follow-up at the end of the experiment, the FEX positive and PANAS_PA scores dropped to values similar to those of the TD group. As shown by the VAS about the quality of imagery, we can assume that there were no significant qualitative differences between the BPS and the TD group concerning the success and vividness of the subjects' imaginations. The observed differences between the groups in terms of positive affect and state optimism, therefore, seem to be specifically due to a more positive content in the writing and imagery of the BPS group. This is in line with the aims of the BPS paradigm and further corroborates the assumption that BPS treatments can be successful. Though the experimental induction of optimism may seem somewhat 'artificial', we would like to stress the clinical relevance of changes in expectations, as can be seen, for example, from effects that are known to occur during placebo responses. In fact, there are some promising reports of longer-term effects of optimism trainings in healthy and clinical populations (Flink et al., 2015; Meevissen et al., 2011; Peters et al., 2017).

4.4 | Methodological strengths and weaknesses

The present study is to our knowledge the first to examine the effect of optimism on the facial expression of pain. While the sample was balanced in regard to sex and age, it has to be taken into account that the study only included healthy participants. Therefore, no conclusions regarding clinical populations can be derived. Furthermore, results in our experimental setting—allowing for causal conclusions and control of many confounding variables—might not be in every respect applicable to more natural everyday contexts. Thus, the generalisability of our conclusions to clinical contexts and clinical pain models has yet to be examined.

5 | CONCLUSIONS

The present study found a specific increase in facial expression during pain after an optimism induction, not accompanied by corresponding changes in pain rating. This effect could possibly be interpreted in terms of a greater readiness to communicate one's pain in hope of empathy and help when in an optimistic state. Studies applying an explicit social manipulation (e.g. alone versus others being familiar or not), as well as other pain models, could provide further insights into the general consequences of state optimism on social non-verbal pain behaviour. The interaction between trait and state optimism in their effects on pain remains to be clarified. If our findings are confirmed, clinicians should take into account that optimistic persons might signal more pain, while pain starts to fade in their positive expectation to still receive help and empathy from their others.

ACKNOWLEDGEMENTS

We gratefully acknowledge the contributions of Eva Capito and Sonja Pähl to data analysis.

CONFLICT OF INTEREST

The authors state that there is no conflict of interest.

AUTHOR CONTRIBUTIONS

We declare that all authors discussed the results and commented on the manuscript.

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How to cite this article: Basten-Günther J, Kunz M, Peters M, Lautenbacher S. The effect of optimism on the facial expression of pain: Implications for pain communication. *Eur J Pain*. 2021;25:817–830. https://doi.org/10.1002/ejp.1712

Anhang 3

Basten-Günther, J., Peters, M. L., & Lautenbacher, S. (2022). The Effect of Induced Optimism on Situational Pain Catastrophizing. *Frontiers in Psychology*, *13*, 900290. Doi: 10.3389/fpsyg.2022.900290

frontiers | Frontiers in Psychology

ORIGINAL RESEARCH
published: 23 June 2022
doi: 10.3389/fpsyg.2022.900290

The Effect of Induced Optimism on Situational Pain Catastrophizing

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Background: There is broad evidence that optimism is associated with less pain, while pain catastrophizing leads to increased pain. The aim of this study was to examine whether experimentally induced optimism can reduce situational pain catastrophizing and whether this relation is moderated by dispositional optimism and/or dispositional pain catastrophizing.

Methods: Situational pain catastrophizing during two thermal stimulations was measured in 40 healthy participants with the *Situational Catastrophizing Questionnaire (SCQ)*. Between the two stimulations, the *Best Possible Self (BPS)* imagery and writing task was performed to induce situational optimism in the experimental group while the control group wrote about their typical day. Questionnaires were administered to assess dispositional optimism [*Life Orientation Test-Revised (LOT-R)*] and dispositional pain catastrophizing [*Pain Catastrophizing Scale (PCS)*].

Results: There was a significant interaction between the optimism induction and trait pain catastrophizing: the association of trait pain catastrophizing with state pain catastrophizing was weakened after the optimism induction. No overall effect of induced optimism on situational pain catastrophizing and no significant moderating influence of trait optimism were found.

Conclusion: The state optimism induction apparently counteracted the manifestation of dispositional pain catastrophizing as situational pain catastrophizing. This implies that high trait pain catastrophizers may have especially benefitted from the optimism induction, which is in line with resilience models stressing the buffering role of optimism.

Keywords: pain, pain catastrophizing, optimism, resilience, positive psychology

OPEN ACCESS

Edited by:
Carolina Baeza-Velasco, Université de Paris, France

Reviewed by:
Nathan Rlsch, Université Montpellier, France
Francisco Javier Cano-García, Sevilla University, Spain
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Specialty section:
This article was submitted to Psychology for Clinical Settings, a section of the journal Frontiers in Psychology

Received: *20 March 2022*
Accepted: *02 June 2022*
Published: *23 June 2022*

Citation:
Basten-Günther J, Peters ML and Lautenbacher S (2022) The Effect of Induced Optimism on Situational Pain Catastrophizing. Front. Psychol. 13:900290. doi: 10.3389/fpsyg.2022.900290

INTRODUCTION

Optimism—defined as positive expectancies concerning the future (Scheier and Carver, 1985)—is known to have pain-dampening effects in experimental as well as in acute and chronic clinical pain (for overviews, see Garofalo, 2000; Goodin and Bulls, 2013; Basten-Günther et al., 2019). Pain catastrophizing is a negative mental set during actual or anticipated pain, consisting of rumination, magnification and feelings of helplessness when in pain (Sullivan, 2009; Campbell et al., 2010a; Pulvers and Hood, 2013). Pain catastrophizing leads to higher pain reports (Adams et al., 2007; Sullivan, 2009; Campbell et al., 2010b). Both optimism and pain catastrophizing are conceptualized as having a trait component (dispositional optimism/pain catastrophizing) and a

state component (situational optimism/pain catastrophizing; Kluemper et al., 2009; Quartana et al., 2009; Campbell et al., 2010a).

As pain catastrophizing and optimism influence pain experience in opposite ways, it is interesting to examine how these two variables interact. It has been assumed that optimists are less likely to engage in pain catastrophizing, which in turn leads to lower pain reports, i.e., that the negative association between optimism and pain is fully or partially mediated by pain catastrophizing (Hood et al., 2012; Goodin et al., 2013; Hanssen et al., 2013; Pulvers and Hood, 2013, for an overview). The present study therefore aims at exploring whether an experimental induction of state optimism can successfully reduce the situational pain catastrophizing occurring during painful heat stimulation. Furthermore, we examine whether the levels of dispositional optimism and dispositional pain catastrophizing moderate this relationship. In accordance with theories on resilience factors (for example, Catalano et al., 2011), situational optimism might act as a "buffer" by preventing or attenuating the manifestation of trait pain catastrophizing as situational pain catastrophizing in a given pain situation. This implies that high dispositional pain catastrophizers might benefit more from the optimism induction as regards their situational pain catastrophizing than low dispositional pain catastrophizers, who would already show low situational catastrophizing responses without the optimism manipulation.

As regards dispositional optimism, there have so far not been found any differences in the responsiveness to an optimism induction between participants with high vs. low trait optimism (Harrist et al., 2007; Peters et al., 2010; Hanssen et al., 2013). It is thinkable that analogously to low dispositional pain catastrophizers, high trait optimists might benefit less from an induction of additional optimism as they are already sufficiently optimistic and in consequence less prone to pain catastrophizing even without an additional optimism "boost." In this sense, high trait optimists would show weaker changes in situational pain catastrophizing after the experimental induction of state optimism.

Firstly, we hypothesize that experimentally induced situational optimism leads to reduced situational pain catastrophizing. Secondly, we hypothesize that the influence of the optimism induction is stronger in high dispositional pain catastrophizers. Thirdly, we hypothesize that the influence of the optimism induction is weaker in individuals with high dispositional optimism.

MATERIALS AND METHODS

Participants

A total of 40 healthy, pain-free individuals [20 men and 20 women, 10 from each decade between 20 and 60; mean (±SD) age 39.9 ± 13.5 years] participated in the current study. The participants were recruited *via* advertisements in the local newspaper (Bamberg, Germany). To ensure normal affectivity, current psychological disorders as assessed *via* self-report were an exclusion criterion. Participants were asked not to take alcohol or analgesic and psychotropic drugs on the day of the experiment. All participants provided informed consent and received monetary compensation. The study protocol was approved by the ethics committee of the University of Bamberg (Bamberg, Germany).

Procedure

General Protocol

We chose an experimental design comparing situational pain catastrophizing in an experimental group receiving an optimism manipulation with a control group receiving a neutral state induction. Part of the data have been published before in an analysis of different outcome variables, namely self-report pain ratings and facial expression of pain (Basten-Günther et al., 2021). Group assignment was randomized. The two groups were balanced with regard to age and sex and—for female participants not using hormonal contraceptives—with regard to phase of menstrual cycle (follicular, ovulatory and luteal) in order to control for mood swings over the course of the menstrual cycle (Natale and Albertazzi, 2006). Situational pain catastrophizing was measured with reference to two identical painful stimulations applied before (pre measurement) and after the optimism/control manipulation (post measurement).

The experiment consisted of one session taking place at 1.30 PM for one half of the participants and at 3.30 PM for the other half. Participants from the experimental and the control group were distributed equally across the two points of time in order to control for fluctuations of mood across the day (Murray et al., 2002). After providing informed consent and filling out questionnaires to assess trait optimism, trait pain catastrophizing and baseline state optimism (see below), participants underwent two identical blocks of painful heat stimulation which served as a standardized reference of situational pain catastrophizing. After each block, participants rated the catastrophizing thoughts they had experienced during the painful stimuli which they had just received, on the Situational Catastrophizing Questionnaire (SCQ; see below). Results of pain variables (ratings of pain intensity and pain unpleasantness as well as facial expression of pain) recorded during this stimulation have recently been reported by Basten-Günther et al. (2021). In between the two pain blocks, which will be described in detail below, the experimental manipulation (optimism-inducing vs. neutral writing task) was executed, which acted as independent variable. The state questionnaires Positive and Negative Affect Schedule (PANAS) and Future Expectancies Scale (FEX), which served as a manipulation check, were filled out three times in order to record induced changes in affect and situational optimism: before the first pain block (baseline), immediately after the optimism intervention and after the second pain block (follow-up). After roughly 2 h, the participants were thanked and debriefed and the session was concluded (**Figure 1**).

Measurement of Situational Pain Catastrophizing

To reference situational pain catastrophizing to a standardized pain situation, participants underwent two blocks of heat

Abbreviations: BPS, Best Possible Self; TD, Typical day; LOT-R, Life Orientation Test-Revised Version; PCS, Pain Catastrophizing Scale; SCQ, Situational Catastrophizing Questionnaire; FEX, Future Expectancies Scale; PANAS, Positive and Negative Affect Schedule; ANCOVA, Analysis of covariance.

FIGURE 1 | General protocol of the experiment. LOT-R, Life Orientation Test-Revised Version; PCS, Pain Catastrophizing Scale; FEX, Future Expectancies Scale; PANAS, Positive and Negative Affect Schedule; and SCQ, Situational Catastrophizing Questionnaire.

stimulation (one before and one after the experimental manipulation of optimism), which each consisted of 10 painful and 10 non-painful phasic heat stimuli in the same random order. Each stimulus had a duration of 5 s. Using an experimental procedure to trigger acute situational pain catastrophizing—rather than asking participants to reference a past everyday pain experience—prevents memory effects and variation in referenced pain events. Most importantly, it allows for a standardized pain stimulation which can be subjected to a pre–post-manipulation comparison.

The stimuli were applied to the left volar forearm with a 30×30 mm contact thermode. To ensure that temperature intensities were perceived as painful but not too painful in all participants, temperature intensities were tailored to the individual pain threshold, which was determined by the method of adjustment (for example, Horn et al., 2012) in four trials. Both painful (+3°C above the pain threshold) and non-painful (−1°C below the pain threshold) intensities were applied in a random order to sustain participants' vigilance and to prevent changes in pain sensitization which might in turn alter situational pain catastrophizing and in the following distort or conceal the optimism effects on situational pain catastrophizing.

Optimism Manipulation

In between the two blocks of heat stimulation, the experimental optimism induction was performed. Optimism was induced by the *Best Possible Self* task (BPS), a positive future thinking technique based on work by King (2001). BPS has been proven effective in increasing optimism temporarily (Peters et al., 2010, 2016; Hanssen et al., 2013). Participants were instructed to carry out a writing and imagery exercise. Half of the participants were assigned to the BPS condition ($n = 20$), which required them to write about their life in the future where everything had turned out for the best. The other half of the participants were assigned to the control condition ($n = 20$), whose task consisted in writing about a typical day (TD). The instructions for BPS and TD were as follows (cf. Sheldon and Lyubomirsky, 2006).

