Improving acute pain management with emotion regulation strategies: A comparison of acceptance, distraction, and reappraisal

Besserer Umgang mit akutem Schmerz mithilfe von Emotionsregulationsstrategien: Ein Vergleich von Akzeptanz, Ablenkung und Reappraisal

Doctoral thesis for a doctoral degree
at the Graduate School of Life Sciences,
Julius-Maximilians-Universität Würzburg,
Section Neuroscience

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Würzburg, 2022

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Acknowledgements

Nach vielen Jahren der Promotion am Lehrstuhl für Psychologie 1 der Universität Würzburg gibt es eine ganze Reihe an Menschen, die mich auf diesem Weg begleitet, gefördert und unterstützt haben.
Als Erstes möchte ich meinem gesamten Betreuerkomitee für die langjährige Betreuung meiner Promotion danken. Ich danke Prof. Dr. Paul Pauli für das Ermöglichen der Promotion, das konstruktive Feedback und die Betreuung in den vielen Kolloquien und Treffen, die immer für einen fachlichen und kollegialen Austausch sorgten und die Gemeinschaft an dem Lehrstuhl förderten. Ich danke Ihnen für Ihr Vertrauen und die Möglichkeit, als erste Promotionsstipendiatin am Standort Würzburg im Promotionsschwerpunkt „Resilienzfaktoren der Schmerzverarbeitung“ des Evangelischen Studienwerks Villigst e.V. mitwirken zu dürfen. Im Rahmen dieses Schwerpunkts, dem sich über die Jahre hinweg immer mehr Doktoranden anschlossen, ergaben sich unzählige sowohl fachliche als auch fachübergreifende Austauschmöglichkeiten, die ich sehr schätzte.
Ich danke außerdem ganz besonders meinem Doktorvater Prof. Dr. Matthias J. Wieser für die Betreuung, Unterstützung, Förderung und Geduld. Ich danke dir für die Zeit, die du dir immer genommen hast, sei es vor Ort noch in Würzburg oder aus der Ferne aus Rotterdam. Ein großer Dank dafür, dass du an mich geglaubt hast, immer ein offenes Ohr für mich hattest und mir die nötige Konsequenz mit der noch wichtigeren Entspanntheit vermittelt hast. Danke, dass du mir diese Promotion ermöglicht hast und mich in dein Team geholt hast.
Weiterer Dank gilt Prof. Dr. Stefan Lautenbacher für die Organisation der Bamberg-Würzburg Kolloquien sowie der Dolores-Treffen des Promotionsschwerpunkts Villigst, was für wertvolle Austausch- und Diskussionsmöglichkeiten sorgte und viel Struktur brachte. Ich danke Ihnen für die hilfreiche Mitgestaltung und die kritische Auseinandersetzung mit meinem Promotionsprojekt sowie die Unterstützung, die ich erfahren durfte.
Darüber hinaus danke ich Prof. Dr. Erhard Wischmeyer für den fachübergreifenden Einblick in meine Promotionsthematik, wichtige Anmerkungen zum Projekt und deine sehr erfrischende Unkompliziertheit.

Ein ganz besonderer Dank gilt Dr. Philipp Reicherts, der einen Großteil der Betreuung vor Ort von Matthias übernommen hat. Danke für all die Zeit und Energie, den Schweiß und die Tränen, die Geduld, die du in meine Betreuung gesteckt hast, egal wie viel du selbst um die Ohren hattest. Danke, dass du von Anfang an mich geglaubt hast. Danke, dass du mich immer bedingungslos unterstützt hast, immer für mich da warst und immer an meiner Seite warst. Danke für deine Freundschaft. Ohne dich wäre diese Arbeit kaum möglich gewesen.

Ein großer Dank gilt natürlich meinen Kolleginnen und Kollegen, die die Zeit in der Marcusstr. unvergesslich gemacht haben. Danke an mein erstes Büro 007, an Hannah Genheimer, Daniel Gromer und Markus Winkler, die mich mit Geduld und offenen Armen aufnahmen und meine unzähligen Fragen beantworteten und meinen Unsicherheiten begegneten. Danke für die gemeinsamen Pausen, die

„Challenges", die „Wutliste" und die vielen weiteren kreativen Spaßigkeiten, die den gemeinsamen Alltag bereicherten und Freundschaften entstehen ließen. Danke an mein zweites Büro 111 mit den „Pain Girls", Sarah Schneider, Anna-Lena Zillig und Isabel Neumann. Danke für eure Freundschaft, euer offenes Ohr und die Geburtstags-Essengeh-Tradition, die hoffentlich weiter bestehen bleibt.
Danke an das beste Betriebsausflug-Kanu-Gewinnerteam Octávia Madeira, Aleya Flechsenhar und Lara Rösler. Unendlicher Dank für euren emotional support und die überdauernde Freundschaft, die wir bis heute haben. Danke an Octávia für die unzähligen Schreibtreffen, ohne die ich es nie geschafft hätte – trotz Wochenende, trotz Urlaub, trotz Corona durchgepowert! Danke für's Zuhören und für mich da sein, für die Motivation (JETZT ABER!) und dein Verständnis.
Danke an ALLE Kolleginnen und Kollegen der AG Pauli und AG Gamer, die gemeinsamen Mittagessen- und Kaffeepausen, unsere „Klassenfahrten" aka Kongressbesuche, die Betriebsausflüge, die Hiwi-Grillabende (Stuhl-Curling!), die Weihnachtsfeiern, die Sommerfeste, und vieles mehr. Danke an die „Null plus ultra" und die „Würzburg Finest" für die Freundschaft über den Lehrstuhl hinaus.

Last but not least, die Menschen in meinem Leben, die mich im Hintergrund bei jedem Schritt begleitet haben und mich etwas zu häufig vor dem Laptop sitzend gesehen haben. Ich danke meinen Eltern, die immer an mich geglaubt haben und mir Unterstützung entgegengebracht haben. Danke, dass ihr so geduldig wart, mich nie unter Druck gesetzt habt und mir alle Zeit und den nötigen Freiraum gegeben habt.
Und zum Schluss danke ich von Herzen Domi, für die Geduld und Liebe, die unermüdliche Unterstützung und den fortwährenden Glauben an mich. Danke, dass du alle Höhen und Tiefen mit mir mitgemacht und durchgestanden hast – und das, ohne dich jemals zu beschweren. Du bist der Beste!

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Abbreviation list

ACC	Anterior cingulate cortex
ACT	Acceptance and Commitment Therapy
bpm	Beats per minute
CBT	Cognitive Behavior Therapy
CPT	Cold pressor task
ECG	Electrocardiography
EEG	Electroencephalogram
ER	Emotion regulation
HR	Heart rate
HRV	Heart rate variability
IASP	International Association for the Study of Pain
ICD	International Classification of Diseases
M	Mean
MCS	Manipulation check survey
N	Total number of subjects in the sample
NRS	Numeric rating scale
n_x	Number of subjects in group x
N_y	Total number of subjects in the sample for dependent variable y
PFC	Prefrontal cortex
SEM	Standard error of the mean
SC	Skin conductance
SCL	Skin conductance level
SCR	Skin conductance response
SD	Standard deviation
WHO	World Health Organization
VAS	Visual analog scale

Abstract

Pain conditions and chronic pain disorders are among the leading reasons for seeking medical help and immensely burden patients and the healthcare system. Therefore, research on the underlying mechanisms of pain processing and modulation is necessary and warranted. One crucial part of this pain research includes identifying resilience factors that protect from chronic pain development and enhance its treatment. The ability to use emotion regulation strategies has been suggested to serve as a resilience factor, facilitating pain regulation and management. Acceptance has been discussed as a promising pain regulation strategy, but results in this domain have been mixed so far. Moreover, the allocation of acceptance in Gross's (1998) process model of emotion regulation has been under debate. Thus, comparing acceptance with the already established strategies of distraction and reappraisal could provide insights into underlying mechanisms. This dissertation project consisted of three successive experimental studies which aimed to investigate these strategies by applying different modalities of individually adjusted pain stimuli of varying durations. In the first study ($N = 29$), we introduced a within-subjects design where participants were asked to either accept (acceptance condition) or react to the short heat pain stimuli (10 s) without using any pain regulation strategies (control condition). In the second study ($N = 36$), we extended the design of study 1 by additionally applying brief, electrical pain stimuli (20 ms) and including the new experimental condition distraction, where participants should distract themselves from the pain experience by imagining a neutral situation. In the third study ($N = 121$), all three strategies, acceptance, distraction, and reappraisal were compared with each other and additionally with a neutral control condition in a mixed design. Participants were randomly assigned to one of three strategy groups, including a control condition and a strategy condition. All participants received short heat pain stimuli of 10 s, alternating with tonic heat pain stimuli of 3 minutes. In the reappraisal condition, participants were instructed to imagine the pain having a positive outcome or valence. The self-reported pain intensity, unpleasantness, and regulation ratings were measured in all studies. We further recorded the autonomic measures heart rate and skin conductance continuously and assessed the habitual emotion regulation styles and pain-related trait factors via questionnaires. Results revealed that the strategies acceptance, distraction, and reappraisal significantly reduced the self-reported electrical and heat pain stimulation with both durations compared to a neutral control condition. Additionally, regulatory efforts with acceptance in study 2 and with all strategies in study 3 were reflected by a decreased skin conductance level compared to the control condition. However, there were no significant differences between the strategies for any of the assessed variables. These findings implicate similar mechanisms underlying all three strategies, which led to the proposition of an extended process model of emotion regulation. We identified another sequence in the emotion-generative process and suggest that acceptance can flexibly affect at least four sequences in the process. Correlation analyses further indicated that the emotion regulation style did not affect regulatory success, suggesting that pain regulation strategies can be learned effectively irrespective of habitual tendencies. Moreover, we found indications that trait factors such as optimism and resilience facilitated pain regulation, especially with acceptance. Conclusively, we propose that acceptance could be flexibly used by adapting to different circumstances. The habitual use of acceptance could therefore be considered a resilience factor. Thus, acceptance appears to be a promising and versatile strategy to prevent the development of and improve the treatment of various chronic pain disorders. Future studies should further examine factors and circumstances that support effective pain regulation with acceptance.

Zusammenfassung

Schmerzen und chronische Schmerzstörungen, welche eine enorme Belastung für Betroffene und das Gesundheitssystem darstellen, zählen zu den häufigsten Gründen für eine medizinische Behandlung. Die Erforschung von Mechanismen der Schmerzverarbeitung und -modulation ist daher hochgradig relevant. Ein Teil dieser Schmerzforschung befasst sich mit der Ermittlung von Resilienzfaktoren, die der Chronifizierung von Schmerzen vorbeugen und deren Behandlungen erleichtern sollen. Emotionsregulationsstrategien können als solche Resilienzfaktoren fungieren und die Behandlung von Schmerzen unterstützen. Studien zur Strategie Akzeptanz zeigten bereits Hinweise auf eine effektive Schmerzregulation, jedoch ist die Befundlage hinsichtlich der Effektivität noch uneindeutig. Eine weitere Unklarheit besteht bei der Einordnung von Akzeptanz als eine antezedent- oder reaktionsfokussierte Strategie in Gross Prozessmodel der Emotionsregulation (1998). Ein direkter Vergleich zwischen Akzeptanz und den bereits intensiv beforschten Strategien Ablenkung und Neubewertung könnte dabei Klarheit über die zugrunde liegenden Mechanismen und deren Einordnung schaffen. Das Ziel des aktuellen Dissertationsprojekts bestand daher darin, diese drei Strategien einander experimentell in einem akuten Schmerzkontext gegenüberzustellen. Zu diesem Zweck wurden drei aufeinanderfolgende Studien mit gesunden Probanden durchgeführt, die jeweils individuell eingestellte Schmerzreize erhielten. In der ersten Studie ($N = 29$) im Within-Design wurden den Probanden kurze Hitzeschmerzreize von 10 s verabreicht, welche sie akzeptieren (Akzeptanzbedingung) oder auf welche sie reagieren sollten, ohne eine Strategie anzuwenden (Kontrollbedingung). In der zweiten Studie ($N = 36$) wurde Studie 1 um zwei Bedingungen erweitert, indem phasische, elektrische Schmerzreize von 20 ms zum Within-Design hinzugefügt wurden. Darüber hinaus sollten sich die Versuchspersonen zusätzlich mithilfe neutraler Vorstellungen von den Schmerzreizen ablenken (Ablenkungsbedingung). In der dritten Studie ($N = 121$) wurden alle drei Strategien – Akzeptanz, Ablenkung und Neubewertung – einander sowie einer neutralen Kontrollbedingung in einem gemischten Within-Between-Design gegenübergestellt. Die Teilnehmenden wurden zufällig einer der drei Strategiegruppen zugewiesen, welche jeweils die Kontrollbedingung und eine der drei Strategiebedingungen enthielt. Die Probanden erhielten in allen Gruppen sowohl kurze, 10-sekündige als auch lange, 3-minütige Hitzeschmerzreize. Bei der Strategie Neubewertung sollten sich die Probanden vorstellen, dass der Hitzereiz eine positive Wirkung hätte. In allen Studien gaben die Probanden nach jedem Durchgang an, wie schmerzhaft und unangenehm sie die Schmerzreize erlebt hatten und wie gut es ihnen gelungen war, mit der jeweiligen Strategie zu regulieren. Außerdem wurden die peripherphysiologischen Messverfahren Herzrate und Hautleitfähigkeit als Schmerzkorrelate kontinuierlich aufgezeichnet. Zuletzt wurden die Emotionsregulationsstile und schmerzrelevante Persönlichkeitsfaktoren anhand von Fragebögen erfasst. Über alle Studien zeigte sich, dass die drei Strategien Akzeptanz, Ablenkung und Neubewertung die selbstberichtete Wahrnehmung der kurzen und langen Hitzeschmerzreize sowie der phasischen elektrischen Reize im Vergleich zur Kontrollbedingung signifikant verringerten. Des Weiteren deutete eine signifikant verminderte Hautleitfähigkeit in der Akzeptanzbedingung in Studie 2 und in allen