- BPS condition:
  Thinking about your best possible self means that you imagine yourself in the future, after everything has gone as well as it possibly could. You have worked hard and succeeded at accomplishing all the goals of your life. Think of this as the realization of your dreams, and that you have reached your full potential.
- TD condition:
  Thinking about your typical day means that you take notice of ordinary details of your day that you usually do not think of. These might include particular classes or meetings you attend to, people you meet, things you do, typical thoughts you have during the day. Think of this as moving through your typical day, hour after hour.

Both manipulations had the same procedural format: participants were requested to think for 1 min about what to write, then to write uninterrupted for 15 min, followed by 5 min of imagining the story they had just been writing. Instructions were given both verbally and in writing. The manipulation check followed immediately by asking the participants to complete the FEX and PANAS a second time and to answer three questions about the quality and valence of their writing and imaginations (*Quality of imagery*, Peters et al., 2010).

Questionnaires

Situational Catastrophizing Questionnaire

Situational pain catastrophizing with reference to the two painful stimulations was assessed with the German version of the SCQ (Edwards et al., 2006) which was translated by the authors and has been applied before in several studies (for example, Horn-Hofmann et al., 2018; Karmann et al., 2018; Stroemel-Scheder et al., 2019). There is evidence that situational catastrophizing as measured by the SCQ correlates significantly stronger with pain reports than dispositional pain catastrophizing as measured by the Pain Catastrophizing Scale (PCS; Sullivan et al., 1995; Dixon et al., 2004; Edwards et al., 2005; Campbell et al., 2010a). The SCQ is an adaptation of the PCS and consists of six items referring to catastrophizing thoughts and feelings during a specific noxious stimulation which was applied before filling out the questionnaire. The items tap the three dimensions of pain catastrophizing (rumination, for example: "I could not stop thinking about how much it hurt."; magnification: "I felt that the procedures were awful."; helplessness: "I felt that I could not stand it.") and are rated on a five-point scale, with the end points "not at all" and "all the time." Cronbach's alpha in this study was $\alpha = 0.91$ for the measurement after the first block of stimulation and $\alpha = 0.94$ for the measurement after the second block of stimulation.

Pain Catastrophizing Scale

A German translation (Meyer et al., 2008) of the PCS (Sullivan et al., 1995) was used to assess catastrophic thinking related to pain. Participants are instructed to reflect on thoughts or feelings during past painful experiences. The scale comprises 13 items on the subscales rumination, magnification and

helplessness, which are rated on a five-point scale, with the end points "not at all" and "all the time." The PCS has been widely used in research on pain catastrophizing and has been shown to have high internal consistency. Internal consistency in the present case was Cronbach's $\alpha = 0.91$.

Life Orientation Test Revised

The validated German version (Krohne et al., 1996) of the Life Orientation Test-Revised (LOT-R; Scheier et al., 1994) was used to assess the level of dispositional optimism. The LOT-R has 10 items which are rated on a five-point Likert scale, ranging from 0 ("strongly disagree") to 4 ("strongly agree"). There are three positively phrased items (optimism subscale), three negatively phrased items (pessimism subscale), and four filler items. A total trait optimism score is calculated over the six items with either positive or negative content after reversing the negatively phrased items. Internal consistency as measured by Cronbach's alpha was $\alpha = 0.76$.

Future Expectancies Scale

The FEX (Hanssen et al., 2013) was administered to assess state optimism. A German version of the questionnaire was used, which was translated in a standard "forward-backward" procedure and applied in a prior study by the authors (Peters et al., 2016). The FEX consists of 10 statements describing a positive future event and 10 statements describing a negative future event. Participants rated the likelihood that they will experience each specific event on a seven-point Likert scale, ranging from 1 ("not at all likely to occur") to 7 ("extremely likely to occur"). The FEX has previously been demonstrated to be responsive to optimism manipulations (Hanssen et al., 2013; Boselie et al., 2014). The subscores FEX positive and FEX negative were used for further analyses. Internal consistency at the three assessment times ranged from Cronbach's $\alpha = 0.89$ to $\alpha = 0.91$ for the subscale FEX positive and from $\alpha = 0.83$ to $\alpha = 0.87$ for the subscale FEX negative.

Positive and Negative Affect Schedule

Mood was assessed with the PANAS (Watson et al., 1988). The PANAS consists of 20 items measuring positive (10 items) and negative (10 items) affect. Participants indicate the degree to which a certain feeling is present at that moment on a five-point Likert scale ranging from 1 ("not at all") to 5 ("extremely"). The subscores PANAS positive (PANAS_PA) and PANAS negative (PANAS_NA) were used for further analyses. For the PANAS, a validated German version (Glaesmer et al., 2008) was used. Internal consistency at the three assessment times ranged from Cronbach's $\alpha = 0.86$ to $\alpha = 0.93$ for PANAS_PA and from $\alpha = 0.66$ to $\alpha = 0.83$ for PANAS_NA.

Quality of Imagery

Two visual analogue scales (0–100 mm; Peters et al., 2010) were used to rule out qualitative (in contrasts to content-related) differences in participants' imagery between the BPS and the TD group (Hanssen et al., 2013): "How well could you imagine yourself in the situation you described in your writing" and "How vivid were the pictures you imagined?." A third VAS ("How negative or positive were your imaginations?") was administered to rule out that imaginations and writing content were equally positive in the TD group as in the BPS group.

Statistical Analyses

In order to examine the effect of the optimism induction on situational pain catastrophizing, we tested for a time x condition interaction effect in a 2×2 repeated measures ANOVA. Experimental condition was entered as fixed factor.

To test moderating effects of dispositional pain catastrophizing and dispositional optimism, preliminary bivariate correlations were computed to test for associations between the SCQ score and the LOT-R and PCS score, respectively. In case of significant correlations, separate analysis of covariances (ANCOVAs) were performed with *LOT-R* or *PCS* as covariates. Second-order interaction effects (time x condition x *LOT-R*/*PCS*) were specified in the model. In case of significant second-order interactions, within group regressions of SCQ change scores on LOT-R/PCS were performed to determine the direction on the interaction.

In order to assess differences in demographic or baseline variables between the BPS and the TD group, independent samples *t*-tests comparing the two groups were applied. To control whether the optimism induction was successful, a 3×2 (time x group) repeated measures ANOVA was computed for each FEX/PANAS subscale. Independent samples *t*-tests were used to investigate group differences as regards the quality of writing and visualization (Basten-Günther et al., 2021). All analyses were conducted with SPSS 24 and the alpha-level was 0.05 throughout.

RESULTS

Descriptive Statistics

Means and SDs for demographic variables, dispositional optimism (*LOT-R*), dispositional pain catastrophizing (*PCS*) and situational pain catastrophizing (*SCQ*) are shown in **Table 1**. The LOT-R mean score is exactly the same as the population-based norm recently reported by Schou-Bredal et al. (2017). The *PCS* score is similar to the ones found in prior studies (for example, Kunz et al., 2016; Horn-Hofmann et al., 2017; Basten-Günther et al., 2021).

Randomization Check

The optimism and control group did neither significantly differ in their pain threshold nor in any demographic variable or baseline state measurement (first assessment of *SCQ*, *FEX*, and *PANAS*). For this reason, neither of these variables was controlled for in subsequent AN(C)OVAs (Basten-Günther et al., 2021).

Manipulation Check

As already reported in Basten-Günther et al. (2021), there was a significant time x group interaction effect for PANAS_PA [subscale positive affect; $F(2,76) = 3.89$, $p = 0.03$ $\eta_p^2 = 0.09$] and

TABLE 1 | Demographics and trait measures of optimism and pain catastrophizing and situational pain catastrophizing.

	TD		BPS		*t*-test for independent samples (TD vs. BPS)	
Sex male	***n* = 20**		***n* = 20**			
	10 (50%)		**10 (50%)**			
	Mean	***SD***	**Mean**	***SD***	***t***	***p***
Age *(years)*	40.50	11.69	40.20	12.60	0.08	0.94
LOT-R	16.40	3.17	18.05	4.06	1.43	0.16
PCS	15.50	7.94	11.83	8.04	1.45	0.15
SCQ pre	6.30	5.74	7.40	6.06	0.59	0.56
SCQ post	7.10	7.01	8.55	6.40	0.68	0.50

BPS, Best Possible Self (experimental group); TD, Typical Day (control group); LOT-R, Life Orientation Test-Revised Version; PCS, Pain Catastrophizing Scale; and SCQ, Situational Catastrophizing Questionnaire.

FEX_pos [subscale positive future expectancies; $F(2,76) = 3.07$, $p = 0.05$, $\eta_p^2 = 0.08$].

Within-condition analyses of repeated measurements with planned contrasts indicated that in the BPS condition, FEX_pos was significantly larger at the post-manipulation assessment [$F(1,19) = 6.5$, $p = 0.02$, $\eta_p^2 = 0.255$] compared to the pre-manipulation assessment. In the TD group, there were no differences between the three assessments. Corresponding analyses for the PANAS_PA scale showed a significant decrease of positive affect in the TD group at the post-manipulation assessment compared to baseline [$F(1,19) = 7.6$, $p = 0.01$, $\eta_p^2 = 0.287$] whereas positive affect in the BPS group remained stable after the manipulation [$F(1,19) = 1.2$, $p = 0.29$, $\eta_p^2 = 0.058$]. There were no significant differences between the three assessment times in the negative subscales of FEX and PANAS.

The differences between the groups after the experimental manipulation suggests that the optimism induction was successful. This is in accordance with prior studies using the same paradigm (Peters et al., 2010, 2016; Hanssen et al., 2013).

The groups did not significantly differ in the VAS about the quality (BPS: $M = 77.35$, $SD = 15.09$, TD: $M = 74.05$, SD = 21.75; $t = 0.56$; $p = 0.58$) and the vividness (BPS: $M = 77.15$, $SD = 22.73$, TD: $M = 69.25$, $SD = 22.09$; $t = 1.12$; $p = 0.27$) of their imaginations. This is in accordance with prior research (Hanssen et al., 2013). On the third question asking the emotional valence, the BPS group scored, as expected, significantly higher than the TD group (BPS: $M = 86.60$, $SD = 14.73$, TD: $M = 61.15$, $SD = 25.09$; $t = 3.91$, $p < 0.005$; Basten-Günther et al., 2021).

Overall Influence of Optimism Induction on Situational Pain Catastrophizing

As regards the overall influence of the optimism induction on situational pain catastrophizing independent of trait levels, the 2 × 2 repeated measures ANOVA did not show a significant time x condition interaction effect [$F(1,38) = 0.101$, $p = 0.752$, $\eta_p^2 = 0.003$]. This means that there was no overall effect of induced optimism on situational pain catastrophizing across all participants. **Figure 2** shows the level of situational pain catastrophizing depending on time of measurement and experimental condition. There was a non-significant overall increase in the SCQ from the pre- to the post-measurement across both groups ($M = 0.975$, $t = 1.794$, $p = 0.081$).

Influence of Optimism Induction on Situational Pain Catastrophizing Dependent on Level of Dispositional Pain Catastrophizing

Preliminary analyses revealed significant correlations between PCS scores and SCQ pre- and post-scores (whole sample: pre: $r = 0.475$, $p = 0.002$; post: $r = 0.365$, $p = 0.021$; TD group: pre: $r = 0.490$, $p = 0.028$; post: $r = 0.529$, $p = 0.016$; BPS group: pre: $r = 0.533$, $p = 0.016$; post: $r = 0.269$, $p = 0.252$). These linear relations are also shown in regression graphs of SCQ on PCS in supplement A. Upon visual examination of p–p-plots, residuals were approximately normally distributed, with the exception of the BPS post-measurement, which seems to reflect the disparition of the association between PCR and SCQ after the optimism induction.

Subsequently, 2 × 2 repeated measures ANCOVA was conducted to examine the influence of the optimism induction on situational pain catastrophizing dependent on participants' level of trait pain catastrophizing. The ANCOVA revealed a significant main effect of dispositional pain catastrophizing [*PCS*; $F(1,36) = 10.399$, $p = 0.003$, $\eta_p^2 = 0.224$]—higher *PCS* scores were associated with higher *SCQ* scores—, a close to significant trend of the time x condition interaction [$F(1,36) = 4.027$, $p = 0.052$, $\eta_p^2 = 0.101$] and a significant time x condition x *PCS* second-order interaction effect [$F(1,36) = 4.902$, $p = 0.033$, $\eta_p^2 = 0.120$; **Table 2**].

Figure 3 illustrates this second-order interaction by showing pre-post SCQ change scores regressed on the PCS score for each group. As can be seen in **Figure 3**, high PCS scores predicted an increase from the pre- to the post-measurement in the BPS group, but a difference of around zero in the TD group. The SCQ level of low pain catastrophizers (low values of PCS) remains approximately constant in the TD condition, while an increase from pre to post is predicted in the BPS task.

Anmerkung: Die Begriffe BPS und TD wurden an dieser Stelle vertauscht.

Corresponding to the main effect of PCS, low dispositional pain catastrophizers scored several points lower in the SCQ

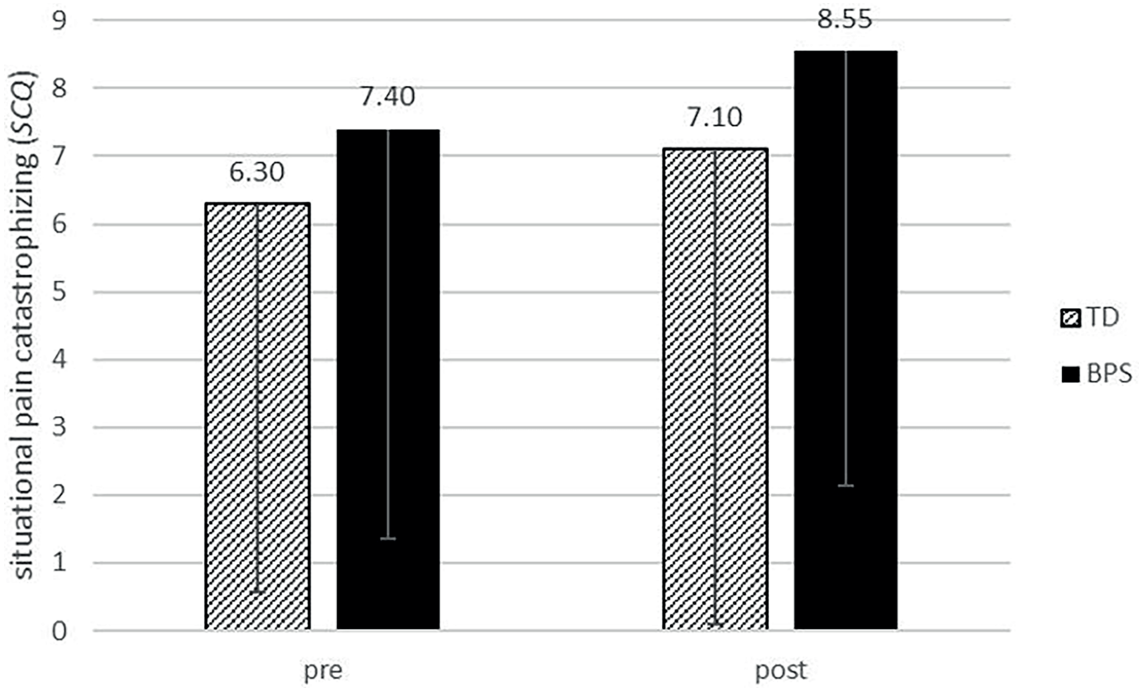

FIGURE 2 | Mean score of overall situational pain catastrophizing (SCQ) depending on experimental condition and time of measurement. Error bars = −1 SD. TD, typical day and BPS, Best Possible Self.

TABLE 2 | *F*-Tests, value of *p* and effect sizes of the analysis of covariance (ANCOVA) with the factors condition (between-subjects, levels: BPS and TD), time (within-subject, levels: pre and post) and the covariate dispositional pain catastrophizing (Pain Catastrophizing Scale: *PCS*) for the dependent variable situational pain catastrophizing.

	Condition	**Time**	***PCS***	**Condition x *PCS***	**Time x *PCS***	**Time x condition**	**Time x condition x *PCS***
Situational Pain Catastrophizing (*SCQ*)	$F(1,36) = 1.286$; $p = 0.264$; $\eta_p^2 = 0.034$	$F(1,36) = 0.1.270$; $p = 0.267$; $\eta_p^2 = 0.034$	$F(1,36) = 10.399$; **$p = 0.003$**; **$\eta_p^2 = 0.224$**	$F(1,36) = 0.215$; $p = 0.646$; $\eta_p^2 = 0.006$	$F(1,36) = 0.305$; $p = 0.584$; $\eta_p^2 = 0.008$	$F(1,36) = 4.027$; $p = 0.052$; $\eta_p^2 = 0.101$	$F(1,36) = 4.902$; **$p = 0.033$**; **$\eta_p^2 = 0.120$**

Significant effects ($p \leq 0.05$) are marked by bold text and gray-shaded background.

than high dispositional pain catastrophizers across both groups and both times of measurement.

To sum it up, a significant time x condition x *PCS* second-order interaction effect was found. Descriptively, there was a less pronounced pre–post-SCQ increase in high trait pain catastrophizers of the optimism group compared to high trait pain catastrophizers of the control group.

Influence of Optimism Induction on Situational Pain Catastrophizing Dependent on Level of Dispositional Optimism

Preliminary analyses indicated that the LOT-R score was significantly correlated with the SCQ pre score ($r = -0.342$, $p = 0.031$), but not the SCQ post score ($r = -0.178$, $p = 0.273$; TD group: pre: $r = -0.224$, $p = 0.343$; post: $r = -0.161$, $p = 0.497$; BPS group: pre: $r = -0.412$, $p = 0.071$; post: $r = -0.159$, $p = 0.504$). Due to the former, a 2×2 repeated measures ANCOVA was conducted to examine the influence of the optimism induction on situational pain catastrophizing dependent on participants' level of trait optimism. As shown in **Table 3**, there was neither a significant main effect of the LOT-R [$F(1,36) = 2.144$, $p = 0.152$, $\eta_p^2 = 0.056$] nor a significant time x condition x LOT-R second order interaction effect [$F(1,36) = 0.102$, $p = 0.320$, $\eta_p^2 = 0.027$]. Thus, dispositional optimism did not have a direct association with situational pain catastrophizing and did not alter the effect of the optimism induction on situational pain catastrophizing.

DISCUSSION

The aim of the present study was to examine the effect of an experimental optimism induction on situational pain

catastrophizing (SCQ; Hypothesis 1) and to explore the moderating roles of dispositional pain catastrophizing (PCS; Hypothesis 2) and dispositional optimism (LOT-R; Hypothesis 3). There was no direct effect (Hyp.1) of the optimism induction and no moderating influence of dispositional optimism (Hyp.3) on situational pain catastrophizing. As regards the moderating role of dispositional pain catastrophizing, there was a significant time x condition x PCS interaction effect, suggesting a stronger influence of the optimism induction on situational pain catastrophizing in high pain catastrophizers This finding supports Hypothesis 2. The discussion will follow the order of hypotheses.

Direct Influence of Optimism Induction on Situational Pain Catastrophizing (Hyp.1)

Contrary to our hypothesis, the experimental optimism induction did not impact on situational pain catastrophizing. Thus, our results do not support prior studies which found a negative association between optimism and pain catastrophizing. Two of these studies (Hood et al., 2012; Goodin et al., 2013) only applied trait questionnaires without an experimental manipulation of optimism or a situational measure of pain catastrophizing and may therefore be less comparable. The other one (Hanssen et al., 2013) used the BPS task and a measure of state pain catastrophizing. In this study, pain catastrophizing during a

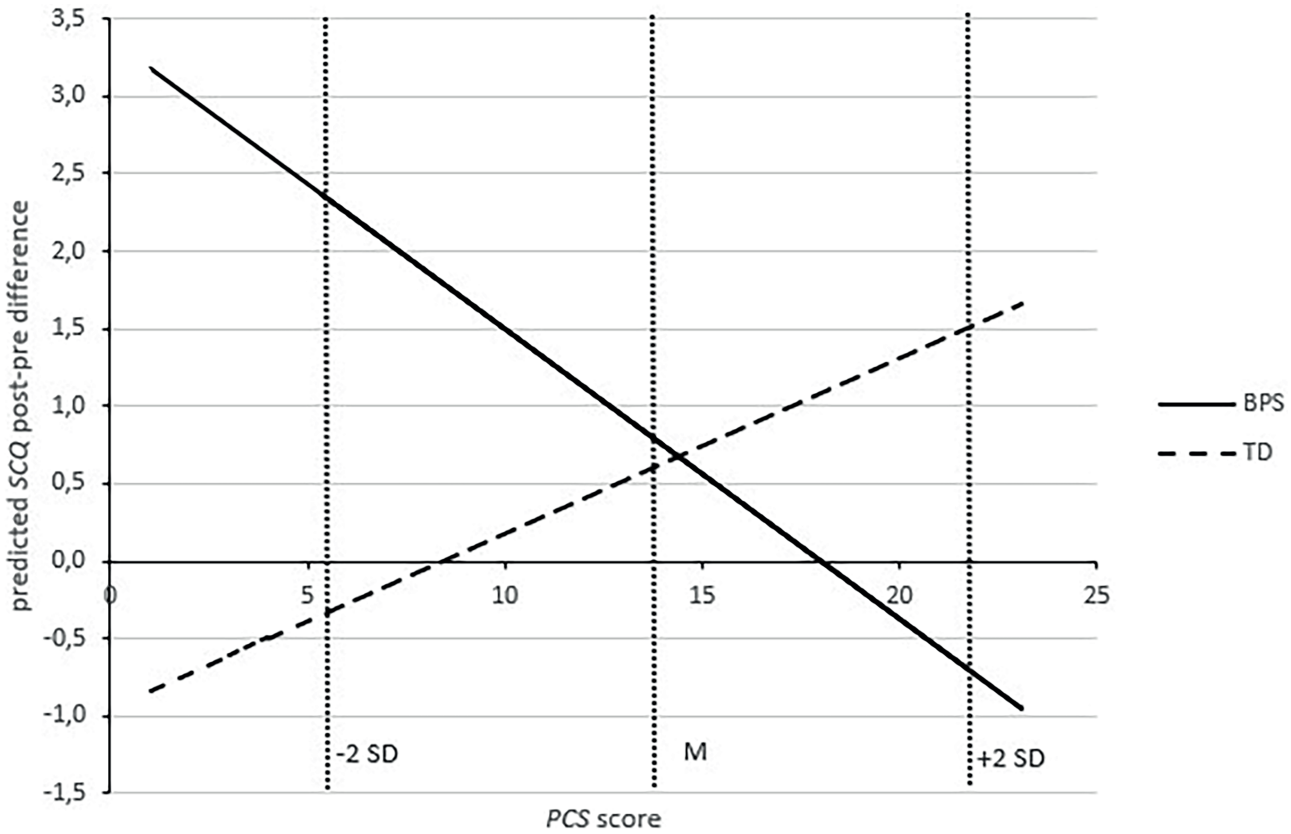

FIGURE 3 | Regression of change in situational pain catastrophizing (post minus pre difference) on dispositional pain catastrophizing (PCS score). Estimated SCQ values at means (M) and plus/minus two SDs of PCS score are indicated by vertical lines. Positive values indicate an increase in SCQ from the pre to the post measurement, while negative values indicate a decrease. BPS, Best Possible Self (experimental group). TD, Typical Day (control group). SCQ, Situational Catastrophizing Questionnaire. PCS, Pain Catastrophizing Scale.

TABLE 3 | *F*-Tests, value of *p* and effect sizes of the ANCOVA with the factors condition (between-subjects, levels: BPS and TD), time (within-subject, levels: pre and post) and the covariate dispositional optimism (Life Orientation Test-Revised: *LOT-R*) for the dependent variable situational pain catastrophizing.

	Condition	**Time**	***LOT-R***	**Condition x *LOT-R***	**Time x *LOT-R***	**Time x condition**	**Time x condition x *LOT-R***
Situational Pain Catastrophizing (*SCQ*)	$F(1,36) = 0.023$; $p = 0.880$; $\eta_p^2 = 0.001$	$F(1,36) = 0.771$; $p = 0.386$; $\eta_p^2 = 0.021$	$F(1,36) = 2.144$; $p = 0.152$; $\eta_p^2 = 0.056$	$F(1,36) = 0.009$; $p = 0.926$; $\eta_p^2 < 0.001$	$F(1,36) = 1.734$; $p = 0.196$; $\eta_p^2 = 0.046$	$F(1,36) = 0.728$; $p = 0.399$; $\eta_p^2 = 0.020$	$F(1,36) = 1.018$; $p = 0.320$; $\eta_p^2 = 0.027$

2-min cold pressor task was measured. As has been argued before (Basten-Günther et al., 2021), the longer duration of this pain may have provided more opportunity for optimistic attitudes to unfold their effect *via* cognitive appraisal processes than the 5 s stimuli in our study. Catastrophizing thoughts may thus have been prevented more effectively. The pain ratings corresponding to the present data were likewise not influenced by the optimism induction which could be a further indication that the effect of the experimental optimism induction had not yet resulted in any significant changes in pain experience as well as the accompanying catastrophizing thoughts (Basten-Günther et al., 2021). Moreover, it is thinkable that although no overall effect was found, certain subgroups may well have benefitted from the optimism induction, which will be discussed below.