Strategiebedingungen in Studie 3 – verglichen mit der Kontrollbedingung – auf peripherphysiologisch erkennbare Regulationsprozesse hin. Zwischen den Strategien ließen sich jedoch bei keiner der Messvariablen signifikante Unterschiede finden. Dieses Ergebnis könnte auf ähnliche, den Strategien zugrunde liegende Mechanismen hindeuten, sodass im Rahmen des Dissertationsprojekts ein erweitertes Prozessmodell der Emotionsregulation aufgestellt wurde. Dabei wurde der emotionsgenerierende Prozess um einen Schritt erweitert und es wurden mindestens vier Positionen vorgeschlagen, an welchen Akzeptanz flexibel ansetzen könnte. Korrelationsanalysen ergaben außerdem, dass der Emotionsregulationsstil keinen Einfluss auf den Regulationserfolg hatte, was darauf hindeutet, dass Schmerzregulationsstrategien unabhängig von gewohnheitsmäßigen Tendenzen effektiv erlernt werden können. Darüber hinaus gab es Hinweise darauf, dass höhere Ausprägungen von Persönlichkeitsfaktoren wie Optimismus und Resilienz zu einer effektiveren Schmerzregulation insbesondere mit Akzeptanz führen können. Insgesamt scheint Akzeptanz flexibel einsetzbar und anpassungsfähig zu sein, was sie zu einem Resilienzfaktor im alltäglichen Gebrauch sowie zu einer vielversprechenden Strategie in der Prävention und Behandlung chronischer Schmerzerkrankungen macht. Zukünftige Forschung sollte daher die Faktoren und Umstände untersuchen, die zu einer wirksamen Schmerzregulation mit Akzeptanz beitragen können.

1. General introduction

Pain is experienced by all, even the simplest organisms, and is one of the earliest and most frequent experiences in life. Even though pain is thus a widely researched topic, many unresolved issues remain (Kröner-Herwig, 2017). Especially when it comes to the prevention and treatment of chronic pain syndromes, further research is still due and warranted.
Chronic pain is one of the main reasons people seek medical help, and it contributes to a great deal of suffering and impairments in daily functioning (Treede et al., 2019). Approximately 20% of the adult population globally is affected by chronic pain, and around 10% are actually diagnosed each year with chronic pain (Goldberg & McGee, 2011). The Global Burden of Disease Study 2016 disclosed that pain and pain-related diseases are the primary cause of disability and disease burden globally (GBD 2016, Disease and Injury Incidence and Prevalence Collaborators, 2017), with recurring tension-type headaches leading as the most common chronic pain condition (Mills et al., 2019). Low back and neck pain have also been found to be the leading causes of disability worldwide (GBD, 2016; Mills et al., 2019). Pain conditions can lead to severe and growing comorbidities such as depression, suicidal tendencies, and impairments in functionality such as the inability to work and maintain social relationships (Goldberg & McGee, 2011). These interferences not only burden the individuals themselves tremendously but also the health care system (Koechlin et al., 2018) and further justify handling pain as a public health priority (Goldberg & McGee, 2011).

On the one hand, psychological risk factors can contribute to the development and maintenance of chronic pain (Koechlin et al., 2018; Kröner-Herwig, 2017). Protective factors or resilience mechanisms, on the other hand, can protect from pain chronification (Kröner-Herwig, 2017). Adaptive and flexible emotion regulation strategies can serve as such resilience factors and ensure better pain management abilities (Koechlin et al., 2018). These regulation strategies are therefore helpful and already included in various psychological interventions seeking better pain management. One promising regulation strategy increasing in popularity is acceptance, as part of the Acceptance and Commitment Therapy (Hayes et al., 1999b). However, other strategies such as distraction or reappraisal are established regulation strategies used in, e.g., Cognitive Behavior Therapy. These regulation strategies have been considered valuable in the treatment of psychological as well as pain disorders. However, mixed findings, especially in the context of pain, have raised questions regarding the underlying mechanisms and specific circumstances of their effectiveness. For instance, distraction has been considered an effective strategy for acute pain regulation but appears to lose effectiveness in chronic pain (Van Ryckeghem et al., 2017). Reappraisal seems to be effective for chronic pain but also demands cognitive resources and training (Denson et al., 2014; Fardo et al., 2015; Hovasapian & Levine, 2016). Acceptance is a relatively new approach in pain regulation research, and mechanisms have yet to be studied.

Consequently, this dissertation project investigates the regulation of experimental pain with the strategies acceptance, distraction, and reappraisal through three studies conducted with healthy populations. Different pain modalities and durations have been implemented to further examine the underlying mechanisms and temporal dynamics of pain regulation

In its first chapter, the general introduction will depict how pain is generated, how chronic pain develops and is treated, and how pain can be experimentally investigated. Afterward, the connection between pain and emotions will be further explored. The second chapter will detail emotions and emotion regulation theories, focusing on Gross's process model of emotion regulation and acceptance-based approaches. Next, prior knowledge and other factors contributing to successful or less successful emotion regulation – including health outcomes – will be reviewed. Subsequently, the importance of researching the temporal dynamics of emotion regulation will be highlighted. The third chapter will review the latest and current findings on the regulation strategies in the emotion and pain context and explore the role of personality traits and prior regulation experiences on the regulatory performance. The last chapter of the general introduction will summarize the findings and present the design, aims, and hypotheses of this dissertation project.

1.1. Pain

In 1979, the International Association for the Study of Pain (IASP) released definitions for pain and pain-related terms. They updated some of the terms and completed the list over the years, but the definition of pain remained unmodified until recently. These definitions provided guidelines for health care professionals, pain researchers, and organizations worldwide, including the World Health Organization (WHO) (Raja et al., 2020). Until 2020, the IASP described pain as "an unpleasant sensory and emotional experience associated with actual or potential tissue damage or described in terms of such damage" (Raja et al, 2020, pp. 1976-1977). The definition included the note that "pain is always subjective" and "should be accepted as pain" even though tissue damage or pathophysiological causes are absent (IASP Task Force on Taxonomy, 2011). Over the years, as pain research grew, many pain experts demanded an updated definition including more of the multidimensional facets of pain. The main critique was the exclusion of people with impairments in cognition or language and non-human animals from the defined pain experience (Mogil & Edwards; Raja et al., 2020). Therefore, the IASP Taxonomy Task Force developed a revised pain definition published in the review by Raja et al. (2020). They modified the definition to apply to acute and chronic pain and all pain conditions and to be suitable for humans and non-human animals regardless of verbal abilities. Moreover, they prioritized the individual's pain experience rather than observations and emphasized the complexity of the pain construct (see Box 1.1 for the full revised pain definition).

Box 1.1. Revised IASP definition of pain (2020).

Pain

An unpleasant sensory and emotional experience associated with, or resembling that associated with, actual or potential tissue damage.

Six key notes:

- Pain is always a personal experience that is influenced to varying degrees by biological, psychological, and social factors.
- Pain and nociception are different phenomena. Pain cannot be inferred solely from activity in sensory neurons.
- Through their life experiences, individuals learn the concept of pain.
- A person's report of an experience as pain should be respected.
- Although pain usually serves an adaptive role, it may have adverse effects on function and social and psychological well-being.
- Verbal description is only one of several behaviors to express pain; inability to communicate does not negate the possibility that a human or a nonhuman animal experiences pain.

Etymology: Middle English, from Anglo-French peine (pain, suffering), from Latin poena (penalty, punishment), in turn from Greek poine (payment, penalty, recompense).

Note. Updated pain definition by the IASP (2020). Adapted from "The revised International Association for the Study of Pain definition of pain: concepts, challenges, and compromises." by S.N. Raja et al., 2020, in Pain, 161(9), pp. 1976-1982.

As outlined by the revised pain definition, sensory and emotional aspects are involved in pain perception. Moreover, pain is a construct of biological, psychological, and social factors and therefore, a highly individualized phenomenon. Furthermore, pain can be expressed verbally and behaviorally. This chapter will deal with these aspects in greater detail and explore how pain is generated, how it can be assessed, how chronic pain develops, and how emotions modulate pain.

1.1.1. Generation and function of acute pain sensations

The sensory aspect of pain is usually, but not necessarily, associated with a noxious stimulus, which informs the organism about the stimulus's intensity, temporality, and spatial location (Krahé & Fotopoulou, 2018). The IASP has defined a noxious or ***nociceptive stimulus*** as "an actually or potentially tissue-damaging event" transmitted and encoded by a "high-threshold sensory receptor of the peripheral somatosensory nervous system" called ***nociceptor*** (IASP, 2011). Thus, ***nociception*** is the neural process of detecting and encoding noxious stimuli processed in a particular part of the somatosensory system, the nociceptive system (IASP, 2011; Magerl & Treede, 2017). When nociception is perceived consciously and evaluated, the actual perception of ***pain*** is generated (Magerl & Treede, 2017).

As soon as a nociceptive stimulus occurs, the sensation is transmitted to the brain by nociceptive afferent fibers. The primary nociceptive fibers (nociceptors) are the small, fast-conducting, lightly myelinated

Aδ-fibers and the very small, slow-conducting, unmyelinated ***C-fibers*** (Krahé & Fotopoulou, 2018; Rainville et al., 1992). The Aδ-fibers are connected to pricking or stinging sensations, while the C-fibers are associated with burning, dull sensations (Krahé & Fotopoulou, 2018; Magerl & Treede, 2017). Both fibers are involved in sharp, scratching, itching, and intense olfactory sensations (Magerl & Treede, 2017). The conduction velocity of the Aδ-fibers is very high (15–25 m/s), which allows for fast reflex responses of 200 ms after stimulus onset and a very clearly defined sensation (first pain). C-fibers have a velocity of 1 m/s, a reaction time of approximately 1000 ms, and the sensation is less clearly defined (second pain). A needle puncture on the hand, for example, would lead to a double pain sensation due to the different conduction velocities of the two stimulated fibers. Because of the high velocity, Aδ-fibers are responsible for fast reflex responses, such as reflexively removing the hand, but have a relatively high threshold. Even though C-fibers are slower than Aδ-fibers, they have a lower threshold and serve as a more sensitive detection system of nociception (Magerl & Treede, 2017).

Nociceptors react to mechanical, thermal, and chemical stimuli and integrate various modalities of stimuli; thus, they are polymodal. There are subtypes of nociceptors with unique sensitivities. CMH nociceptors, for example, are C-fibers sensitive to heat and mechanical stimuli. When it comes to the perception of heat pain, the CMH nociceptors receive noxious stimuli in a thermal range of 40-50°C, with a mean threshold of 43°C. On the other hand, some Aδ-fibers conduct quickly and are very sensitive to mechanical stimulation but relatively insensitive to heat. For example, AMH type II is an Aδ-fiber with a very high mean threshold for heat pain of 47°C. AMH type I even requires a stimulation duration of at least 10 s with a temperature of more than 50°C (Magerl & Treede, 2017). When a heat pain stimulus is applied several times on the same skin area, the polymodal C-fibers' stimulus-response is reduced. This ***habituation to heat pain*** correlates with a reduced perception of pain and can be prevented by changing where pain is applied on the skin. In turn, when C-fibers are repeatedly stimulated with a frequency of more than 0.3 Hz, it can lead to a so-called wind-up or ***nociceptive summation*** that lasts for a maximum of one minute and leads to a higher pain perception (Magerl & Treede, 2017).

The ***neural correlates of pain perception*** are reviewed in the book section of Krahé and Fotopoulou (2018). Brain areas associated with pain or noxious stimulation, either sensory or emotionally, have been identified in neuroimaging studies and termed as the "*pain matrix*" (Melzack, 1999; Tracey & Mantyh, 2007). In particular, the brain areas integrated in the pain matrix are the primary and secondary somatosensory cortices, the insular cortex, the anterior cingulate cortex (ACC), the prefrontal cortex (PFC), and the thalamus (Apkarian et al., 2005). Another theoretical framework combining these brain areas suggested that they could form a general neural "*salience network*" that is activated due to, e.g., the novelty or threat value of a stimulus (Legrain et al., 2011). However, identifying brain patterns that are pain-specific and different from general aversive events would be more useful as a measurement of non-verbal pain experiences. Wager et al. (2013) have provided such a promising framework and identified a neurological pattern triggered specifically by experimentally induced heat pain, including the posterior and anterior insulae, the secondary somatosensory cortex, the thalamus, the hypothalamus, and the ACC. They showed that this pattern differed from a general salience signal and discriminated physical pain from other aversive events.

This brief overview shows that the pain experience itself is generated in and reflected by the brain. However, the specific patterns are still under investigation, and further research is warranted with chronic pain patients.

The development of a nociceptive system can be traced far back to even the most simplistic organisms. The lack of such a nociceptive system would mean a tremendous evolutionary disadvantage as this system detects damages or infections to the organism (Magerl & Treede, 2017). Every human being experiences acute pain in daily life, which functions as a vital warning signal. This warning leads to avoidance of harmful behavior or promotes healing, thus protecting the organism from damage (Kröner-Herwig, 2017). Acute pain can last for seconds up to weeks and is usually caused by aversive or noxious external stimuli or endogenous processes. As soon as these disturbances disappear, the pain diminishes (Kröner-Herwig, 2017). However, pain can persist without any apparent cause for extended periods to the point that it loses its vital function and does not serve as a warning signal anymore. In this case, pain as a symptom becomes the disease itself (Kröner-Herwig, 2017). The following section will follow up with the development and treatment of chronic pain.

1.1.2. Development and treatment of chronic pain

Chronic pain involves pain that persists for more than three months, whose cause is not apparent, or whose damage and extent are not in proportion (Kröner-Herwig, 2017). In 2018, the WHO released their revised diagnostic classification system, the eleventh revision of the International Classification of Diseases (ICD-11). Until then, chronic pain could only be coded as a somatoform pain disorder in the previous version of the ICD-10, excluding any pathophysiology (Nicholas et al., 2019). A German version adapted the ICD-10 by adding the chronic pain disorder with somatic and psychological factors to the psychiatric section (Nicholas et al., 2019), labeling chronic pain as a psychiatric condition. There was a need for a revision and inclusion of chronic pain with all its facets and subtypes, including multimodal pain treatment recommendations. Therefore, the IASP has provided the ICD-11 with a definition of primary chronic pain (see Box 1.2).

Box 1.2. ICD-11 definition of primary chronic pain.

Chronic primary pain is defined as pain in one or more anatomical regions that

(1) persists or recurs for longer than 3 months
(2) is associated with significant emotional distress (eg, anxiety, anger, frustration, or depressed mood) and/or significant functional disability (interference in activities of daily life and participation in social roles),
(3) and the symptoms are not better accounted for by another diagnosis.

Note. ICD-11 definition of primary chronic pain (2019). Adapted from "The IASP classification of chronic pain for ICD-11: chronic primary pain" by M. Nicholas et al., 2019, in Pain, 160(1), pp. 28–37.

Secondary chronic pain syndromes are now represented for the first time in the ICD, including chronic cancer-related pain, postsurgical or post-traumatic pain, neuropathic pain, secondary headache or orofacial pain, secondary visceral pain, and secondary musculoskeletal pain. The introduction of these classifications is supposed to promote further research and better access to multimodal treatments for chronic pain patients (Treede et al., 2019).

Complex interactions between sensory, environmental, psychological, and individual pain regulatory risk factors can result in the development of chronic pain (Koechlin et al., 2018). Kröner-Herwig (2017) reviewed the multidimensional factors that can lead to chronic pain syndrome in a ***biopsychosocial model***. The biopsychosocial model outlines how a pain syndrome often starts with a pain-triggering event, such as a trauma, an inflammation, or an injury. The persisting pain constantly interrupts the individual's attention, leading to the formation of a vigilant attentional style for pain and somatosensory stimuli in general (Van Ryckeghem et al., 2017). Increased sensitivity for pain could also serve as an underlying mechanism for higher attention to pain and therefore increase the risk for the development of chronic pain (Snijders et al., 2010). However, psychosocial factors play a central reinforcing role. The evaluation of pain as uncontrollable or as a threat can impair the sensory and affective pain experience (Kröner-Herwig, 2017). This, in turn, could lead to avoidance behavior motivated by fear of new injuries or fear of increased pain caused by activities (Kröner-Herwig, 2017; Lethem et al., 1983). This operant reinforcement of avoidance pain behavior is critically implicated in the development and maintenance of chronic pain (Kröner-Herwig, 2017). Other reinforcing emotions and evaluations could be, for example, feeling of helplessness, sadness, or despair (Kröner-Herwig, 2017). On a cognitive level, pain catastrophizing and the belief of helplessness also serve as reinforcements of pain behavior (Kröner-Herwig, 2017).

In contrast to treating acute pain, the objective of chronic pain management is not necessarily the complete freedom of pain but rather attenuating the pain until bearable, improving coping with pain, and reducing the pain interferences (Koechlin et al., 2018).

The most prominent and conventional treatment for chronic pain is medication. Nevertheless, pain medication can have serious side effects, cause physical harm, and lead to substance abuse or dependencies (Kröner-Herwig & Frettlöh, 2017). Therefore, psychological interventions of chronic pain can enhance or even replace drug treatments. They focus on restoring a patient's functionality and counteract the pain avoidance behavior by targeting the emotional and cognitive factors mentioned above. Cognitive Behavioral Therapy or Acceptance and Commitment Therapy are psychological therapies effectively deployed in pain treatment. They have integrated coping mechanisms and emotion regulation strategies that can help chronic pain patients regain their functioning in life despite their pain condition (see 1.2.2.1 and 1.3).

Research on chronic pain intends to cover the multidimensionality of pain and aims to locate risk and protective factors to improve chronic pain treatments. The following subsections provide an overview of methods used in experimental pain research and pain assessment methods in a laboratory setting.

1.1.3. Experimental pain and its outcomes

Investigating pain conditions and syndromes is crucial for understanding their underlying mechanisms and for developing suitable treatments for people suffering from them. Even though pain conditions are considered a public health priority (Goldberg & McGee, 2011) and affect a considerable part of the population, many chronic pain syndromes are still not completely understood and therefore not treated appropriately (Turk & Melzack, 2011). One of the challenges in investigating pain conditions is that pain assessment mainly relies on self-reported pain, which can be distorted by memory bias and influenced by personal evaluation. Moreover, these self-reports are challenging to obtain from people with cognitive or semantic impairments and animals. Thus, non-verbal indices of pain such as physiological measures are much needed in addition to the pain reports.

1.1.3.1. Experimental pain induction

In order to study pain mechanisms and treatments, systematical research is needed. Methods frequently used to find associations between chronic pain and other factors are correlation or regression analyses. Even though correlational studies are essential for retrieving data in a natural setting, experimental studies are crucial for finding causal associations. Thus, another method is to investigate chronic pain patients or healthy participants in the laboratory and directly induce controlled pain by varying, e.g., the pain magnitude, modality, or duration. Standardized pain stimulation has the advantage that different ways of pain processing can be evaluated, and pain can be applied to different tissues (Arendt-Nielsen & Yarnitsky, 2009). This experimental research can be applied in basic, clinical, and pharmacological studies and its methods have advanced greatly in the last decades (Arendt-Nielsen & Yarnitsky, 2009). These experiments can be conducted with either chronic pain patients or healthy subjects. Investigating chronic pain patients has the benefit that results can be translated more easily to the chronic pain population. However, chronic pain patients vary immensely regarding their sensory or affective pain levels, pain-related interferences, and pain-related experience, making a systematic investigation rather challenging. In healthy volunteers with no prior pain condition, it is possible to systematically control the pain they receive in a controlled environment. Even though using healthy subjects limits direct generalization to the chronic pain population, it can serve as fundamental research to determine underlying mechanisms and aspects of pain that can be explored in chronic pain patients subsequently. Arendt-Nielsen and Yarnitsky (2009) argue in their review that inductions of pain in healthy volunteers can serve as models for pain conditions simulating, e.g., hyperalgesia, the increased sensitivity to pain, or allodynia, that is reacting with pain to non-painful stimuli.

Standard methods to induce pain in humans in the laboratory are chemical, mechanical, thermal, and electrical stimulation and can be applied in part to the skin (cutaneous pain), the muscle (muscle pain), or the visceral tissue (visceral pain) (Arendt-Nielsen & Yarnitsky, 2009). Examples of chemicals inducing pain are capsaicin or acid, which can be applied topically, intradermally, or injected. Pain can be induced mechanically, for example, by pressure stimuli. Ischemic stimulation can be generated by a tourniquet inflated around, e.g., the leg, leading to a relatively long, tonic ischemic muscle pain caused by pressure and limb ischemia (Staahl & Drewes, 2004). Thermally, pain is usually induced by heat or cold stimuli applied to the skin via, e.g., contact thermodes, laser pulses, or cold- or hot-water immersions. A widespread method is the cold pressor task (CPT), where subjects immerse a hand or a foot into 0-2°C cold water for a duration of a maximum of 1-2 minutes or as long as the subject can endure the pain (pain tolerance) (Staahl & Drewes, 2004). Another prevalent method is using a Peltier thermode inducing contact heat pain, activating first (Aδ-fibers) and second pain (C-fibers). To avoid habituation to the heat pain stimulation, changing the thermode's location on the skin is fundamental (Magerl & Treede, 2017). Typically, 32°C is the baseline temperature where neither warmth nor cold is perceived. The perception of warmth begins typically at approx. 35°C and heat pain is evoked starting at approx. 43°C, with a maximum endurable temperature at around 49°C (Staahl & Drewes, 2004). Electrical pain stimulation is frequently induced via electrodes attached to the skin surface, connected to electrical stimulator devices. These stimulators can deliver various electrical stimulation patterns with different frequencies, durations, and intensities (Staahl & Drewes, 2004). This method is especially suited for neurophysiological measures but does not constitute a good simulation of pain conditions as electrical stimulation activates other nerve fibers directly but bypasses the nociceptors (Staahl & Drewes, 2004).

1.1.3.2. Pain assessment

As mentioned earlier, pain is complex, and the assessment of pain involves some challenges. The perception of pain can be detected primarily via the verbal or non-verbal communication of the individual (Turk & Melzack, 2011). Thereby, (pain) patients usually rate their pain level on a self-report scale. The most frequently and simply assessed, dimension of pain is the ***pain intensity***, "a quantitative estimate of the severity or magnitude of perceived pain" (Jensen & Karoly, 2011, p. 23). Another but rather complex pain dimension assessed via self-reports is pain affect. ***Pain affect or unpleasantness*** involves the degree of emotional arousal and discomfort caused by the pain experience. It is often described as a mental state of feeling “distressed” or “frightened” as it triggers an implicit or explicit threat appraisal. It is considered the leading cause of daily life interferences and can be one of the most salient aspects for chronic pain patients (Jensen & Karoly, 2011). Pain intensity and unpleasantness are distinct dimensions but are not independent of each other (Price et al., 1987). Rainville et al. (1992) showed that brief, “phasic” pain stimuli such as contact heat and electrical pain led to lower pain unpleasantness ratings than continuous, “tonic” pain stimuli such as pain caused by a CPT or ischemic pain. They suggested that phasic pain stimuli could serve better for sensory-discriminative purposes in experiments. Other pain dimensions are pain quality and pain location, referring to specific physical sensations and their localization, respectively (Jensen & Karoly, 2011).

A standard quantitative assessment method to assess pain intensity is the ***visual analog scale (VAS)***, consisting of a usually 10 cm line with the endpoints 0 and 100, corresponding to the extremes of pain, e.g., “no pain” to “unbearable pain” or “pain as bad as it could be”, respectively (Jensen & Karoly, 2011; Staahl & Drewes, 2004). A continuous, paper-and-pen or digital collection can provide detailed information with 101 response levels of the ratings (Staahl & Drewes, 2004). Jensen and Karoly (2011) gave an overview of literature providing data on the high validity, reliability, and sensitivity of the VAS. The VAS is sensitive to treatment effects and has ratio scale qualities, meaning that the scale differences represent the actual magnitude of differences in pain intensity. The VAS can be difficult to understand or complete, especially for patients with cognitive impairments or motor disabilities. Thus, numeric or verbal rating scales might be advisable in a clinical setting (Jensen & Karoly, 2011).