While state measures of optimism and pain catastrophizing in our study were not associated, trait measures of optimism (*LOT-R*) and pain catastrophizing (*PCS*) were moderately (in the experimental group strongly and significantly) negatively correlated with each other. This confirms the above-mentioned findings by Hood et al. (2012) and Goodin et al. (2013) on the negative association of optimism with pain catastrophizing and underlines the need for differential analyses—and eventually treatments—taking into account prior individual differences or "risk factors" which render certain subgroups especially responsive for certain types of interventions.

Influence of Optimism Induction on Situational Pain Catastrophizing Dependent on Level of Dispositional Pain Catastrophizing (Hyp.2)

Since the expected main effect of the optimism induction on situational pain catastrophizing was not found, it seems particularly interesting to look for moderating variables to identify possible subgroups which might nevertheless benefit from the optimism induction. To begin with, our model including dispositional pain catastrophizing (PCS) revealed that higher PCS scores were associated with higher situational catastrophizing (SCQ). This is in accordance with traditional state–trait theories and with prior empirical evidence (Quartana et al., 2009; Campbell, 2010a,b; Sturgeon and Zautra, 2013).

More importantly, in line with our hypotheses, there was a significant time x condition x PCS second order interaction effect, providing evidence that depending on participants' level of trait pain catastrophizing, the optimism induction acts to different degrees on their situational pain catastrophizing. In other words, the association of PCS with SCQ scores varied dependent on experimental condition (optimism or control group) and time of measurement (pre vs. post-optimism induction). In order to get an impression on which difference(s) exactly this global second order interaction effect might be based on, correlations were calculated separately for both groups at both assessment times (pre/post). As shown by the correlation analyses, it descriptively appears that in the control group, PCS and SCQ scores are strongly and significantly correlated at both times of measurement. In contrast, in the optimism group, there is a similarly significant correlation in the first measurement but this correlation is lower and no longer significant after the optimism induction.

Regarding scores of situational pain catastrophizing, participants with low levels of dispositional pain catastrophizing tended to manifest comparably lower levels of situational pain catastrophizing, whether they received an optimism induction or not. In high trait pain catastrophizers, on the contrary, those in the BPS group would on average have a lower pre–post increase of situational pain catastrophizing than those in the TD group. This suggests that the impact of dispositional catastrophizing on situational catastrophizing is attenuated by the optimism induction. The trait's manifestation in the actual pain situation (Tett and Guterman, 2000) seems to be counteracted by situational optimism. Thus, high dispositional pain catastrophizers benefitted more from the optimism induction as regards their situational pain catastrophizing than low dispositional pain catastrophizers. These results—though still wanting an inferential statistical testing in larger samples—provide preliminary results for resilience models according to which protective factors such as optimism buffer against risk factors such as pain catastrophizing (for example, Catalano et al., 2011).

Participants with *low* trait pain catastrophizing in the BPS condition descriptively showed a pre-post SCQ increase, while in the TD group, low trait pain catastrophizers' situational pain catastrophizing remained almost the same. Possibly, the descriptively observed increase was caused by some participants who tended to downplay their catastrophizing thoughts in the PCS and the first SCQ measurement but were more open about these thoughts in the more optimistic state induced by the writing task. Thus, there would not have been a change in actual catastrophizing but only in the willingness to report it. A similar speculation was made concerning the pre–post increase in facial expression of pain in the BPS group in the study by Basten-Günther et al. (2021), which was interpreted as reflecting participants' increased openness and readiness to communicate their pain after being made more optimistic.

Both optimism and pain catastrophizing have been ascribed a communicative, interpersonal function (Dougall et al., 2001; Brissette et al., 2008). As proposed by the "communal coping model," pain catastrophizing could serve as a coping strategy aiming at amplifying pain experience and pain behavior in order to pursue relational goals such as maximizing proximity or soliciting assistance and empathic responses from one's social environment (Keefe et al., 2000; Sullivan et al., 2001, 2004). It is thinkable that in optimists, pain catastrophizing is more dispensable as a coping strategy because optimism in itself leads to higher perceived social support (Dougall et al., 2001; Brissette et al., 2008) and possibly more trust in the social environment, which might subsequently provoke increased pain communication. Indeed, as reported above, the analysis of facial responses in the first part of the study (Basten-Günther et al., 2021) showed stronger facial expression of pain after the optimism induction. As most of the mentioned studies do not distinguish between state and trait optimism/catastrophizing,

more research is needed to clarify to which of these concepts and in what way these considerations apply.

Influence of Optimism Induction on Situational Pain Catastrophizing Dependent on Level of Dispositional Optimism (Hyp.3)

Including the LOT-R score as a covariate in the ANCOVA, there was no main or interaction effect of trait optimism regarding situational pain catastrophizing. Therefore, in accordance with prior findings (Harrist et al., 2007; Peters et al., 2010; Hanssen et al., 2013), trait optimists do not seem to have benefitted more or less from the optimism induction and trait optimism does not seem to have acted directly on situational pain catastrophizing in our study. Nevertheless, there was a negative correlation between trait optimism (*LOT-R*) and SCQ which was moderately strong and significant in the SCQ pre measurement but only weak and no longer significant in the post measurement. Regarding the two experimental conditions, it descriptively appears that only in the BPS group, the association falls from pre: $r = -0.412$ ($p = 0.071$) to post: $r = -0.159$ ($p = 0.504$; TD group: pre: $r = -0.224$, $p = 0.343$; post: $r = -0.161$, $p = 0.497$). These correlations might cautiously be interpreted as a hint for a compensatory mechanism: due to our optimism manipulation, the association between trait optimism and situational pain catastrophizing seems to be weakened which could mean that the optimism induction somehow levels out effects of prior interindividual differences in optimism. Consequently, participants low in dispositional optimism might benefit slightly more from the optimism induction compared with participants who dispose of high optimism regardless of the writing task, as a result of their general disposition to view things—including pain—in a more positive way. However, given the fact that these correlations were not significant and our hypothesis was not confirmed by the ANCOVA, these are only cautious speculations which would need to be explored in further studies.

Limitations

The present study is to our knowledge the first to examine the effect of an experimental optimism induction on situational pain catastrophizing. While well-established measures for optimism and pain catastrophizing were used, it would still be interesting to compare our results with studies using different questionnaires such as, for example, the Coping Strategies Questionnaire (*CSQ*; Rosentiel and Keefe, 1983) to measure trait catastrophizing. It also has to be stressed that the BPS optimism induction does not aim at fostering unrealistic optimism, which is also called wishful thinking and could have adverse effects in pain conditions (Jefferson et al., 2017), but instead at increasing realistic optimism, leading to the maintenance of a positive outlook on life despite pain (Nes and Segerstrom, 2006; Esteve et al., 2007). Our sample was balanced with regard to sex and age and the experimental manipulation of optimism allows for causal conclusions and the control of many confounding variables. Referencing pain catastrophizing to a preceding experimental pain—compared to recalling a past clinical pain experience—provides a high standardization. It nevertheless has to be taken into account that the study only included healthy participants in an experimental setting. Therefore, it would firstly be interesting to examine the generalizability of our results to naturalistic, everyday contexts where pain experiences can be less predictable and less controllable than during experimental pain and therefore possibly provide more opportunity for catastrophizing thoughts and feelings or else to experimentally manipulate predictability and controllability. Secondly, applying the paradigm in clinical, possibly post-operative or chronic pain populations with higher levels of pain catastrophizing appears as a logical next step. While we did not find any association between catastrophizing and pain outcomes, this relation has been found in clinical populations which tend to display higher levels of pain catastrophizing (for example, Granot and Ferber, 2005). Furthermore, the relation between situational catastrophizing and *chronic* pain should be studied as well. It has to be stressed, however, that regardless of the effects on pain, catastrophizing in itself constitutes a large burden implying huge mental distress, which is way diminishing it must be seen as clinically relevant *per se* (Petrini and Arendt-Nielsen, 2020). However, it has to be kept in mind that on the individual level, not all participants responded to the optimism induction. A small number of participants showed no increase or even decreases in situational optimism. An investigation of these non-responders could provide useful insights. Lastly, it has to be acknowledged that our sample size was 40, which appears adequate given the high time expense and staff effort of conducting a 2-h experimental pain session, but nevertheless could constitute a certain risk for a lack of power in detecting effects, particularly with the second-order interactions. For this reason, results should be treated with some caution, and we strongly recommend validating our findings and testing the contrasts in the second-order interaction in studies with larger sample sizes.

Conclusion

In the present study, the effect of an experimental optimism manipulation on situational pain catastrophizing was moderated by participants' level of trait catastrophizing. Descriptively, it appeared that participants with higher trait pain catastrophizing benefitted more from the optimism manipulation in that they showed a less pronounced increase in situational pain catastrophizing than the control group. These results support resilience models stressing the buffering role of optimism. Further research is needed to validate the findings in larger sample sizes and to test the buffering function of optimism in everyday pain and in clinical populations. By developing preventive or therapeutic interventions which focus on subgroups at risk, optimism-fostering visualization techniques, which have been shown to lead to longer-term benefits when applied repeatedly (Peters et al., 2017; Molinari et al., 2018 for preliminary evidence in fibromyalgia patients; Malouff and Schutte, 2017; Carrillo et al., 2019 for meta-analyses), could become an important complement to existing cognitive-behavioral and other approaches.

DATA AVAILABILITY STATEMENT

The raw data supporting the conclusions of this article will be made available by the authors, without undue reservation.

ETHICS STATEMENT

The studies involving human participants were reviewed and approved by the Ethikkommission, Otto-Friedrich-Universität, Bamberg. The patients/participants provided their written informed consent to participate in this study.

AUTHOR CONTRIBUTIONS

All authors listed have made a substantial, direct, and intellectual contribution to the work and approved it for publication.

SUPPLEMENTARY MATERIAL

The Supplementary Material for this article can be found online at: https://www.frontiersin.org/articles/10.3389/fpsyg.2022.900290/full#supplementary-material

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Anhang 4

Basten-Günther, J., Jutz, L., Peters, M. L., Priebe, J. A., & Lautenbacher, S. (2023). The effect of induced optimism on early pain processing: indication by contact heat evoked potentials (CHEPs) and the sympathetic skin response (SSR). *Social Cognitive and Affective Neuroscience*, nsad042. Doi: 10.1093/scan/nsad042

OXFORD

Social Cognitive and Affective Neuroscience, 2023, **18**(1), 1–11

DOI: https://doi.org/10.1093/scan/nsad042
Advance Access Publication Date: 1 September 2023
Original Manuscript

The effect of induced optimism on early pain processing: indication by contact heat evoked potentials (CHEPs) and the sympathetic skin response (SSR)

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Abstract

Situationally induced optimism has been shown to influence several components of experimental pain. The aim of the present study was to enlarge these findings for the first time to the earliest components of the pain response by measuring contact heat evoked potentials (CHEPs) and the sympathetic skin response (SSR). Forty-seven healthy participants underwent two blocks of phasic thermal stimulation. CHEPs, the SSR and self-report pain ratings were recorded. Between the blocks of stimulation, the 'Best Possible Self' imagery and writing task was performed to induce situational optimism. The optimism manipulation was successful in increasing state optimism. It did, however, neither affect pain-evoked potentials nor the SSR nor self-report pain ratings. These results suggest that optimism does not alter early responses to pain. The higher-level cognitive processes involved in optimistic thinking might only act on later stages of pain processing. Therefore, more research is needed targeting different time frames of stimulus processing and response measures for early and late pain processing in parallel.

Keywords: pain; pain-evoked potentials; EEG; optimism; resilience

Introduction

Optimism is commonly defined as generalized positive expectancies concerning the future (Scheier and Carver, 1985). Among other positive health-related outcomes, optimism is reportedly related to less experimental and less acute and chronic clinical pain (for overviews, see Garofalo, 2000; Goodin and Bulls, 2013; Basten-Guenther *et al.*, 2019). Thus, it may be a pain resilience factor, i.e. a pain-protecting personal characteristic.

To establish a causal link, an experimental manipulation of optimism is essential. The Best Possible Self (BPS) imagery and writing task (King, 2001) has repeatedly and successfully been used to induce state optimism (Peters *et al.*, 2010; Hanssen *et al.*, 2013; Boselie, *et al.*, 2014; Basten-Günther *et al.*, 2021), leading to lower pain ratings (Hanssen *et al.*, 2013, but not in Basten-Günther *et al.*, 2021; Boselie *et al.*, 2014), as well as to changes in facial expression of pain, attentional preference and executive functioning (Boselie *et al.*, 2014; Peters *et al.*, 2016; Basten-Günther *et al.*, 2021).