For the ***numeric rating scale (NRS)***, patients or subjects should rate their pain from 0 representing “no pain” to 10 (11-point scale), 20 (21-point scale), or 100 (101-point scale), representing the worst imaginable pain. Patients simply indicate the corresponding number to their pain level verbally, by circling or checking the number, or by pressing the number on a computerized version. Jensen and Karoly (2011) again showed the high validity and sensitivity of the NRS, especially when combined with a visual display of the numbers. Breimhorst et al. (2011) showed in an experimental study with healthy subjects that pain intensity ratings assessed via NRS were reliable measures of different pain stimulus intensities and modalities (electrical, mechanical, and laser heat pain). Its simple administration and no material requirements make the NRS one of the most preferred pain assessment methods for a diversity of patients in a clinical setting but at the expense of ratio scale qualities. Other common pain rating methods are the verbal rating scale (VRS), a list of adjectives depicting different pain levels, and the picture or faces scales, including photographs or drawings of facial pain expressions (for further details, see Jensen and Karoly, 2011). For the assessment of pain unpleasantness, similar methods can be used, and the labels of the endpoints can be changed into, e.g., “not bad at all” to “most unpleasant feeling”. However, results regarding its discriminative validity from pain intensity are mixed, and its multidimensional nature makes the assessment more complex (Jensen & Karoly, 2011).

Self-reported pain levels or pain ratings can refer to different time points, such as pain at the moment, highest or lowest pain in a defined time period, or typical pain (Mason et al., 2011). However, retrospective pain ratings entail potential biases such as an over- or underestimation of the experienced pain resulting from memory biases (Turk & Melzack, 2011). Furthermore, patients with cognitive or verbal restrictions, disabilities, or motor difficulties of any kind cannot communicate their pain accurately. Therefore, non-verbal and less-biased pain measures are needed (Loggia et al., 2011; Turk & Melzack, 2011).

Pain can be expressed by verbal reports, paralinguistic vocalizations, motor activity, facial expressions, gesticulations, and postural adjustments (Turk & Melzack, 2011). These ***pain behaviors*** can be verified by others and used as a complementary pain measure. For instance, Kunz et al. (2012) recorded facial responses to pain stimulation on video and showed specific facial encoding regarding sensory and affective pain experiences. Moreover, Kunz et al. (2007) demonstrated that patients with dementia showed more facial reactions to painful stimuli than healthy controls, but both groups displayed facial expressions according to the pain intensity. However, expressions can be prone to conditioning and learning effects and can contain errors regarding the actual pain. Moreover, patients with, e.g., certain forms of paralysis, cannot show facial expressions (Loggia et al., 2011), leading pain researchers and physicians to rely more on physiological pain correlates.

Staahl and Drewes (2004) reviewed ***electrophysiological methods*** for pain assessment. The nociceptive withdrawal reflex is caused by a noxious stimulus, representing activation of Aδ-fibers or C-fibers. A commonly used measurement is the Aδ-mediated RIII reflex, where the sural nerve is stimulated electrocutaneously, while the biceps femoris muscle activity is assessed via an EMG. Another method is the brain evoked potential measured by an electroencephalogram (EEG) response, evoked by painful electrical, laser, or rapidly increased temperature stimuli.

Autonomic measures reflect the activation of the sympathetic and parasympathetic nervous system, parts of the autonomic nervous system. Electrodermal activity or skin conductance (SC) reflects the sympathetic nervous system while cardiovascular activation measured by, e.g., heart rate (HR), reflects both sympathetic and parasympathetic nervous system. Painful stimulation activates the sympathetic system, leading to an increased SC and HR (Loggia et al., 2011). In an experimental study by Loggia et al. (2011), healthy participants received heat pain stimuli with different intensities. The pain intensity and unpleasantness were assessed via VAS, and continuous SC and HR were recorded. They showed that the pain ratings and autonomic measures gradually increased along with the temperature, suggesting experiential and autonomic discrimination between different levels of warmth and pain. The authors also concluded that SC and HR serve as adequate pain measures. More specifically, SC was a better predictor of the pain perception on a within-subjects level, while HR better predicted the overall pain level. Furthermore, Breimhorst et al. (2011) showed that the skin conductance response (SCR) discriminated reliably between different pain intensities of mechanical and heat pain stimuli but failed for painful electrical stimulation. Treister et al. (2012) remarked that Loggia et al. (2011) only used phasic and not subject-calibrated pain stimuli while assessing only two autonomic measures. Instead, Treister and colleagues conducted a study with heat pain and adjusted the temperature individually to each subject, and introduced four heat levels, no pain and low, medium, and high pain intensity resembling 30, 60, and 90 on a NRS, respectively. They presented heat pain stimuli with a duration of one minute and assessed five autonomic parameters (HR, HR variability, SCL, SC fluctuations, blood volume changes) by recording SC and electrocardiography (ECG) data continuously. Participants rated the pain intensity verbally every 10 s. Results showed that the pain intensity ratings and all autonomic parameters successfully discriminated between pain and no pain. Nevertheless, none discriminated between the three heat pain levels. However, a combination of the five autonomic measures differentiated between all four pain levels, from which SCL and blood volume were the most sensitive ones. With these results, Treister et al. (2012) expanded the findings by Loggia et al. (2011) from phasic to tonic heat pain stimuli and suggested a multiparametric approach for autonomic pain measurement. Geuter et al. (2014) investigated the temporal dynamics of pain intensity ratings, SC, and pupil diameter as responses to different heat pain intensities (45-47.5°C) and durations (8-20 s). As expected, pain intensity ratings increased with higher temperature and more prolonged stimulation. More interestingly, the autonomic measures accurately predicted pain intensity ratings for single trials, especially when temporal information was integrated. A review by Kyle and McNeil (2014) showed that electrodermal and cardiovascular activity increased consistently with higher reported pain intensity caused by electrical or heat pain stimulation. However, results for cardiovascular responses appeared more heterogeneous. Despite a relatively clear association between noxious stimulation and autonomic responses, the question remained whether these reactions were related to the stimulus intensity or the experienced pain intensity. Nickel et al. (2017) aimed at answering this question by conducting a study with healthy participants receiving tonic (10 min) individually adjusted heat pain and assessed autonomic measures (SC, HR). They showed that SC and stimulus intensity were more closely associated than SC and pain intensity, indicating that nociceptive rather than perceptual processes caused the autonomic responses. However, HR was related to neither stimulus intensity nor pain intensity. The authors acknowledged previous studies as, e.g., by Geuter et al. (2014), finding relationships between pain experiences and autonomic measures, but noted that the duration of a noxious stimulus might play a critical role as these were rather phasic.

1.1.4. Emotional modulation of pain

As noted at the beginning of this chapter 1.1, pain involves emotional aspects that can severely impact an individual's experience and life. Especially when the pain experience becomes chronic, the emotional aspects seem to gain even more relevance and show themselves through impairments in everyday life (see 1.1.2).

Emotions and pain influence each other reciprocally, meaning that experiencing pain elicits emotions, but emotions can also impact pain perception. In his book section, Rhudy (2016) reviewed how the ***motivational priming theory*** (Bradley et al., 2001; Lang et al., 1990) explains this pain and emotion relationship. According to the theory, emotions activate the appetitive or defensive motivational system, leading to various survival or fight-or-flight responses, respectively. As pain usually is evaluated negatively and elicits negative emotions, it activates the defensive system and leads to avoidance or facilitation of a defensive reflex. Moreover, negative emotions usually enhance, while positive emotions normally inhibit, pain perception, ensuring the activation of the appropriate motivational system. This effect occurs irrespective of whether the emotion is pain-related or not and even magnifies with higher emotional intensity (Rhudy, 2016). However, in rare cases, intense negative emotions activating the defense system can also inhibit pain by e.g., releasing endogenous opioids (Rhudy, 2016).

Cognitive processes and emotions are firmly connected, and both modulate the perception of pain (Wiech & Tracey, 2009). Kenntner-Mabiala et al. (2007) showed in their study that negative emotions elicited by pictures increased the experienced pressure pain intensity and unpleasantness compared to positive and neutral pictures. Moreover, participants who focused on the pictures reported less pain intensity than participants who focused on either sensory or affective aspects of the pressure pain stimulation. However, attention did not modulate pain unpleasantness significantly. These findings suggested that focusing attention also plays a role in modulating emotions and pain. In turn, pain itself has the ability to disrupt attention, especially when intense (Eccleston & Crombez, 1999; Prins et al., 2014). Wiech and colleagues suggested in their reviews that cognitive processes such as attention, expectation, changing the meaning of an aversive effect (reappraisal), and catastrophizing modulate the pain perception by inducing analgesia[1] through, e.g., placebo effects[2] (Wiech et al., 2008; Wiech & Tracey, 2009). Both cognition and emotions activate ascending nociceptive signals to the brain and descending modulatory pathways, which involve brain areas central for pain control as well as emotional and cognitive functioning (Bushnell et al., 2013; Roy, 2015). Emotions have been shown to modulate the activation of brain structures known as the pain matrix (see 1.1.1) and share neural representations in the periaqueductal grey, amygdala, ACC, anterior insula, and PFC (Wiech & Tracey, 2009; Wieser & Pauli, 2016). Wiech et al. (2008) further noted that pain could be conceptualized as an emotion that can be regulated, referring to the similarities between emotion regulation and cognitive pain modulation. Lapate et al. (2012) showed that emotion regulation success predicted pain regulation success, suggesting that emotion regulation abilities can be applied to pain as well (see subchapter 1.3.3.2 for further details). Koechlin et al. (2018) concluded that dysfunctional emotion regulation could even be a risk factor for developing chronic pain syndrome in their meta-analysis.

In conclusion, emotions, cognitions, and pain perception affect each other inseparably. From a psychological point of view, pain can therefore be managed by regulating emotional and cognitive aspects. Emotion regulation can even play a role in the development of pain chronification. The next

[1] "Absence of pain in response to stimulation which would normally be painful" (IASP, 2011).

[2] Clinically significant response to a substance or nonspecific treatment, deriving from the individual's expectations or beliefs regarding the intervention (VandenBos & APA, 2015).

chapter will explore the theoretical bases of emotions, emotion regulation, and emotion dysregulation. The subsequent chapter will then link emotion and pain regulation and outline current research.

1.2. Theoretical bases of emotion regulation

Emotions are part of everyone's daily experience. We perceive and regulate them throughout all developmental stages of our lives (Thompson, 2011), from infancy to old age. As important as emotions are, however, they can sometimes stand in our way. According to Egloff (2009), emotions aim at putting the organism in a position to act. This action is accomplished by inducing reactions on a subjective, behavioral, and physiological level. Thus, emotions enable efficient reactions to adaptive challenges. Nevertheless, the physical and social environment has changed considerably compared to the one our ancestors lived in. Emotional reaction tendencies which were once useful evolutionarily might be not appropriate anymore or may even be contradictory to social values and circumstances (e.g., showing anger in a working environment). Therefore, successful *emotion regulation* is essential for social adjustment and general well-being (Hofmann & Asmundson, 2008). According to Thompson (2011), every emergence of an emotion involves already a regulation of the very emotion.

Throughout human history, the study of emotions and emotion regulation was at the center of attention. In the ancient philosophy, Plato and Aristotle dedicated themselves to the theories of affect, in which they perceived emotions as a tool to affect others, whereas self-regulation prevented oneself from being influenced by others (Landweer & Renz, 2008). Since the establishment of psychology as a science in the 19th century, emotion theories have thrived and created various study fields (Landweer & Renz, 2008). The field of emotion regulation not only has grown exponentially in the last decades, but new research questions and topics have emerged (Tamir, 2011). There have been various noteworthy, descriptive approaches that assessed and classified the components involved in emotion regulation. Thayer et al. (1994), for example, developed a ***two-dimensional mood theory*** that includes two components of general bodily arousal: energy (vs. tiredness) and tension (vs. calmness). Self-regulation modulates these two components to optimal levels. By analyzing open-ended and fixed questionnaires with the help of factor analyses, Thayer (1989) detected three factors for short term energy enhancement (physical, social and cognitive activity; reduced activity and rest; caffeine, food, and passive stimulation) and three factors for tension reduction (emotional expression, food, and drugs; muscle release, cognitive control, and stress management; pleasant distraction). Another approach is the comprehensive ***classification of strategies by Parkinson and Totterdell (1999)***, which was developed with a cluster analysis. Their analysis proposed two top-level distinctions between *cognitive* and *behavioral strategies* and between *engagement* (cognitive: reappraisal, thinking about problem-solving; behavioral: venting, seeking help, solving the problem) and *diversion*, resulting in a four-field scheme with further subcategories for diversion: distraction (cognitive: thinking about something pleasant, thinking about something that occupies attention; behavioral: doing something pleasant, performing a demanding activity) and disengagement (cognitive: avoid thinking about a problem; behavioral: avoid a problematic situation).