According to the four-stage model of pain processing proposed by Price (1988) and Wade *et al.* (1992), the earliest stage in pain processing comprises the sensory-discriminative dimension. As a second stage, immediate unpleasantness is added. Suffering and first elements of pain behaviour are integrated into stages 3 and 4 (Wade *et al.*, 1996).

Based on this model, the present study aims at examining for the first time the effect of optimism on the earliest stages of pain processing. For this reason, nociceptive-evoked brain potentials and the sympathetic skin response (SSR) are recorded (Price and Bushnell, 2004).

To evoke nociceptive potentials, contact heat was applied. Phasic stimuli with a steep onset and of a short duration have been established as preferable for measuring early nociceptive potentials, whereas tonic stimuli might be more useful for tapping later stages of pain processing (Kobal *et al.*, 1994). The second negative (N2) and second positive (P2) peaks after stimulus onset were measured as contact heat evoked potentials (CHEPs). These, as well as their difference, the N2P2 complex, reflect early sensory processing which precedes more elaborate cognitive appraisal (Chen *et al.*, 2006; Granovsky *et al.*, 2008). CHEPs are a well-established psychophysiological pain measure providing nociceptive specificity and high diagnostic accuracy (Granovsky *et al.*, 2008; Di Stefano *et al.*, 2020). Since the N2P2 amplitude is

Received: 9 September 2022; **Revised:** 26 June 2023; **Accepted:** 29 August 2023

positively correlated with both the physical and subjective intensities of the noxious stimulus (García-Larrea *et al.*, 1997; Iannetti *et al.*, 2005; Kramer *et al.*, 2016), an optimism effect, i.e. a dampening of pain processing, could also be mirrored in a lower amplitude of nociceptive brain potentials.

The SSR reflects changes in the electrical potential of the skin caused by autonomic activation of the sweat glands (Jörg and Boucsein, 1998; Vetrugno *et al.*, 2003). The SSR is a somatosympathetic reflex consisting of spinal and subcortical components (Vetrugno *et al.*, 2003) and therefore likewise belongs to immediate responses, which can be activated by nociceptive stimuli. While the effect of optimism on the SSR during pain has so far not been examined, optimism has been associated with a weakened reaction of the autonomic nervous system in a prior study measuring cardiac responses as pain-related outcomes (Geers *et al.*, 2008). It can therefore be hypothesized that the SSR is likewise reduced by an optimism induction.

To examine whether there is a selective effect of optimism on the perception of painful, rather than heat stimuli in general, both non-painful and painful heat stimuli are used. We expect that optimism impacts only or at least more strongly on painful stimuli.

Our hypotheses are as follows: first, we hypothesize that induced optimism leads to lower amplitudes of both early CHEPs and the SSR during phasic painful heat stimuli. Second, we hypothesize that induced optimism leads to lower self-report pain ratings of these stimuli.

Methods

Participants

A total of 47 healthy, pain-free individuals participated in the current study. Of them, 57% were women ($n = 27$). Age ranged from 18 to 35 years [mean (±s.d.) age: 23.13 (±3.75) years]. The sample size was computed in G*Power based on the literature-based assumption of moderate effect sizes of psychological variables on pain responses (Thorn *et al.*, 2004; George *et al.*, 2007). The following parameters were entered in G*Power: statistical test = repeated measures analysis of variance (ANOVA), within-between factor interaction, alpha level = 0.05, estimated effect size = 0.25, number of groups = 2, number of measurements = 2 and correlation among repeated measures = 0.60. Participants were recruited via advertisements and mailing lists in the local university (Bamberg, Germany). The exclusion criteria were current experience of acute or chronic pain, psychological or physical illnesses, pregnancy or pain-influencing medication. These were assessed via self-report. Participants were asked not to take alcohol or other psychotropic drugs 24 h before the experiment, not to consume cigarettes 1 h before the experiment and to postpone the appointment if the participants developed clinical pain or if any central nervous system-relevant medication had to be taken on that day. All participants provided informed consent and received course credits or monetary compensation. The study protocol was approved by the ethics committee of the University of Bamberg (Bamberg, Germany).

Procedure

General protocol (Figure 1)

The experiment consisted of one laboratory session. After providing informed consent and demographic information (age, sex; use of contraception and phase of the menstrual cycle for women) and filling out the trait questionnaires (Pain Catastrophizing Scale: 'PCS', Life Orientation Test-Revised Version: 'LOT-R'), the electrodes for the CHEPs and the SSR were attached. Having received instructions, participants practiced giving their ratings on five stimuli with temperatures of either 45°C or 51°C in a randomized order. After these trials, the first block containing 40 stimuli of either 45°C or 51°C (see later for details) was administered. Directly afterwards, the state questionnaires 'Future Expectancies Scale' (FEX; Hanssen *et al.*, 2013) and the 'Positive and Negative Affect Schedule' (PANAS; Watson *et al.*, 1988), which served as a manipulation check to register changes in affect and situational optimism, were filled out for the first time (pre-measurement). Subsequently, the experimental manipulation ('BPS' or 'Typical Day' (TD) imagery and writing task) was performed. After filling out the 'FEX' and 'PANAS' for a second time (post-measurement), participants received the second block of painful stimulation consisting again of 40 stimuli. During both blocks of stimulation, CHEPs, SSR and self-report pain ratings were recorded. After roughly 2 h with intermittent breaks, the participants were thanked and debriefed, and the session was concluded.

Experimental manipulations

Optimism induction. Situational optimism was induced with the BPS manipulation, a positive future-thinking technique based on work by King (2001), which has been repeatedly and successfully used before in experimental studies (Peters *et al.*, 2016; Traxler *et al.*, 2019; Basten-Günther *et al.*, 2021). Participants were instructed to carry out a writing and imagery exercise. In a randomized order, half of the participants were assigned to the BPS condition ($n = 24$), which required them to write about their life in the future where everything had turned out for the best. The other half of the participants were assigned to the control condition ($n = 22$), whose task consisted of writing about a TD. The instructions for BPS and TD were as follows (Sheldon and Lyubomirsky, 2006):

- BPS condition:

  Thinking about your best possible self means that you imagine yourself in the future, after everything has gone as well as it possibly could. You have worked hard and succeeded at accomplishing all the goals of your life. Think of this as the realization of your dreams, and that you have reached your full potential.

- TD condition:

  Thinking about your typical day means that you take notice of ordinary details of your day that you usually don't think of. These might include particular classes or meetings you attend to, people you meet, things you do, typical thoughts you have during the day. Think of this as moving through your typical day, hour after hour.

Both manipulations had the same procedural format: participants were requested to think for 1 min about what to write, then to write uninterrupted for 15 min, followed by 5 min of imagining the story they had just been writing. Instructions were given both verbally and in writing. The manipulation check was followed immediately by asking the participants to fill out the FEX and PANAS for a second time to register changes in situational optimism and affect and to answer three questions about the valence, vividness and positivity of their imaginations ['Quality of Imagery' (QoI); Peters *et al.*, 2010] to check whether the imagination task was carried out successfully.

Fig. 1. General protocol of the experiment.

Pain induction. Contact heat evoked brain potentials (CHEPs) and skin potentials (SSR) were elicited with a CHEP sensory and pain evaluation stimulator (CHEPS; Medoc, Israel). Participants received 40 phasic heat stimuli per block, which had fixed temperatures of 45°C for 50% of the stimuli and 51°C for the other 50% (a baseline temperature of 35°C, a plateau duration of 10 ms, a rate of rise/fall of 70°C/40°C per second and an interstimulus interval of 15 s). In accordance with prior studies, the 45°C stimuli were expected to be perceived as non-painful but still clearly distinguishable from the baseline temperature and to elicit the same types of evoked potentials (N2 and P2) as painful stimuli, albeit with a smaller amplitude (Granovsky *et al.*, 2008). The 51°C stimuli were expected to be rated as painful (Le Pera *et al.*, 2002; Granovsky *et al.*, 2008; Roberts *et al.*, 2008; Campbell *et al.*, 2010). Participants were instructed that there were going to be both 'weak' and 'strong' stimuli. They were thus not aware that there were only two different intensities. The sequence of the 45°C and 51°C stimuli was randomized once and then set for all participants. Rules for randomization were that per 10 stimuli there had to be five painful and five non-painful stimuli. Each set of 10 stimuli was randomized separately by drawing the order of 10 pieces of paper, five of which were labelled with 'painful' on the inside, five labelled with 'non-painful'. All stimuli were applied to participants' volar part of the left forearm (2–4 cm beneath the cubital joint) with a round surface stimulator of a 27 mm diameter. The thermode was held by the experimenter, allowing for flexible placement to prevent receptor fatigue and peripheral habituation. It was moved several millimetres after each stimulus so that the overlapping positions described a full circle across the upper inner part of the forearm during each block of stimulation (Priebe *et al.*, 2016). 2000 ms before each stimulus, a small light located in front of the participant lit up for 500 ms to indicate the imminent stimulus onset.

Measures

Contact heat evoked potentials

Electroencephalography (EEG) recording drew upon the guidelines proposed by Keil *et al.* (2014). Recording was accomplished by a BrainAmp DC amplifier (Brain Products GmbH, Germany) with a sampling rate of 500 Hz and a recording bandwidth from 0.15 to 100 Hz. For electrode placement, a commercial cap with 20 tin electrodes (Electro-Cap International Inc, Eaton, OH, USA) realizing the international 10–20 system (Silverman, 1963) was used. For our study, we recorded from Cz (central, reference), Pz (parietal) and Fz (frontal). Further electrodes were placed on the mastoids (A1, A2) for offline re-referencing the data in order to regain Cz. The ground was placed between Fz and Fpz. In addition, tin electrodes were placed above and below the right eye for a vertical electrooculogram (EOG) and on the outer canthi for a horizontal EOG to correct evoked potentials for eye movements and blinks. To keep the impedances low, the respective skin parts were cleansed with ethanol, dead skin cells were removed and a gel for improving electrical connectivity (Electro-Cap International Inc, USA) was applied. Participants were instructed to move as little as possible and keep a relaxed sitting position. As soon as impedances on the EEG recordings were <5 kΩ for all EEG electrodes and <8 kΩ for all EOG electrodes, and the signal seemed free of disturbances by movements, the stimulation protocol was started.

Data parameterization. To determine N2 and P2 amplitudes as well as N2P2 peak-to-peak amplitudes, EEG data were analysed offline in the BrainVision Analyzer (Brain Products, Germany) following the protocol described by Granovsky *et al.* (2008) and Priebe *et al.* (2016). Data were segmented from 100 ms before to 2000 ms after stimulus onset. The 100 ms before stimulus onset was used for baseline correction. Automatic and manual artefact correction tracked all potentials with amplitudes less than −50 μV and more than +50 μV, with differences of >50 μV between two consecutive sampling points or with differences of >100 μV between the most positive potential and the most negative potential. Segments with artefacts were excluded from all analyses. Only data from Cz were analysed as N2P2 has been shown to be highest at this site (García-Larrea *et al.*, 1997). For each block, averages were calculated for the 20 potentials evoked by the 45°C stimuli as well as for the 20 potentials evoked by the 51°C stimuli. If <70% (i.e. 14 out of 20) of the trials per stimulus category (45°C or 51°C) were free from artefacts, a missing value was entered for this stimulus category. The averaged signals were used to determine two components: based on the study by Priebe *et al.* (2016), N2 was defined as the most negative peak in a time window from 200 to 500 ms; P2 was defined as the most positive peak in a time window from 400 to 650 ms. As latencies of these peaks may slightly vary depending on different factors such as the heating rate of the stimulator or the distance of the site of stimulation from the brain, time windows were chosen a little more liberally than with Granovsky *et al.* (2008). Visual and statistical inspection confirmed that peaks in our data occurred during the chosen time windows (N2: average 353.43 ms; P2: average 523.18 ms) and that latencies were comparable to those found in prior studies. For further analyses, the peak-to-peak N2P2 amplitude, i.e. the absolute difference between the voltage of the N2 and the P2, was calculated. Consequently, four N2-, P2- and N2P2-difference amplitude scores resulted for each subject (45°C pre, 45°C post, 51°C pre and 51°C post). N2 and P2 latencies were not kept for further analyses as stimulus intensity has been shown to be associated with N2 and P2 amplitudes, but not with their latencies for other pain modalities (Iannetti *et al.*, 2005).

Sympathetic skin response

SSRs were assessed by use of the SUEmpathy100 (SUESS Medizintechnik, Germany). The skin was prepared as described with the CHEPs. Afterwards, the measurement electrode was fixed on the thenar eminence of the right hand, and the reference electrode was fixed on the proximal third of the right forearm (Jörg and Boucsein, 1998). The ground electrode was fixed on the lateral part of the right elbow. The biosignal was sampled at a rate of 512 Hz.

Following the protocol described in detail by Dittmar *et al.* (2015), SSR data were analysed in order to determine the peak-to-peak amplitude between the first negative peak (N1) and the

subsequent positive peak (P1), i.e. the N1P1-difference amplitude (Kucera *et al.*, 2004). To be valid, an N1P1 complex had to show a first deflection from zero before 2.1 s and a latency of P1 <6 s. The amplitudes of all valid stimuli were averaged for each category of stimulus intensity (45°C pre, 45°C post, 51°C pre and 51°C post). Thus, four N1P1-difference amplitude values resulted for each subject. In case of <70% (i.e. 14 out of 20) of valid trials in a category, a missing value was entered for this category.

Self-report pain ratings

Participants were instructed to rate the perceived painfulness of each stimulus by answering two questions after each stimulus: (I) was this stimulus painful? (II) How painful was this sensation? For the first question, a dichotomous answer (yes or no) had to be given. For the second question, participants had to choose the respective category from an 11-point numeric rating scale (NRS) ranging from 0 ('not painful at all') to 10 ('most intense pain imaginable'). Answers were given orally, recorded and transcribed after the experiment. Participants were asked to give their rating without request after they had sensed the stimulus but were reminded by the experimenter if necessary.

Questionnaires

Trait questionnaires

Life Orientation Test-Revised The validated German version (Krohne *et al.*, 1996) of the LOT-R (Scheier *et al.*, 1994) was used to assess the level of dispositional optimism. The LOT-R has 10 items that are rated on a 5-point Likert scale, ranging from 0 ('strongly disagree') to 4 ('strongly agree'). There are three positively phrased items, three negatively phrased items and four filler items. A total score was calculated after reversing the negatively phrased items.

Pain Catastrophizing Scale. A German translation (Meyer *et al.*, 2008) of the PCS (Sullivan *et al.*, 1995) was used to assess habitual catastrophic thinking related to pain. The PCS has been widely used in research on pain catastrophizing (Wheeler *et al.*, 2019). Participants are instructed to reflect on thoughts or feelings during past painful experiences. The scale comprises 13 items that are rated on a 5-point scale, with the end-points 'not at all' and 'all the time'.

State questionnaires

Future Expectancies Scale. The FEX (Hanssen *et al.*, 2013) was administered to assess state optimism. A German translation of the questionnaire was used, which has been translated in a standard 'forward-backward' procedure and used in prior studies by the authors (Peters *et al.*, 2016; Basten-Günther *et al.*, 2021). The FEX consists of 10 statements describing a positive future event and 10 statements describing a negative future event. Participants rate the likelihood that they will experience each specific event on a 7-point Likert scale, ranging from 1 ('not at all likely to occur') to 7 ('extremely likely to occur'). The FEX has previously been demonstrated to be responsive to the 'BPS' optimism manipulation (Hanssen *et al.*, 2013; Boselie *et al.*, 2014; Basten-Günther *et al.*, 2021). The subscores FEX positive and FEX negative were used for further analyses.

Positive and Negative Affect Schedule. Mood was assessed with the PANAS (Watson *et al.*, 1988). The PANAS consists of 10 items measuring positive affect and 10 items measuring negative affect. Participants indicate the degree to which a certain feeling is present at that moment on a 5-point Likert scale ranging from 1 ('not at all') to 5 ('extremely'). The subscores PANAS positive affect (PANAS_PA) and PANAS negative affect (PANAS_NA) were used for further analyses. For the PANAS, a validated German version was available (Glaesmer *et al.*, 2008), which has repeatedly been used before (Peters *et al.*, 2016; Basten-Günther *et al.*, 2021).

Quality of Imagery: Two 10 cm visual analogue scales (VASs) were used to rule out qualitative differences in participants' imagery between the BPS group and the TD group. Participants were asked 'How well could you imagine yourself in the situation you described in your writing?' (not at all to extremely well) and 'How vivid were the pictures you imagined?' (not vivid at all to very vivid). A third 10 cm VAS was administered to determine whether imagery in the BPS group was more positive than in the TD group: 'How negative or positive were your imaginations?' (very negative to very positive). These questions have been used before with the BPS paradigm (Hanssen *et al.*, 2013; Basten-Günther *et al.*, 2021).

Statistical analyses

Manipulation check

To control whether the optimism induction was successful (manipulation check), four separate 2 × 2 repeated measures ANOVAs were computed. The PANAS and FEX subscales served as dependent variables, while the experimental condition was entered as the fixed factor. These ANOVAs were meant to analyse differences between the pre- and post-measurement, i.e. to detect changes in state affect and optimism induced by the experimental manipulation.

Independent samples *t*-tests were used to investigate group differences in each of the three scales of the 'QoI Questionnaire'.

To check the efficacy of the pain manipulation, chi-squared tests were applied to compare the frequency by which the 45°C stimuli and the 51°C stimuli were rated as painful, respectively. Besides, the main effect of stimulus intensity was tested in the analysis of covariance, which will be described in the following section.

Effect of optimism induction

CHEP data (N2P2-difference amplitudes and N2 and P2 amplitudes) and SSR data (N1P1-difference amplitudes), as well as the self-report pain ratings, were subjected to separate 2 × 2 × 2 repeated measures ANOVAs with the between-factor experimental condition (BPS *vs* TD) and the within-factors time of measurement (pre *vs* post) and stimulus intensity (45°C *vs* 51°C). According to our hypotheses, we expected a time × condition × intensity interaction effect showing a significant influence of the optimism induction on the outcome variables during truly painful stimuli (51°C).

All analyses were conducted with SPSS 24, and the alpha level was 0.05 (α) throughout.

Results

Descriptive statistics

Data of one participant who aborted the experiment during the TD imagery and writing task due to acute headaches were excluded. Thus, data of 46 participants (BPS: $n = 24$; TD: $n = 22$) were included in the analyses. Means and standard deviations for demographic variables, dispositional optimism ('LOT-R') and dispositional pain catastrophizing ('PCS') are shown in Table 1.

In the TD group, 54.5% ($n = 12$ out of 22) of participants were female, and in the BPS group, 58.3% ($n = 14$ out of 24) were female.

Table 1. Demographics and trait measures of optimism and pain catastrophizing—BPS, treatment group; TD, control group

	TD			BPS		
	$n = 22$			$n = 24$		
Sex: female	12 (54.5%)			14 (58.3%)		
	Mean (s.d.)	Min.	Max.	Mean (s.d.)	Min.	Max.
Age (years)	23.36 (3.36)	18	31	23.00 (4.18)	18	35
LOT-R	17.86 (2.75)	13	23	17.88 (3.60)	8	23
PCS	18.45 (6.03)	2	29	18.92 (6.14)	10	30

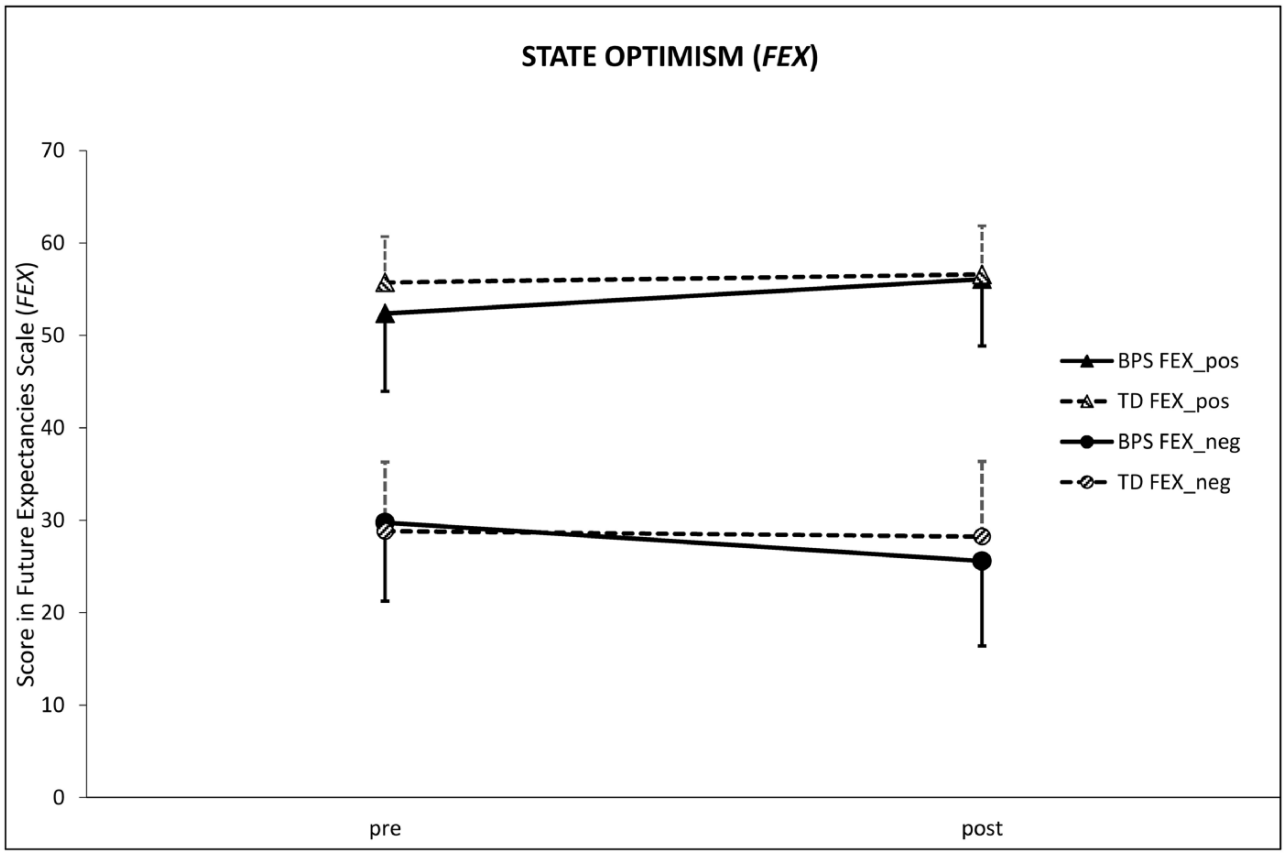

Fig. 2. Mean of state optimism (FEX_pos and FEX_neg) at baseline (pre) and after the experimental manipulation (post). A significant time × group interaction effect was found for both FEX subscales. Error bars = +1s.d. (TD)/−1s.d. (BPS). BPS, optimism group; TD, control group.

Manipulation check: optimism induction

To control whether the optimism induction was successful, state measures of optimism and affect were analysed.

Future Expectancies Scale

The significant time × group interaction effect, which we expected in the 2 × 2 repeated measures ANOVAs, was found for the FEX subscale negative future expectancies [$F(1, 44) = 9.42$, $P = 0.004$, $\eta p^2 = 0.18$], but not for the subscale positive future expectancies [$F(1, 44) = 7.15$, $P = 0.01$, $\eta p^2 = 0.14$]. As shown in Figure 2, negative future expectancies (FEX_neg) remained constant in the TD group from the first assessment to the second assessment [$t(21) = 0.62$, $P = 0.54$], whereas the BPS group scored significantly lower after than before the optimism induction [$t(23) = 4.77$, $P < 0.001$]. In the positive expectations subscale, the BPS group significantly increased from the pre- to the post-measurement [$t(23) = 4.11$, $P < 0.001$], while the TD group's level remained constant [$t(21) = 0.62$, $P = 0.54$].

Given these significant decreases in negative future expectancies after the BPS task, we can assume that the optimism manipulation was successful. This is in accordance with prior studies using the same paradigm (Peters *et al.*, 2010, 2016; Hanssen *et al.*, 2013; Basten-Günther *et al.*, 2021).

Positive and Negative Affect Schedule

State positive affect measured by the PANAS was influenced by the optimism induction as there was a significant time × group interaction effect for the subscale positive affectivity [$F(1, 44) = 4.13$, $P = 0.048$, $\eta p^2 = 0.09$]. As indicated by the *post hoc t*-tests, the groups did not differ in the pre-assessment [($t(44) = 0.092$, $P = 0.36$], while in the post-assessment, the BPS group scored significantly higher than the TD group [$t(44) = 2.57$, $P = 0.01$]. The BPS group's score significantly increased from the pre- to the post-measurement [$t(23) = 4.34$, $P < 0.001$], while the TD group's score remained constant [$t(21) = 0.06$, $P = 0.57$]. For the subscale PANAS negative affectivity, no time × group interaction effect was found [$F(1, 44) = 0.00$, $P = 0.995$, $\eta p^2 = 0.00$] (Figure 3).