Wegner (1994) developed the ***Ironic Process Theory***, describing two processes underlying cognitive control and running simultaneously: the operating process and the monitoring process. The operating process is conscious and targets the desired mental state. The monitoring process conducts an active unconscious search "in the background" of the consciousness and targets anything than the desired mental state as it functions as the control system of the operating process. However, the system can be prone to errors when the mental load is too high (e.g., under pressure or after a more extended time) and produces paradox or ironic effects (Wegner, 2009). For example, ironic effects could be thinking about the white bear exactly when not supposed to (implemented through thought suppression) (Wegner et al., 1987). According to this theory (Wegner, 1994), a distraction from pain would only work initially. After a while, the monitoring process would bring the pain back to the consciousness, along with anything not targeted as a distractor. Suppression would even worsen the pain as the monitoring process would yield only pain. On the contrary, attention to pain would initially bring the pain to the consciousness, but the monitoring process would yield anything other than pain and thus lead to pain relief in the long-term.

Also worth mentioning are the ***delay-of-gratification paradigm*** by Mischel and Ebbesen (1970) and the ***nature of psychological defenses*** by Freud (1946). These and the work by Lazarus (1966) on ***stress and coping mechanisms*** set important fundaments for many current emotion regulation theories, such as the development of the ***process model of emotion regulation by Gross (1998b)***. This process model, along with the working definitions and conceptualizations of emotion regulation, will be introduced in more detail in the next section as they lay the theoretical groundwork for this dissertation.

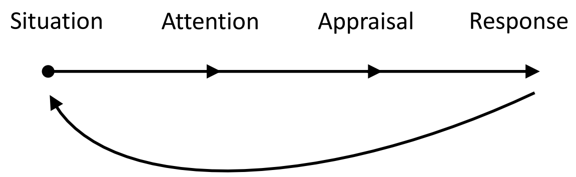
1.2.1. Process model of emotion regulation

Emotion regulation (ER) describes the process by which we continuously shape our emotions in order to successfully adjust to social situations (Hofmann & Asmundson, 2008; Hofmann et al., 2009). By regulating emotions, we try to influence when and how we experience and express them (Gross, 1998b). Gross (2014) detected three ***core features of emotion regulation***. The first core feature is the *regulatory goal*, which can be intrinsically (by oneself) or extrinsically (by another person) activated. Intuitively, it is easy to understand that people tend to downregulate negative and upregulate positive affective states. Nevertheless, various regulatory goals motivate people to downregulate positive emotions (e.g., not making a failing friend jealous of one's good results in an exam) and upregulate negative emotions (e.g., trying to be empathetic for a sad friend). The second core feature is the *emotion regulation strategy*, which refers to the activation of the regulatory process explicitly (consciously) or implicitly (unconsciously) by applying a specific strategy. The third core feature constitutes the *regulatory outcome*, which means the extent (latency, rise time, magnitude, duration, offset) to which the applied ER strategy alters the emotional response.

To identify the diverse and broad research on emotion regulation, it is crucial to bear in mind that the term emotion regulation can be used interchangeably with the terms coping, affect regulation or mood regulation while describing the same or very similar processes. However, these terms can also refer to different constructs. Gross (2014) provides a terminology of related processes to help distinguish them. He first defines the terms affect and ***affect regulation*** as the umbrella terms for three different states and their regulation. These states comprise emotions (e.g., sadness), stress responses, and mood (e.g., depression). While emotions can include both positive and negative affective responses, stress responses usually only involve negative ones. Moods last longer than emotions and do not require a specific object as a trigger. The affect regulation, therefore, includes emotion regulation, coping, and mood regulation. *Coping* focuses on decreasing the negative stress response over a more considerable time period, while *emotion regulation* can include both up- and downregulation of any affective state. *Mood regulation* targets the emotional experience more than the emotional behavior, contrary to emotion regulation.

It is further indispensable to recognize how emotions are generated in the first place to understand the process of emotion regulation. For this purpose, Gross (1998b) developed the ***modal model of emotion***, where he describes an emotion's formation as a process of four sequences. See Figure 1.1 for a simple representation of the model with the sequences that build upon one another from left to right over time. At first, a psychologically relevant situation occurs, usually external (e.g., a snake crawling into the tent). Then, this situation is *attended* to and *appraised* regarding the individual relevant goals (e.g., wanting to stay alive). This appraisal initiates the emotional reaction (e.g., fear), which entails changes in experiential (e.g., feeling fearful), behavioral (e.g., freezing), and physiological (e.g., sweating, faster heartbeat) response systems. In turn, this response can alter the situation that created the emotion in the first place (e.g., the snake does not notice you and slithers off). Thus, the emotion generation is an ongoing process.

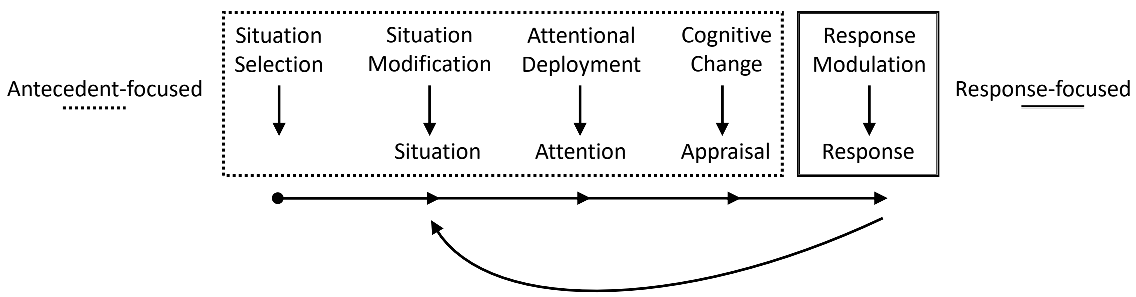
Figure 1.1. The modal model of emotion (Gross, 1998a).



Note. The emotion-generative process by Gross (1998a). Adapted from "Emotion regulation: Conceptual and empirical foundations" by J. J. Gross., 2014, in J. J. Gross (Ed.), Handbook of Emotion Regulation, second edition, pp. 3-20. Copyright 2014 by The Guilford Press.

The ***process model of emotion regulation*** (Gross, 1998b) further expands the modal model of emotion. According to this model, there are five points where ER can take place within the emotion-generative process. These points simplify ER into five families of regulatory processes and are illustrated in Figure 1.2. The first ER family is *situation selection* and starts before the situation occurs, even before the emotion-generative process is initiated. This ER process is proactive and involves anticipating situations that will evoke a specific type of emotion. To avoid an undesired or promote a desired emotion, actions are activated that make this anticipated situation occur more or less likely (e.g., avoiding an exam we are not prepared for; calling a friend who can cheer us up). The second ER family is *situation modification*, which refers to actively changing the external environment to alter the situation (e.g., suggesting watching a movie when someone is bored). The third ER family is *attentional deployment*, which means directing one's attention towards or away from the emotion-eliciting stimulus. The most prominent form of attentional deployment, which develops early in childhood (Cole et al., 2018), is *distraction*. Distraction includes focusing the attention on other aspects of the situation or directing the attention away from the situation entirely. This distraction process may be internal (e.g., thinking about something unrelated) or external (e.g., looking away from something disgusting). The fourth ER family is *cognitive change*, is set on the appraisal sequence in the emotion-forming process. This regulatory process refers to altering the evaluation of an internal (e.g., being more focused instead of nervous before giving a talk) or external situation (e.g., reinterpreting a failure as a new opportunity). A well-investigated form of cognitive change is *reappraisal*. The fifth ER family and the last in the emotion-generative process is *response modulation*. At this point, the emotional reaction has already been generated by triggering its experiential, behavioral, and physiological components. Thus, this regulatory family refers to directly influencing these responses by, e.g., physical exercise, breathing practices, or food or drug intake. A well-studied form of response modulation is *expressive suppression*, which encompasses the attempt to inhibit emotion-expressive behavior (e.g., not showing nervousness while giving a talk).

Figure 1.2. The process model of emotion regulation (Gross, 1998b).



Note. Five points of emotion regulation during the emotion-generative process, divided into antecedent- and response-focused emotion regulation (Gross, 1998b). Adapted from "Emotion regulation: Conceptual and empirical foundations" by J. J. Gross., 2014, in J. J. Gross (Ed.), Handbook of Emotion Regulation, second edition, pp. 3-20. Copyright 2014 by The Guilford Press.

Gross (1998a) differentiates between two classifications of ER strategies: the antecedent-focused and the response-focused strategies (see Figure 1.2). The *antecedent-focused strategies* summarize all strategies that start before an emotional reaction is generated. In contrast, the *response-focused strategies* target the already ongoing emotional reaction and change its experiential, behavioral, and physiological outcome. According to the process model, the earlier a regulation strategy is engaged in the emotion-generative process, the less cognitive resources[3] are necessary and the easier the regulatory goal is achieved (Gross, 2002; John & Gross, 2004). Suppression of already ongoing emotions requires constant self-monitoring and self-correctness, which is considered effortful and demands more cognitive resources (e.g., that become evident in memory impairment) (Gross, 2002). Then again, reappraisal does not require constant self-regulation and less cognitive resources, so the latter can be implemented where needed and appropriate (e.g., attending more to the interaction partner) (Gross, 2002; John & Gross, 2004). Whether these strategies are considered adaptive or maladaptive depends on the regulatory outcome and many other determinants such as context and individual factors. In the long-term, the regular use of emotion dysregulation can lead to dysfunctional mental health outcomes. This issue will be elaborated further in section 1.2.3.

1.2.2. Theoretical foundations of acceptance

A unique ER strategy not yet mentioned in this chapter is acceptance. Acceptance is originally not part of the process model of emotion regulation but has been discussed within this framework. This section will explore the foundations of acceptance, its relevance for chronic pain patients, its placement in the ER research, and its distinction from mindfulness.

1.2.2.1. Acceptance and Commitment Therapy

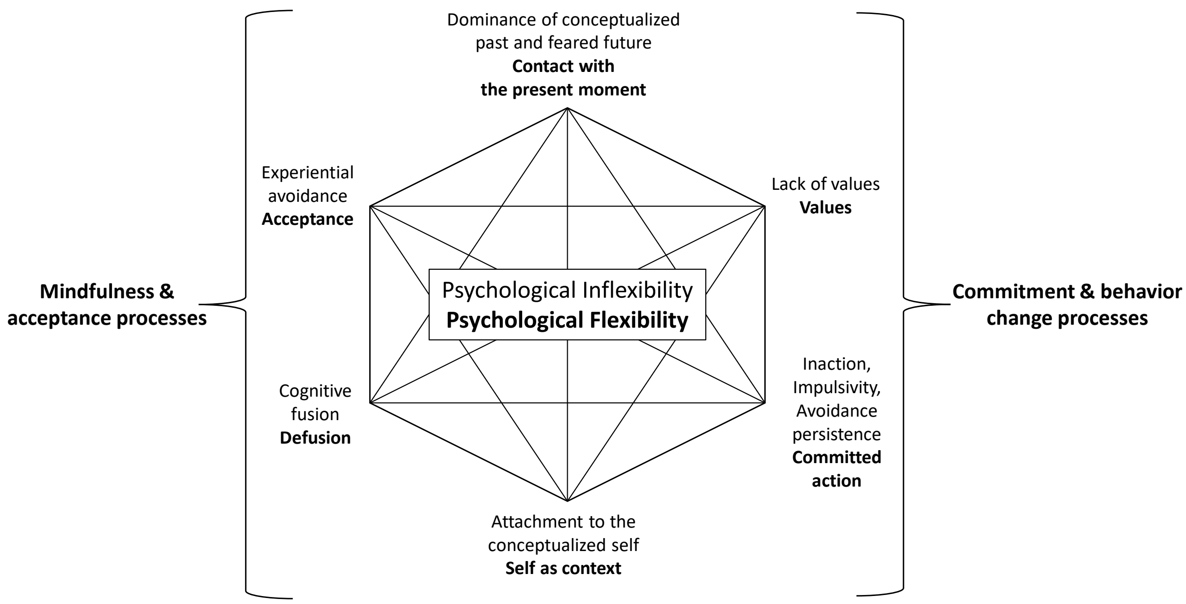
The origin and meaning of the word acceptance refer to "to take or receive what is offered", while psychologically acceptance means "an active process of taking in an event or situation" (Hayes et al., 1999a, p. 34). Hayes defines acceptance as an "attempt (…) to feel emotions and bodily sensations more fully and without avoidance, and to notice fully the presence of thoughts without following, resisting, believing, or disbelieving them" (Hayes et al., 1999a, p. 34). Acceptance does not target changes of forms or frequencies of events but rather their function (Hayes et al., 1999a).

To fully grasp the concept of psychological acceptance, it is essential to comprehend its part in the Acceptance- and Commitment Therapy (ACT) (Hayes et al., 1999b). After the "first wave" of behavioral therapies in the first half of the 20th century, a "second wave" emerged in the late 1970s – the classic Cognitive Behavioral Therapy (CBT), focusing on maladaptive patterns in emotion and behavior (Hayes & Hofmann, 2017). Then, about two decades ago, the "third wave" of behavioral therapies arrived and started focusing more on the relationships with thoughts and emotions rather than on their content (Hayes & Hofmann, 2017). One of these "third wave" behavioral therapies is ACT, which is rooted philosophically in contextualism. Theoretically, it derives from the Relational Frame Theory (Barnes-Holmes & Roche, 2001), the theory of human language and cognition, which entails the ability to

[3] According to current information-processing models (Lang, 2000; Sheppes & Gross, 2011), the ability to process information is constrained due to a limited pool of mental capacities or *cognitive resources*. When different information sources co-occur and the pool of cognitive resources reaches its full capacity, the sources start competing for dominance and cannot be processed simultaneously. Consequently, the cognitive or mental load is high, resulting in less effective execution of mental operations.

arbitrarily relate events (Hayes, 2002; Hayes et al., 2006). The ACT perspective sees psychological health as a process of upholding selected values while maintaining non-defensive contact with private events and reactions to them (Hayes, 2002). In turn, psychopathology emerges from psychological inflexibility, the inability to persist or change value-based behavior (Hayes et al., 2006). Thus, the overall goal of ACT is to increase ***psychological flexibility***, which refers to the ability to stay fully and consciously in contact with the present moment and to change or persist goal-directed action (Hayes et al., 2006).

Figure 1.3. Six core ACT processes of psychological flexibility and inflexibility.



Note. The model of psychological processes targeted by ACT (bold) and the ACT model of psychopathology (non-bold) by Hayes et al. (2006). Adapted from "Acceptance and commitment therapy: Model, processes and outcomes" by S. C. Hayes, J. B. Luoma, F. W. Bond, A. Masuda, & J. Lillis, 2006, in Behaviour Research and Therapy, volume 44, issue 1, pp. 1-25. Copyright 2005 by Elsevier Ltd.

Psychological flexibility is targeted by ***six core ACT processes*** that are all overlapping and connected. Figure 1.3 depicts the six core processes by Hayes et al. (2006) including their respective opposite leading to either psychological flexibility or inflexibility. *Acceptance* is one of the six core processes and fosters the "active and aware embrace of (…) private events" (Hayes et al., 2006, p. 7). Its alternative is *experiential avoidance*, the unwillingness to experience certain negative emotions or events and the attempt to change their form or frequency even when harmful (Hayes et al., 2004; Hofmann & Asmundson, 2008). Experiential avoidance is supported by *cognitive fusion*, which refers to the "excessive or improper regulation of behavior by verbal processes" (Hayes et al., 2006, p. 6) instead of learned contingencies. It includes, e.g., reason-giving (e.g., attempt to make sense of a psychological event even when unnecessary) and emotional control (e.g., as a primary goal of success). *Defusion* counters cognitive fusion and is a technique that helps to detach from events rather than changing them, and that decreases their believability. Defusion can lead to increased *contact with the present moment* by putting a stronger focus on the here and now instead of focusing on past experiences or future concepts (e.g., “living in one’s head”). Therefore, being present fosters contact with an event by using language as a tool, meaning the process of describing the event without judging it. These tools promote *self as context* or the sense of the self in the present (e.g., mindfulness exercises, metaphors), which again provides context for defusion. *Values* are chosen qualities for goal-oriented behavior and can vary and change over time. Choices of values should not be based on avoidance or social compliance. These chosen values are then integrated into *committed action* by setting value-based goals that can be achieved. Acceptance, defusion, contact with the present moment, and self as context can be summarized under ***mindfulness and acceptance processes.*** Values, committed action, and again contact with the present moment and self as context can be grouped into ***commitment and behavior change processes*** (see Figure 1.3).

The ACT is a promising and successful therapeutic intervention for individuals struggling with chronic pain (Stiles & Hrozanova, 2016). As chronic pain patients deal with pain and impairments in the quality of life and mental health, psychological treatments target pain management as well as improvements in overall well-being. Even though traditional CBT has successfully treated chronic pain in the past decades, it has also brought challenges, as outlined in the review by McCracken and Vowles (2014). The cognitive change of thoughts or beliefs and the stress control are central mechanisms of CBT (McCracken & Vowles, 2014; Stiles & Hrozanova, 2016). McCracken and Vowles (2014) argue that cognitive change might not be the mechanism leading to shifts in thoughts or behavior of pain patients observed in past literature on CBT. Thus, cognitive change methods might be unnecessary for the success of the chronic pain treatment or could even be harmful (McCracken & Vowles, 2014). Instead of aiming at the reduction and control of pain, ACT reduces the patients’ avoidance of the pain by focusing the attention on personally valued goals while mindfully observing and experiencing the pain (Stiles & Hrozanova, 2016). Thereby, the goal is to end the constant struggle with pain that usually withholds the patients from engaging in other valued activities.
McCracken and Vowles (2014) provided a review of the strong evidence in favor of ACT as a chronic pain treatment with medium to large effect sizes, including increased physical and social functioning and reduced pain-related medical visits even three years after the intervention. The authors suggested that psychological flexibility – specific to the theoretical approach of ACT – could mediate the positive outcome on chronic pain. ACT has led to more enjoyable daily activities, less perceived pain, better mental health, mood, and emotional stability in chronic pain patients (Stiles & Hrozanova, 2016). In a meta-analysis by Veehof et al. (2016), ACT improved the anxiety and depression levels of chronic pain patients more profoundly than cognitive- or mindfulness-based interventions. ACT has proven to be at least as effective as traditional CBT (McCracken & Vowles, 2014; Stiles & Hrozanova, 2016; Veehof et al., 2016). Hughes et al. (2017) showed in their meta-analysis that ACT was more effective than control conditions and active relaxation to manage chronic pain. Moreover, they found medium to large

effect sizes of ACT for pain acceptance and psychological flexibility. Vasiliou et al. (2020) showed improvements by ACT in headache patients in measures of emotional and physical limitations, quality of life, functionality, and depression compared to a waiting list. These improvements even remained after a 6- and 12-months follow-up. Novel models of internet-based ACT treatments have shown to mitigate pain interference and pain intensity levels of chronic pain patients and modulate their moods and affective states (Lin et al., 2018; Rickardsson et al., 2021; Trompetter et al., 2015). Payne-Murphy and Beacham (2015) demonstrated in an online study that chronic pain patients with higher acceptance levels showed more positive affect and less disability. They suggested integrating acceptance-based concepts into pain treatments and adjust them to the individual acceptance levels.

Therefore, current research started to focus more on core ACT processes to locate the mechanisms involved in the effectiveness of ACT on chronic pain. The core ACT process *acceptance* appears to be one of the most promising concepts in the current literature. The effects of acceptance on chronic pain will be discussed in detail in chapter 1.3.3.3.

1.2.2.2. Similarities and distinctions of mindfulness and acceptance

Mindfulness is a construct derived from Buddhism and other meditative practices or traditions (Bishop et al., 2004; Erisman & Roemer, 2010; Forsyth & Hayes, 2014). Mindfulness has been defined as an open-hearted awareness of a moment-by-moment experience by shifting the attention to the present moment without reacting to it or evaluating it (Bishop et al., 2004; Erisman & Roemer, 2010; Kabat-Zinn, 2015). This definition strongly resembles the two ACT core processes acceptance and being present (Forsyth & Hayes, 2014). As mentioned in the section before, Hayes et al. (2006) grouped mindfulness and acceptance processes into one umbrella term for acceptance, self as context, being in the present moment, and detachment from individual events. Even though there has been a debate on a clear delimitation of acceptance and mindfulness (Aldao et al., 2010), both constructs appear to be overlapping and thus cannot be separated entirely (Thompson et al., 2011). Bishop et al. (2004) suggested a two-component model of mindfulness, comprising self-regulation of attention and an orientation toward one’s experiences in the present moment including curiosity, openness, and acceptance. Even though based on either spiritual or empirical concepts, respectively, both mindfulness-based and acceptance-based interventions emphasize the non-judgmental acceptance of the present in the moment, so these constructs are undoubtedly connected (Thompson et al., 2011). Experimental research on acceptance often uses mindfulness to describe the non-judgmental component of the acceptance definition (Braams et al., 2012; Forsyth & Hayes, 2014; Kohl et al., 2013), which would resemble the ACT core process being present (de Boer et al., 2014; Hayes et al., 2006). Depending on the definition of acceptance or mindfulness investigated in a study, the construct behind it can be very similar or even the same even though declared as the one or the other. Aldao et al. (2010), for example, integrated both mindfulness and acceptance concepts into a single acceptance conceptualization for their meta-analysis and compared it to other ER strategies. Kohl (2012) chose a broad acceptance construct for their meta-analysis as it would not be possible to delimit both concepts. Therefore, it is worthwhile looking into research on both acceptance and mindfulness when dealing with acceptance.

1.2.2.3. Acceptance as an emotion regulation strategy

As pointed out in the previous subsection, acceptance has appeared in a variety of studies that compared it to ER strategies or even labeled it as one (Aldao et al., 2010; Dunn et al., 2009; Hofmann et al., 2009; Kohl et al., 2012; Liverant et al., 2008; Szasz et al., 2011). Even though the concept of acceptance does not aim at altering emotions or pain, it does hold the ability to change the emotional (Aldao et al., 2010; Hofmann et al., 2009; Kohl et al., 2012) or pain experience (Braams et al., 2012; Hayes et al., 1999a; Kohl et al., 2013; Masedo & Esteve, 2007). Even though the process model of emotion regulation by Gross (1998b) (see 1.2.1) does not contain any acceptance-based strategies, the integration of acceptance within the model is widely discussed. More accurately, there is an ongoing debate whether acceptance can be categorized within the process model as antecedent- or response-focused (Hofmann & Asmundson, 2008; Hofmann et al., 2009; Liverant et al., 2008; Wolgast et al., 2011). Hofmann and Asmundson (2008) pointed out in their review that ACT, including acceptance-based strategies, primarily targets response-focused strategies, especially by counteracting suppression and experiential avoidance, while CBT (cognitive behavioral therapy) mostly promotes antecedent-focused strategies. In a later study, Hofmann et al. (2009) referred to that review and concluded that acceptance could also be considered a response-focused strategy. Liverant et al. (2008) argued that acceptance contains both antecedent- and response-focused components. On the one hand, acceptance targets the cognitive change of an emotion's acceptability (Liverant et al., 2008) or an event (Hofmann et al., 2009). On the other hand, an emotion must be already generated to be allowed without any attempts to change it (Liverant et al., 2008). Wolgast et al. (2011) concluded that acceptance has both antecedent- and response-focused elements and intervenes mostly early in the emotion-generating process. Webb et al. (2012) even categorized in their meta-analysis acceptance as a reappraisal strategy and differentiated between reappraising the emotion itself (by, e.g., imagining a positive outcome) and reappraising the emotional response by accepting it and not judging it. Nevertheless, most of the mentioned studies work with the assumption that the more effective an ER strategy is, the earlier it must be embedded in the process model and thus considered anteceded-focused and adaptive (Hofmann et al., 2009; Liverant et al., 2008; Wolgast et al., 2011). However, this conclusion is flawed as other factors influence the effectiveness of successful ER, which will be discussed in the following section.

1.2.3. Emotion regulation vs. dysregulation

According to the process model of emotion regulation (Gross, 1998b) (see 1.2.1) , antecedent-focused strategies are considered to consume less cognitive resources than response-focused strategies and thus should facilitate achieving the regulatory goal. Therefore, antecedent-focused ER strategies should be more effective than response-focused ER strategies (Webb et al., 2012).

Two widely studied representatives of the two categories are the ER strategies *reappraisal* (antecedent-focused) and *suppression* (response-focused). John and Gross (2004) summed up the experimental and correlational evidence on these strategies. In a major study by Gross (1998a), reappraisal successfully decreased negative emotional experience and behavior elicited by watching emotional film clips, while the physiological activation (cardiovascular & electrodermal) remained unaffected. On the contrary, suppression only decreased the negative emotion's behavioral expression but did not change the experience and even increased the physiological activation. Moreover, John and Gross (2004) outlined that suppression is associated with poorer social memory (Richards & Gross, 2000) and impeded social interaction and relationships (Butler et al., 2003) while reappraisal is not. Correlational analyses revealed that the habitual use of reappraisal was associated with more positive and less negative emotion and better psychological health, without having effects on social memory (John & Gross, 2004). Habitual use of suppression was associated with less positive and more negative emotion, impaired social memory, less closeness, and worse psychological health (John & Gross, 2004).