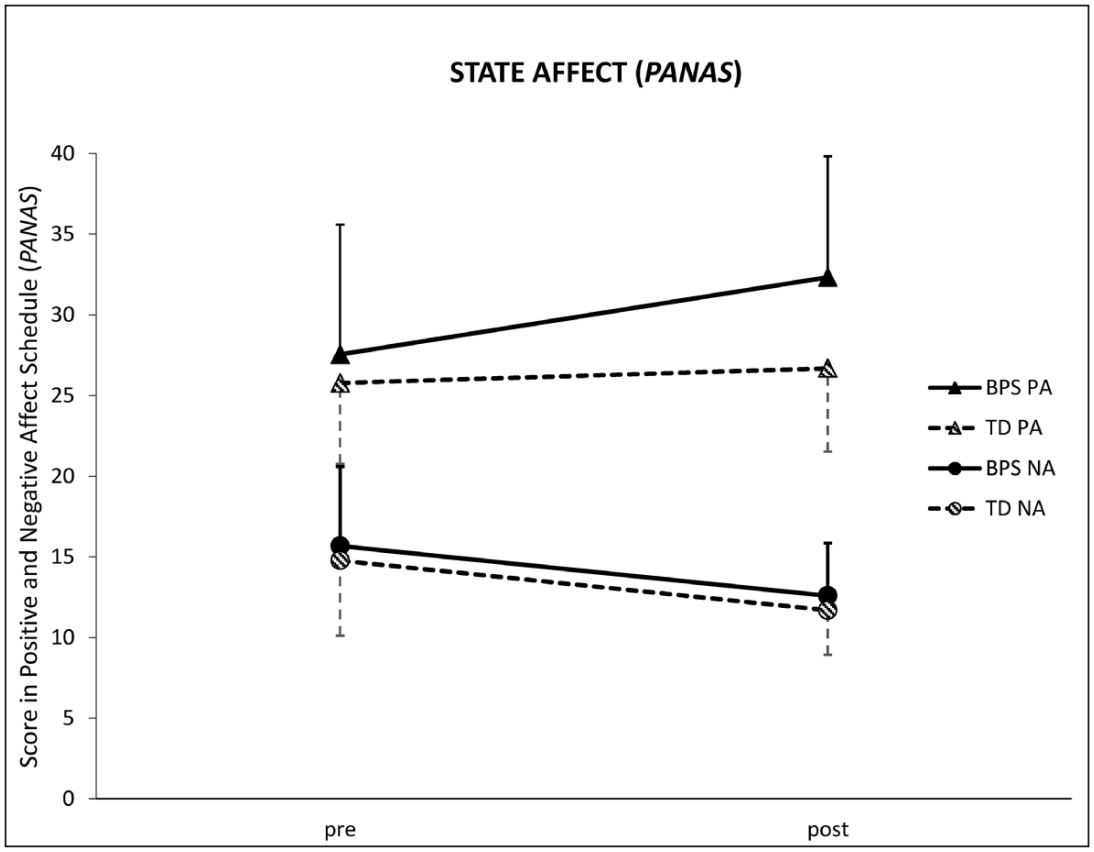

Fig. 3. Mean of PANAS state positive/negative affect (PA and NA) at baseline (pre) and after the experimental manipulation (post). Error bars = +1s.d. (BPS)/−1s.d. (TD). BPS, optimism group; TD, control group.

Quality of Imagery

The BPS and TD groups did not significantly differ in the VAS about the success [$t(44) = 1.39$, $P = 0.17$] and the vividness [$t(44) = 0.64$, $P = 0.59$] of their imaginations, which were assessed after the imagery/writing task. On the third question about the positivity/negativity of the imaginations, the BPS group scored significantly higher than the TD group [$t(44) = 3.15$, $P < 0.01$]. The observed differences between the groups in terms of state optimism therefore seem to be selectively due to a more positive content in the writing and imagery on part of the BPS group. This is in line with the aims of the BPS paradigm and further corroborates the assumption that our optimism manipulation was successful.

Effect of optimism induction: CHEPs (Figure 4)

CHEP data of 39 participants (BPS: $n = 21$, TD: $n = 18$) were valid (i.e. comprising <30% of trials per category with artefacts, as described in the Methods section) and could thus be included in the analyses. EEG plots are shown in Figure 5.

N2

Analyses of the amplitude of the N2 did not reveal a significant time × condition × intensity interaction effect [$F(1, 37) = 0.69$, $P = 0.41$, $\eta p^2 = 0.02$], implying that there was no selective effect of the optimism induction on the N2 during painful stimuli. Validating our stimulus intensity manipulation, the N2 was significantly more pronounced in the 51°C stimuli than in the 45°C stimuli [main effect of temperature: $F(1, 37) = 95.52$, $P \leq 0.001$, $\eta p^2 = 0.72$].

P2

In the amplitude of the P2, there was no significant time × condition × intensity interaction [$F(1, 37) = 0.55$, $P = 0.46$, $\eta p^2 = 0.02$], meaning that there was no selective effect of the optimism induction on the P2 during painful stimuli. As with the N2, there was a significant main effect of temperature [$F(1, 37) = 124.75$, $P \leq 0.001$, $\eta p^2 = 0.77$].

N2P2

In the N2P2 complex, no significant time × condition × intensity interaction effect was found [$F(1, 37) = 0.002$, $P = 0.96$, $\eta p^2 \leq 0.001$]. There was thus no selective effect of the optimism induction on the N2P2 during painful stimuli. The N2P2 was significantly larger in the 51°C stimuli than in the 45°C stimuli [main effect of temperature: $F(1, 37) = 157.24$, $P \leq 0.001$, $\eta p^2 = 0.81$].

Effect of optimism induction: SSR (Figure 6)

For the SSR, data of 42 participants (BPS: $n = 22$, TD: $n = 20$) were valid (i.e. comprising <30% of trials per category with artefacts, as described in the Methods section) and could thus be included in the analyses. No significant time × condition × intensity interaction effect was found [$F(40, 1) = 2.61$, $P = 0.11$, $\eta p^2 = 0.06$] (Figure 6). This means that the optimism induction did not selectively alter the SSR during painful stimuli. The SSR amplitude was significantly bigger in the 51°C stimuli than in the 45°C stimuli [main effect of temperature: $F(40, 1) = 59.49$, $P \leq 0.001$, $\eta p^2 = 0.60$]. Although the SSR was slightly bigger in the control group compared to the optimism group, this difference was non-significant [main effect of condition: $F(40, 1) = 2.238$, $P = 0.14$, $\eta p^2 = 0.05$].

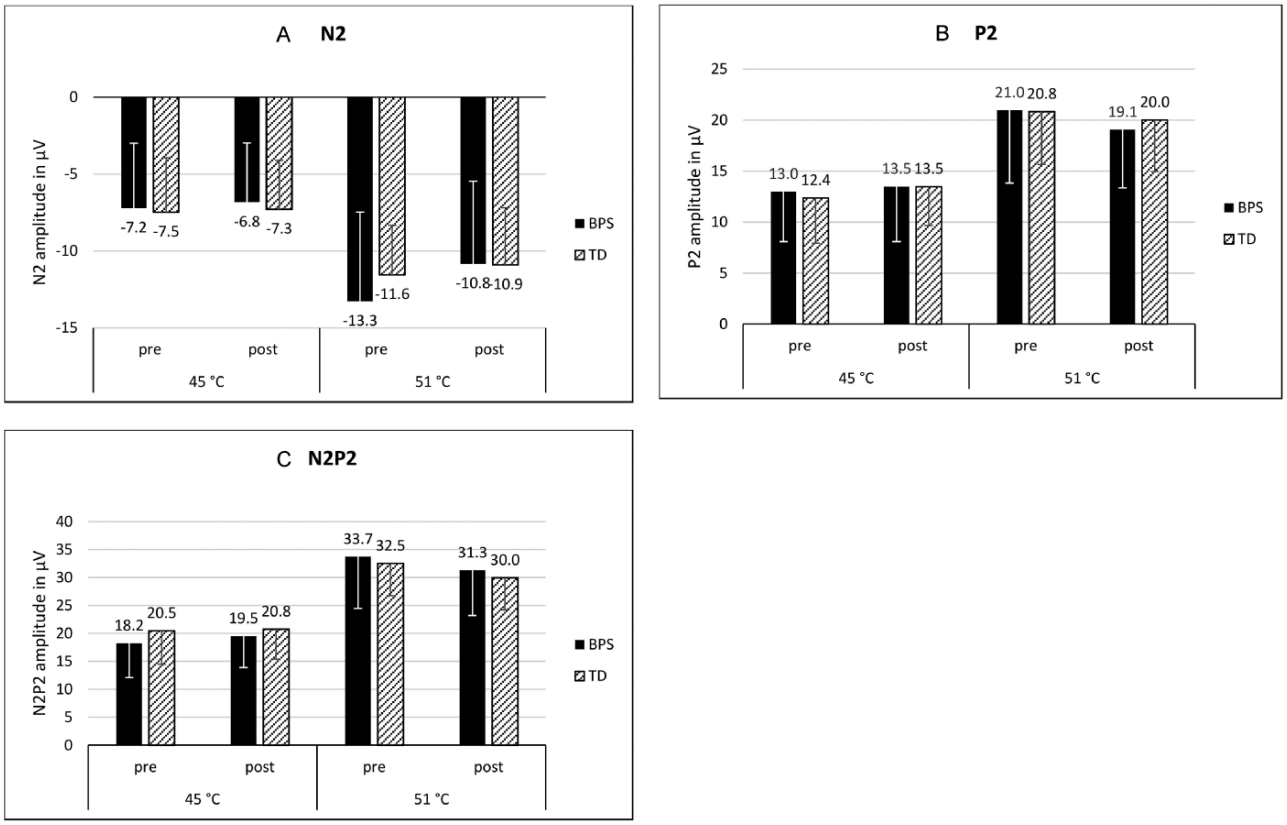

Fig. 4. Mean amplitude of the CHEPs depending on stimulus intensity, experimental condition and time of measurement. (A) N2 component, (B) P2 component and (C) N2P2 complex. Error bars = +1s.d. (N2)/−1s.d. (P2, N2P2). BPS, optimism group; TD, control group.

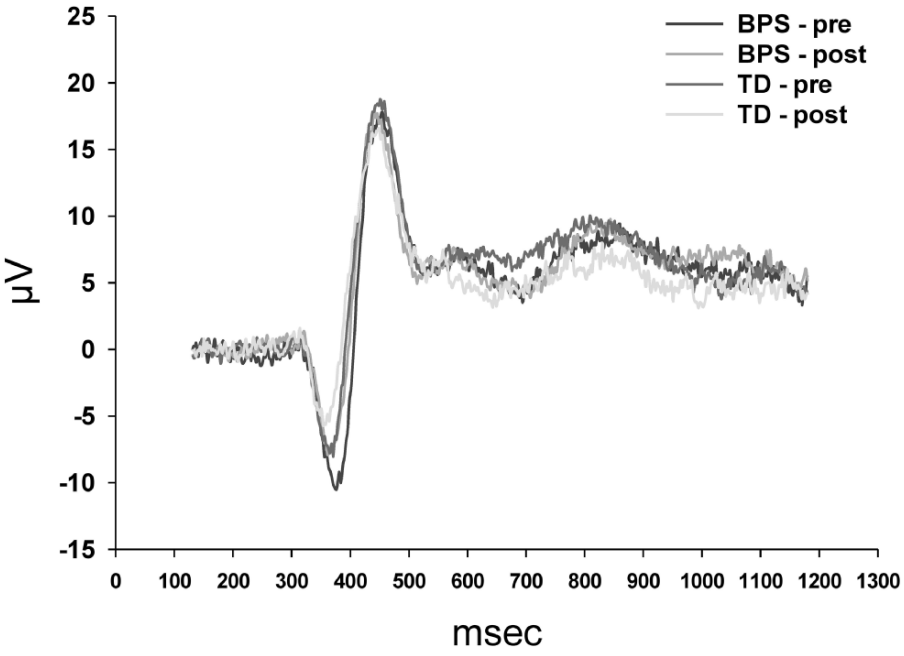

Fig. 5. CHEPs pre and post the induction of optimism (BPS) and in a control condition (TD) evoked by noxious heat (51°C/45°C). As can been seen, there were no differences between pre and post and between conditions (BPS/TD). The number of valid subjects was 39.

Effect of optimism induction: self-report pain ratings (Figure 7)

Dichotomous pain ratings (BPS: $n = 24$, TD: $n = 22$) significantly differed depending on stimulus intensity ($\chi^2(1) = 8.00$, $P = 0.005$). The 45°C stimuli were judged as non-painful with an average relative frequency of 0.42, compared to only 0.02 with the 51°C stimuli. The 51°C stimuli were thus very consistently perceived as painful.