There is a great body of research focusing on detecting specific ER strategies, individual factors, and contexts that result in either successful emotion regulation or emotion dysregulation. On the one hand, successful ER is associated with good health outcomes and improved relationships (Aldao et al., 2010; Gross, 2002). On the other hand, ***emotion dysregulation*** is associated with mental disorders and features various forms of psychopathy (Aldao et al., 2010; Gross, 2002), primarily when the dysregulation occurs chronically (Koole, 2009). The American Psychological Association (VandenBos & APA, 2015) defines emotional dysregulation as an “extreme or inappropriate emotional response to a situation (e.g., temper outbursts, deliberate self-harm)”, which “may be associated with bipolar disorders, borderline personality disorder, autism spectrum disorder, psychological trauma, or brain injury” (see term “dysregulation”, VandenBos & APA, 2015, p. 345). Gross and Jazaieri (2014) argue that emotion dysregulation can occur due to *ER failures*, meaning that no ER is initiated when needed. Alternatively, it can occur due to *emotion misregulation*, meaning that an inappropriate form of ER is used.

Koole (2009) delivers a classification of ER strategies regarding their target and their functioning in his review. According to his classification, ER can ***target*** *attention* (selection of incoming information), *knowledge* (e.g., cognitive appraisals, the relevance of events), or the *body* (e.g., facial expressions, physiological responses). Most importantly, ER not only depends on its target but the function or the regulatory goal. Koole (2009) identified three main ***functions*** of ER, namely *need-oriented* (e.g., inducing pleasure, avoiding pain), *goal-oriented* (e.g., prioritizing social norms), and *person-oriented* functions (e.g., the flexibility of personality, coherence, and long-term stability). ER usually aims at all functions, which can sometimes lead to conflicts and require a balance through prioritization. Concerning the process model by Gross (1998b), the review confirms antecedent-focused ER strategies such as distraction or reappraisal to be more effective than response-focused such as suppression, but only for goal-oriented ER. However, this pattern changes for need- and person-oriented ER. Distraction (e.g., attentional avoidance) seems to be less effective when ER is need-oriented and can even lead to

intrusive thoughts and poor mental health. Response-focused strategies, such as progressive muscle relaxation, were shown to be particularly effective for person-oriented ER. The review by Koole (2009) indicated that the effectiveness of ER strategies also depends on regulatory goals, which is in accordance with the process model by Gross (1998b). However, regulatory goals rarely find consideration in empirical research, which often attempts to classify ER strategies only in adaptive or maladaptive (Aldao et al., 2010; Webb et al., 2012).
Aldao et al. (2010) summed up in their meta-analysis a variety of literature suggesting a classification of ER strategies in *adaptive and maladaptive strategies* associated with emotion regulation or dysregulation, respectively. They analyzed three ER strategies linked to being protective (reappraisal, problem-solving, acceptance) and three ER strategies linked to being a risk factor (expressive and thought suppression, experiential and behavioral avoidance, rumination) of psychopathology associated with emotion dysregulation (depression, anxiety, eating disorders, and substance-related disorders). Indeed, adaptive strategies were associated with less and maladaptive strategies with more psychopathology. More interestingly, the relationship of the maladaptive ER strategies to psychopathology were more robust than for the adaptive ER strategies, suggesting that the presence of maladaptive strategies is riskier than the absence of adaptive ER strategies, questioning their protective quality. Especially reappraisal and acceptance showed small associations with psychopathology. Augustine and Hemenover (2009) analyzed the effectiveness of various ER strategies and showed reappraisal and distraction to be the most effective ER strategies regarding hedonic shifts (e.g., downregulating negative emotions). They also found moderating factors such as gender (women regulated more effective than men), length of regulatory effort (shorter regulatory efforts were more effective than longer), and pre-existing affect (the more negative emotions, the more effective ER.

In their meta-analysis, Webb et al. (2012) analyzed different subtypes of attentional deployment, cognitive change, and response modulation according to the process model of emotion regulation (Gross, 1998b) (see 1.2.1) regarding their ability to alter emotional responses. Cognitive change strategies (including reappraisal and acceptance) proved to be more effective in ER than attentional deployment (including distraction and concentration) and response modulation (suppression) strategies. Looking into the specific ER subtypes, distraction, as example for attentional deployment, was effective in regulating emotions, whereas concentration showed adverse effects. Moreover, instructions used in different experiments had a significant impact on the effectiveness of the ER strategy. For example, active distraction was more effective in regulating emotions than passive distraction. In consideration of the process model, these results showed again that the assumption of antecedent-focused strategies being more effective or adaptive than response-focused is impractical. Webb et al. (2012) also investigated several factors that moderate ER outcomes, showing that successful ER does not only depend on the ER strategy. Positive emotions were easier regulated than neutral or negative, except for sadness, assuming that frequently experienced emotions are easier to regulate. Interestingly, the meta-analysis could not find any effects of the timing of the ER instructions, questioning the process model's assumption of the decrease in cognitive resources and thus ER effectiveness over the emotion-generating process. Finally, the meta-analysis yielded larger ER effects for women than for men, but no effect of age.

Troy et al. (2013) questioned the previous attempts in detecting adaptive or maladaptive ER strategies and proposed a *person-situation approach*, taking the contextual factors of controllability and stress severity into account. In their study, they found that participants showed less self-reported depression (indicating better well-being) when self-reported stressful life events (stress) were severe and uncontrollable, and the ability to use reappraisal was high. However, when stress was severe and controllable, participants with high reappraisal abilities showed more depression and consequently decreased psychological health. These results indicate that using reappraisal may be dysfunctional and maladaptive when events are controllable and problem-solving would be more appropriate, stressing the importance of context. Troy et al. (2013) concluded that emotion dysregulation could result from deficits in ***regulatory flexibility***, which means the flexible, personal adaption of an ER strategy to situational demands (Bonanno & Burton, 2013).

Bonanno et al. (2004) already demonstrated in their within-subject study that the ability to flexibly up- and downregulate positive and negative emotions elicited by pictures accordingly to situational context represents healthy adjustment. More precisely, the ability to both express and suppress emotions predicted reduced distress two years after 9/11. In their review, Bonanno and Burton (2013) proposed a ***multifaceted model for regulatory flexibility*** comprising three sequential components in their review. The first component is *context sensitivity*, which refers to perceiving the demands and opportunities of a situation and determining the most appropriate strategy to react to it. How sensitive an individual is to the context will influence the flexibility of the following components, meaning the more context sensitivity, the more flexibility in the upcoming phases, and the other way around. The second component is the *ER strategies' repertoire*, meaning the availability of a wide range of different ER strategies, which differs individually. The more ER strategies are accessible, the more flexible the regulatory process. The third and last component is *feedback*, the ability to monitor the chosen ER strategy's efficacy and correct either the strategy selection or reevaluate the context. The better an individual can monitor the feedback, the more flexible is the responding.

In a series of studies, Sheppes et al. (2011) investigated the ***ER choice*** by either presenting emotional pictures or unpredictable electrical stimuli that elicited anticipatory anxiety, varying in intensity (low- vs. high-intensity). Participants could choose between the ER strategies distraction and reappraisal to regulate their emotions. In both emotional contexts, participants chose reappraisal to regulate low-intensity and distraction for the regulation of high-intensity emotions, indicating a preference for distraction as an earlier ER strategy in the ER process model by Gross (1998b) when emotional intensity was high. In a further experiment, Sheppes et al. (2014) repeated the previously described experiment but with two different groups: in the self-generated group, participants could select their own distraction or reappraisal strategies (as in the study before), and in the experimenter-generated group, participants were provided with examples for each ER strategy by the experimenter to simplify the ER process. Participants in the experimenter-generated group preferred reappraisal over distraction, indicating the ER choice depended on the complexity of generating the ER. In another study, Sheppes et al. (2014) showed that participants chose reappraisal over distraction when long-term, instrumental ER goals were induced compared to short-term, hedonic ER. All these studies suggest and support the importance of regulatory flexibility in the context.

Gross and Jazaieri (2014) focused on three factors that contribute to emotion dysregulation and reviewed examples of psychopathologies associated with them. The first factor is the *awareness* of one's emotion and the situation that elicited that emotion. ER failures can occur due to either too little (e.g., bulimia nervosa, including alexithymia) or too much awareness (e.g., panic disorder). The second factor is the knowledge about one's short- and long-term ER *goals*. The lack of interest in regulating an inappropriate emotion (e.g., bipolar disorder) or ignoring long-term consequences can lead to ER failures. The third factor is the choice and implementation of the *ER strategy*. The ER strategy choice can depend on the availability of cognitive resources and the intensity of the emotion. The overuse of one specific strategy may reflect a problematic ER strategy choice (e.g., situation selection in agoraphobia), while the implementation can be disturbed by failures in shielding against competing goals (e.g., ADHD).

In summary, emotion dysregulation is associated with multiple psychopathologies, so ER theories and research focus on investigating the circumstances that lead to successful emotion regulation or dysregulation. A great body of research so far has tried to classify ER strategies into either adaptive or maladaptive and thereby focused on ER strategies only (Aldao et al., 2010; Webb et al., 2012). However, there is a growing body of frameworks and empirical research that includes individual and context factors to ER research. Effective ER depends on the ER strategy subtypes and instructions used in experiments as well as the type of emotion (Webb et al., 2012) or ***emotion intensity*** (Gross & Jazaieri, 2014) that is regulated, ***familiarity*** with the emotion, or ***gender*** (Webb et al., 2012). ***Context*** factors such as controllability and severity of previous stressful life events contribute to successful or dysfunctional ER, leading to better or poorer mental health, respectively (Troy et al., 2013). Overall, ***regulatory flexibility*** appears to be an essential ability associated with successful ER and means adapting to contextual demands (Bonanno & Burton, 2013; Troy et al., 2013). The flexible implementation of ER strategies includes ***context sensitivity*** (Bonanno & Burton, 2013) or awareness of the emotional situation (Gross & Jazaieri, 2014), ***regulatory goals*** (Gross & Jazaieri, 2014; Koole, 2009), and ***ER strategy choice*** (Gross & Jazaieri, 2014; Sheppes et al., 2014). Regulatory goals have been shown to influence ER strategies' effectiveness (Koole, 2009) and ER strategy choices (Sheppes et al., 2014). Not being aware of an emotional situation or context, setting inappropriate regulatory goals, or choosing the wrong ER strategy can result in emotion dysregulation and lead to psychological health problems or mental disorders (Gross & Jazaieri, 2014).

1.2.4. Temporal dynamics in emotion regulation

The need to assess temporal parameters in psychological research has been emerging (Roe, 2008) and is slowly entering emotion and pain regulation research. Thompson provided an alternative, more elaborate definition of emotion regulation: "Emotion regulation consists of the extrinsic and intrinsic processes responsible for monitoring, evaluating, and modifying emotional reactions, especially their intensive and ***temporal features*** to accomplish one's goals" (Thompson, 1994, pp. 27-28). Thompson (2011) explained in his review that ER could affect the speed of the onset and persistence of an emotional reaction, the duration of the recovery of an emotion, and the stability and range of an emotional response.

In the process model of emotion regulation (see 1.2.1), Gross (1998b) already considers temporal dynamics. Regarding the emotion-generative process, emotions gain intensity over time. Depending on what time point the ER is initiated, the ER strategies are grouped into either antecedent- or response-focused. As pointed out in the previous section, antecedent-focused strategies have been viewed as being more effective than response-focused as they intervene early in the process. Sheppes and Gross (2011) called this idea the ***generic timing hypothesis***. They criticized in their review that comparing an antecedent-focused strategy such as reappraisal with a response-focused strategy such as suppression does not examine the generic timing hypothesis directly because these strategies differ in more aspects besides timing (e.g., cognitive vs. behavioral). Thus, they suggested investigating different ER strategies by manipulating the emotional intensities. As the process model is dynamic and involves repeated cycles, it should be possible to test ER strategies at any time point of the emotion-generative process under different emotional intensity levels. In support of the generic timing hypothesis, ER should be more effective when intensity is low compared to high. Sheppes and Gross (2011) expanded the timing hypothesis and named it the ***process-specific hypothesis***. Taking into account information processing theories about early filter mechanisms and late semantic filters, they suggested that the later an ER process is initiated in the emotion-generative process, the more effort would be needed, and the more it should be affected by emotional intensity. Thus, early ER strategies should be relatively unaffected, and late ER strategies should be more affected by higher levels of emotion due to minimal or high effort, respectively. Sheppes and Gross (2013) integrated three factors to their extension that serve as the basis for ER strategies' effectiveness: the availability of *cognitive resources* required by the ER strategy, the *intensity* of the targeted emotion, and the *regulation goal* regarding the time (short- or long-term).