As concerns self-report pain ratings on the NRS (BPS: $n = 24$, TD: $n = 22$), there was no significant time × condition × intensity interaction effect [$F(1, 44) = 0.45$, $P = 0.43$, $\eta p^2 = 0.02$], meaning

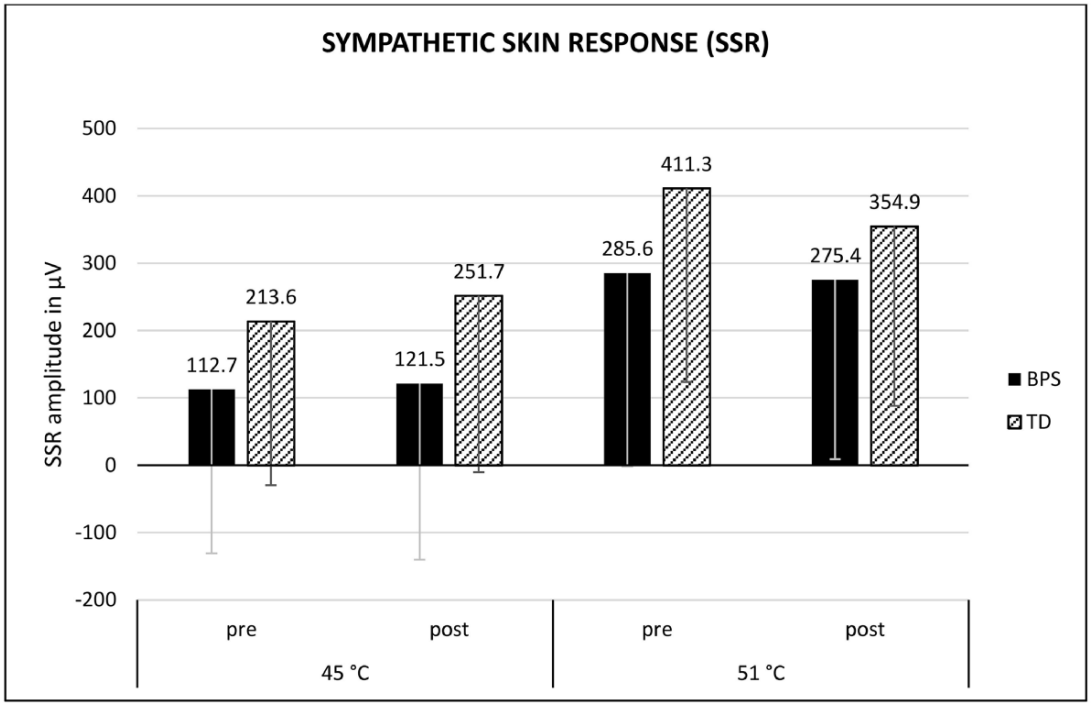

Fig. 6. Mean amplitude of the N1P1 complex (SSR) depending on stimulus intensity, experimental condition and time of measurement. Error bars = –1s.d. BPS, optimism group; TD, control group.

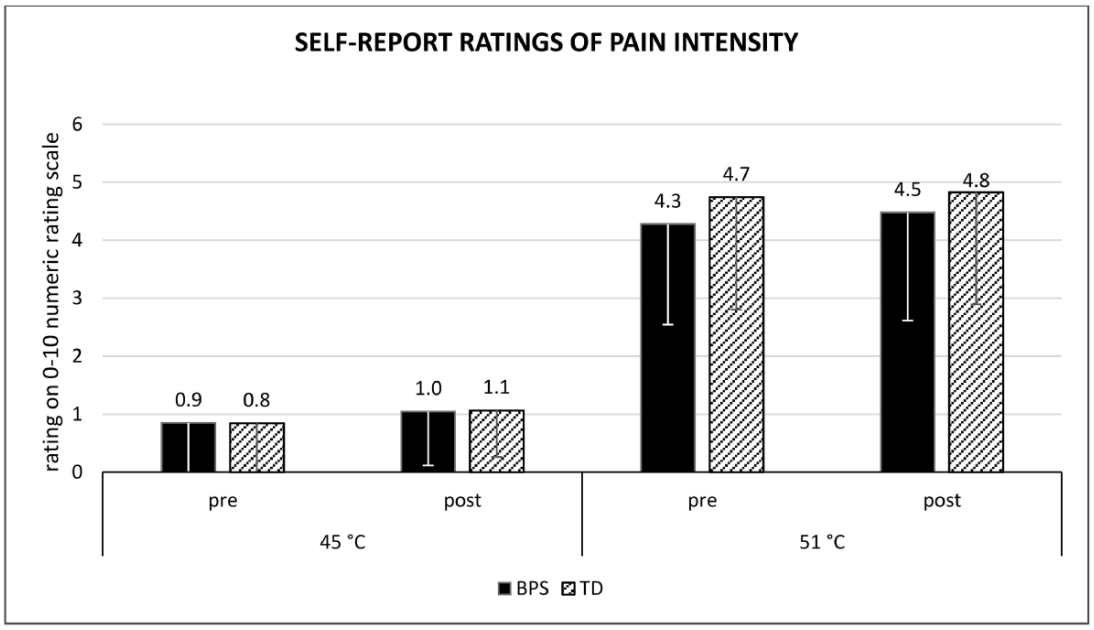

Fig. 7. Mean ratings of pain intensity depending on stimulus intensity, experimental condition and time of measurement. Error bars = –1s.d. BPS, optimism group; TD, control group.

that the optimism induction apparently did not influence how intense the painful stimuli were experienced (Figure 7). The 51°C stimuli were perceived as significantly more painful than the 45°C stimuli [main effect of temperature: $F(1, 44) = 289.00$, $P \leq .001$, $\eta p^2 = 0.87$]. Ratings of the painful stimuli correlated weakly to strongly (r between 0.1 and 0.4) with the N2, P2 and N2P2 components at the corresponding times of measurement (pre and post).

Discussion

In the present study, the effect of experimentally induced optimism on the earliest components of the response to contact heat stimulation was examined. While there is evidence that the manipulations of pain and optimism were successfully applied, our hypotheses were not confirmed. Consistently, all measured pain outcome variables (N2, P2 and N2P2 amplitudes of CHEPs; N1P1 amplitude of the SSR; self-report

pain intensity ratings) were not responsive to the optimism induction.

Optimism effect on early components of the pain response

To begin with, none of the early pain outcome variables measured in this study was influenced by the optimism induction. As elaborated in the introduction, these early components mainly reflect the processing of the sensory dimension of pain, i.e. of pain intensity. Therefore, our results indicate that induced optimism might not act on the immediate experience of pain intensity. It is of note that evoked potentials and the SSR are well-established psychophysiological pain measures that provide a high degree of objectivity as they are much less prone to individual cognitive biases than, for example, self-report ratings (Huang *et al.*, 2004; Granovsky *et al.*, 2008). Therefore, the fact that no optimism effect was found in these measures—while, in contrast, a clear reaction to the manipulation of stimulus intensity could be seen—underlines and in some way objectifies and validates findings on 'subjective' pain measures like self-report ratings, which were likewise unaffected by the optimism manipulation.

It is likely that optimism impacts differentially on different stages in pain processing: According to the four-stage model of pain processing described in the introduction (Price, 1988; Wade *et al.*, 1992), the first, i.e. earliest, stage in pain processing comprises the sensory-discriminative dimension which includes spatial, temporal and intensive features of the sensation. In the second stage, immediate unpleasantness (Wade *et al.*, 1996) is added. It has been shown that the first stage is not at all and the second stage only modestly influenced by individual beliefs, attitudes and reflections on pain. These exert a much bigger influence on the third stage (suffering) and the fourth stage (pain behaviour) (Harkins *et al.*, 1989; Wade *et al.*, 1992). More recent research confirms that early pain components as the P2 and N2 reflect the encoding of sensory aspects of pain (García-Larrea *et al.*, 1997; Iannetti *et al.*, 2005) in a 'first-order' nociceptive network (García-Larrea and Peyron, 2013), while appraisal processes have not yet started at that point of time (Wager *et al.*, 2006). Therefore, the effect of expectations and the assignment of meaning are only or at least more strongly reflected with later components of nociceptive processing (Zaslansky *et al.*, 1996; Wager *et al.*, 2004, 2006). Our finding that consistently—across all measured parameters—reactions at early stages of pain processing occurred unchanged despite the successful optimism induction is in line with this model. It provides more evidence that pain processing at early stages is not influenced by elaborate cognitive processes and characteristics as, in our case, optimistic thinking. Since the immediate responsivity of the nociceptive system was not influenced by optimism in our study, it could be worth re-examining whether significant effects of optimism on pain found in other studies reflect later stages of pain processing. This will be discussed in the following.

Comparison with studies demonstrating positive effects of optimism on pain

To explain the discrepancies between our findings and those of prior studies suggesting positive effects of optimism on pain ratings and autonomic pain responses, it could be helpful to examine the time frames of stimulation and response measurement.

Autonomic pain responses. While no prior evidence on cortical evoked potentials has to our knowledge been available, there is a study on sympathetic nervous system activity that shows a dampening influence of dispositional optimism on cardiac responses during a 2 min cold pressor task (Geers *et al.*, 2008). The fact that this study used the average heart rate and blood pressure during a tonic pain stimulation further corroborates our assumption that optimism only acts on later stages of pain processing which would be tapped by a measure sampling data over 2 min, while in our experiment, a potential optimism influence had not yet unfolded and was therefore not reflected in the SSR as an early pain component. As vegetative pain components are seen as part of or at least closely linked to affective pain responses (Dubé *et al.*, 2009; Boettger *et al.*, 2010), an influence of optimism on later autonomic activity via appraisal and coping processes, which have an impact on pain-related affect (Park and Sonty, 2010; Gruszczyńska and Knoll, 2015), would be plausible and should be examined in further studies.

Self-report pain ratings. For self-report ratings, a similar interpretation might apply: as with the SSR, no optimism effect on ratings of pain intensity was found, which is opposite to one study showing a significant influence of the BPS exercise on self-report ratings (Hanssen *et al.*, 2013). Given the successful optimism manipulation, one could therefore assume that, as argued earlier, the verbal reaction to the short, 10 ms pain pulses that we applied—although retrospectively assessed several seconds after the CHEPs—still reflects early stages of pain processing (stage 1 or 2 according to Price, 1988) when cognitive influences related to optimism are still not likely to have an effect. The fact that Hanssen *et al.* (2013) found a pain-dampening effect of optimism during a longer-lasting, tonic pain stimulation, namely a 2 min cold pressor task, and that of the three ratings given at 20, 40 and 60 s, the highest difference between the BPS group and the TD group was measured in the last rating at 60 s of immersion, supports this idea of late effects.

Since several other studies did not find an effect of the BPS task on self-report pain ratings either (Boselie *et al.*, 2014; Traxler *et al.*, 2019; Basten-Günther *et al.*, 2021), it cannot be ruled out that the effect of this optimism induction on experimental pain either does not exist or is rather weak, which would render significant results unlikely. More research is needed to clarify these speculations.

Limitations

The present study is to our knowledge the first to examine the effect of an experimental optimism induction on the earliest stages of pain processing by measuring pain-related CHEPs and the SSR. Due to the stimulation procedure, the experimenter was standing next to the participants. For this reaon, it has to be taken into account that the optimism–pain relationship might have been modified by social processes. Although the stimulation arrangement provides high ecological validity by resembling clinical examinations or treatment procedures and although a suchlike influence might be rather weak because participants were asked to focus their attention on the signal light in front of them, it seems nevertheless advisable to test for systematic social influences in future studies. Despite the random allocation of participants to the experimental conditions and although a randomization check was performed for some variables such as, for example, age, sex or the trait questionnaire scores, we cannot rule out that groups may still have differed in other, unknown variables which might have distorted the results. Since our study included only young, healthy participants, the results should be further validated in samples with older adults—in whom there are indications of stronger effects of optimism on

pain (Basten-Guenther *et al.*, 2019)—and in clinical populations. As indicated by the manipulation check, our use of the BPS seems to have been effective. Indeed, in a meta-analysis of different optimism-fostering interventions by Malouff and Schutte (2017), the BPS technique has been shown to provoke the strongest increases in participants' optimism. Nevertheless, it could be interesting to also study other optimism manipulations such as, for example, cognitive-behavioural or mindfulness-based exercises, and to apply interventions repeatedly over a longer period of time.

Conclusions and outlook

In the present study, the examined early components of the response to painful heat stimuli were consistently not influenced by an optimism induction. Our findings imply that early stages in pain processing, elaborating mainly on the sensory-discriminative dimension and the immediate pain affect (Price, 1988; Wade *et al.*, 1996), are likely not influenced by optimism. Future research could therefore include measures tapping both early and later stages of pain processing, comparing the influence of optimism on the different stages to look for further validation of our results and hypotheses. The present findings could be enlarged by studying other pain outcome variables such as different autonomic responses to pain, by applying different stimulus lengths and pain modalities and by transferring the paradigm to clinical populations.

Data Availability

The data underlying this article will be shared on reasonable request to the corresponding author.

Funding

None declared.

Conflict of interest

The authors declared that they had no conflict of interest with respect to their authorship or the publication of this article.

Acknowledgements

None declared.

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