Sheppes and colleagues investigated the process-specific hypothesis in several studies by contrasting two antecedent-focused strategies occurring at an earlier and a later time point in the process model, namely distraction and reappraisal, respectively. In support of the process-specific hypothesis, they showed that distraction was equally effective in downregulating low and high negative emotions induced by sad film clips. In contrast, reappraisal was only effective for low levels of sadness (Sheppes & Meiran, 2007, 2008). Interestingly and as also expected by the process-specific hypothesis, regulation success increased with reappraisal of high levels of emotional intensity when applied over a more extended time (Sheppes et al., 2009; Sheppes & Meiran, 2007, 2008). Even though early and low-effort ER strategies provide fast and short-term relief of negative emotions, the authors state that they should not be considered as adaptive in all contexts. When it comes to long-term consequences, strategies such as distraction or avoidance might prevent a more in-depth and elaborated processing of crucial information and understanding and, therefore, become maladaptive. Thus, training ER strategies that are executed later such as reappraisal might be more beneficial in the long run and also reduce cognitive costs over time as it becomes automatic. Sheppes and colleagues investigated the temporal dynamics of emotion regulation by manipulating the emotional context (e.g., intensity) and drawing conclusions about the time point in the emotion-generative process. However, there are also attempts to directly capture the temporal dynamics of emotion regulation by assessing the time course of various variables.

Thiruchselvam et al. (2011) tested the timing hypothesis with the ER strategies distraction and reappraisal using the late positive potential (LPP; electrocortical index) as a measure of the evaluation of a stimulus' affective meaning. As assumed, the LPP decreased earlier for distraction (300 ms after picture onset) than for reappraisal (1500 ms after picture onset) during the regulation of emotions induced by negative or neutral pictures (5 s). More interestingly, the pictures were presented again in a re-exposure phase and should be watched passively. The pictures with a distraction history produced a larger LPP than the control condition, whereas reappraisal did not. These results suggested that distraction prevented the pictures' evaluative processing, indicating that it intervenes earlier in the emotion-generative process. A study by Schönfelder et al. (2014) also measured the LPP by regulating emotions elicited by positive, neutral, and negative pictures (5 s) through distraction and reappraisal. Similar to Thiruchselvam et al. (2011), distraction led to an earlier and more substantial reduction of the LPP (1000 – 2000 ms after picture onset) than reappraisal (2000 – 3000 ms after picture onset) for negative pictures, again in support of the timing hypothesis. However, the LPP decreased only for distraction but not reappraisal for positive pictures. These two studies contrast with the study by Hajcak and Nieuwenhuis (2006) that showed an early attenuation of the LPP by reappraisal of unpleasant pictures (1 s) at 200 ms after picture presentation.

Dan-Glauser and Gross (2011) juxtaposed expressive and physiological suppression of emotions elicited by positive, negative, or neutral pictures and compared them to a control condition. To capture the temporal dynamics of the ER strategies, they assessed continuous valence ratings with a rating dial and segmented continuous expressive-behavioral (e.g., corrugator) and autonomic recordings (e.g., HR) during the 8 s picture presentation into 16 epochs of 500 ms. Experienced downregulation of negative emotions was already evident by lower ratings after 1 to 4 s after picture onset, expressivity (higher corrugator activity) even after half a second, and HR acceleration after 1.5 s, suggesting an early detection of regulatory effects of both types of suppression in a variety of measures. Dan-Glauser and Gross (2015) conducted another very similar study except with the ER strategies acceptance and suppression. Results showed that acceptance did not affect the ratings, while the facial expression was more pronounced for negative (between 3.5 and 5 s after picture onset) and positive pictures (between 1 and 6 s after picture onset), compared to suppression and the control condition. Cardiovascular measures during acceptance, including HR, were very similar to the control conditions. Dan-Glauser and Gross (2015) concluded that acceptance mostly acts on the expressive component in the investigated time window rather than on the subjective or physiological level, indicating that acceptance might facilitate social interaction.

Mocaiber et al. (2011) showed participants briefly (200 ms) pictures of mutilations. They instructed them to either imagine the pictures as parts of movies (reappraisal condition) or as real (control condition). Continuous HR was recorded in a total of 2.2 s after picture onset and averaged into six epochs of 200 ms. HR showed a more considerable deceleration for mutilation pictures compared to neutral pictures only in the control condition, whereas this effect disappeared in the reappraisal condition. Defense or orienting bradycardia, meaning an initial decrease of HR and representing an attentional defense reaction or freezing response due to a threat (Bradley et al., 2001), has been reduced in this study by reappraisal. Another study by Pavlov et al. (2014) compared upregulation of positive and downregulation of negative pictures (5 s presentation) with reappraisal, measured the cardiovascular responses, and analyzed them as 15 epochs of 500 ms. This study showed an initial decrease of HR during the first 3 s of picture presentation in the control condition, pointing towards orienting bradycardia. Only during reappraisal of positive pictures, orienting bradycardia and other cardiovascular measures decreased, whereas reappraisal of negative pictures did not affect the HR. However, the anticipation of reappraisal of negative pictures led to reduced cardiac responses, indicating an adaptive preparation to a potentially negative outcome.

This overview of temporal dynamics in ER demonstrates the inconsistency of the scarce findings. Overall, there is evidence in support of the timing hypothesis, specifically for distraction and reappraisal. ER through ***distraction*** can be apparent in the LPP as early as 300 ms (Thiruchselvam et al., 2011) until 1000-2000 ms (Schönfelder et al., 2014) after stimulus onset. ***Reappraisal*** affected the LPP in a time range of 1500-3000 ms after stimulus onset (Schönfelder et al., 2014; Thiruchselvam et al., 2011) and decreased the initial, orienting HR deceleration in the first 3 s (Mocaiber et al., 2011; Pavlov et al., 2014). Regulatory effects of ***suppression*** have been shown to affect the experience after 1-4 s after stimulus onset, the facial expression even after 500 ms, and HR after 1.5 s (Dan-Glauser & Gross, 2011). However, only one study so far (Dan-Glauser & Gross, 2015) investigated temporal dynamics of ***acceptance*** and did not find any dynamics regarding the self-reported experience and autonomic responses, except for the facial expression for positive (1-6 s) and negative emotions (3.5-5 s). Thus, temporal dynamics seem to play a crucial role and might hold answers about underlying mechanisms but need to be investigated further under different circumstances and with a variety of ER strategies.

1.3. Regulating emotions and pain

A great variety of experimental studies compare ER strategies with each other by inducing various emotions, usually by showing emotion-eliciting pictures or film clips or by inducing physical pain for pain management studies. In this chapter, a brief overview of the taxonomy of the strategies acceptance, distraction, and reappraisal, including different subtypes or concepts, will be presented. Afterward, current findings on the ER strategies distraction, reappraisal, and acceptance will be reviewed separately for emotion and pain regulation contexts. In the last section of this chapter, the importance of individual ER styles will be highlighted.

1.3.1. Taxonomy of the strategies in the current literature

Even though Hayes et al. (1999a) defined ***acceptance*** in ACT as "an active process of taking in an event or situation" as one of the six core processes targeting psychological flexibility (see 1.2.2.1), its concept definition and instructions used in different studies vary greatly. On the one hand, this inconsistency might be due to varying meanings of acceptance in the everyday language. The definition closest to the one by ACT would be the "willingness to accept an unpleasant or difficult situation" (Oxford Advanced American Dictionary, ©2020 Oxford University Press, see term "acceptance" online), focusing on negative events. On the other hand, researchers might refer to different theoretical approaches such as mindfulness (see 1.2.2.2). Acceptance has been investigated in the sense of accepting a partner's behavior or tolerating certain events or situations. In contrast, psychological acceptance refers to individual experiences (Hayes et al., 1999a), which is the more frequent working definition. Coming back to ACT, there is the possibility to use broader or more specific acceptance concepts. According to Hayes, a more precise meaning of acceptance as related to ACT would be defined as an "active and aware embrace of (…) private events occasioned by one's history without unnecessary attempts to change their frequency or form (…). (…) acceptance is fostered as a method of increasing values-based action" (Hayes et al., 2006, pp. 7-8). For example, Hofmann et al. (2009) instructed participants in their acceptance condition to try to experience their feelings fully, not to try to control or change them in any way, and to let their feelings run their natural course. These instructions would represent *acceptance* as the core process following ACT. However, there are also combinations of ACT core processes compiling a broader acceptance construct in past emotion and pain regulation literature. In their study with painful electrical stimuli, Braams et al. (2012) defined acceptance as "the welcoming of thoughts, emotions, and other experiences in the moment, with non-evaluative judgment" (Braams et al., 2012, p. 1015), combing the two ACT core processes *acceptance* and *mindfulness* (being present). Kohl et al. (2013) explained to participants in a pain tolerance study that acceptance or nonjudgmental awareness (*mindfulness*) can help to disengage from thoughts that initiate behavior and introduced "thoughts as clouds in the sky passing by" as an example of *defusion* (Kohl et al., 2013, p. 307). As conceptualized by Hayes et al. (2006), these processes are all overlapping in ACT and connected. Thus, acceptance is rarely investigated as an isolated concept but instead as a combination of several processes.

Regarding the taxonomy of ***distraction***, there exist different subtypes of distraction in the literature that use the same terms but should be differentiated further. Webb et al. (2012) identify in their meta-analysis four types of distraction. First, they discriminate between active and passive distraction. *Active* distraction refers to participants being instructed directly to think about something different than the presented stimulus specifically to distract themselves. *On* the other hand, passive distraction means that participants are provided with materials or tasks unrelated to the stimulus without specific instructions to distract themselves. Second, Webb et al. (2012) distinguish between *positive* and *neutral* distraction, meaning that the distractor has a positive or neutral value unrelated to the stimulus. The authors argue that positive distraction might be more effective than neutral distraction due to its emotional value. However, positive distraction might be considered more effortful when presented actively instead of passively, leading to less effectiveness.

In the literature on ***reappraisal***, two forms are both considered forms of reappraisal. One of them is called *distancing* or *detachment* from the emotional stimulus by adopting a more or a less objective perspective (Dörfel et al., 2014) or called *perspective taking* (Webb et al., 2012). The other form refers to the *reinterpretation* of either the emotional stimulus itself (Dörfel et al., 2014; Webb et al., 2012) or a reinterpretation of the situation (Webb et al., 2012). Dörfel et al. (2014) contrasted four ER strategies: distancing, reinterpretation of the stimulus, expressive suppression, and passive, neutral distraction. They found that distancing, expressive suppression, and distraction led to activations of similar brain regions (right prefronto-parietal regulation network) and decreased the left amygdala activation. However, reinterpretation did not modulate the amygdala and activated the ventrolateral PFC and orbitofrontal gyrus uniquely, suggesting that reinterpretation is distinct from the other three ER strategies. The authors suggested that reinterpreting depends on linguistic and semantic processes represented by the activation in the ventrolateral PFC. They also proposed that the orbitofrontal gyrus reflects the stimulus's motivational relevance, indicating an actual change in the emotion's valence by reinterpretation. Often conceptualized as a single ER strategy named reappraisal, reinterpretation and distancing appear to be distinct strategies.

The following chapters present overviews of the past and current research on acceptance, distraction, and reappraisal in emotion and pain regulation contexts.

1.3.2. ER strategies modulate effectively aversive emotions

This chapter reviews the current literature on the strategies acceptance, distraction, and reappraisal in the context of ER. The strategies will be categorized according to the taxonomy presented in the previous chapter if the primary literature provides enough information.

Distraction and reappraisal have been widely studied and compared with each other in multiple experimental studies. One of the main goals of these studies was usually to contrast two temporarily consecutive and antecedent-focused ER strategies according to the process model of emotion regulation (see 1.2.1) in order to develop and extend the understanding of the timing hypothesis (Gross, 1998b; Sheppes & Gross, 2011) (see 1.2.4).

As mentioned briefly in the chapter on temporal dynamics (see 1.2.4), Sheppes and Meiran (2007) showed that active distraction of sad film clips by thinking about something neutral and unrelated to the film was an effective strategy in downregulating self-reported experience of both low and high negative emotions or when initiated early and late (before and after an emotion has been elicited respectively). However, reappraising (distancing) the film clips by adopting a neutral attitude was only effective when the induced negative emotions were low, or reappraisal was initiated early. Additionally, reappraisal of high negative emotion gained effectiveness when the regulation duration became longer. On the contrary, late reappraisal led to impaired cognitive resources measured by a Stroop task, whereas distraction only impaired memory (Sheppes & Meiran, 2008; Thiruchselvam et al., 2011). In support of these results, Sheppes et al. (2009) found an increased SC level for late reappraisal, indicating a higher cognitive effort. These results clearly demonstrate different underlying mechanisms of active, neutral distraction and reappraisal in the sense of distancing/detachment. Distraction might be a very effective short-term strategy for any emotional intensity and independent of the initiation time point. On the other hand, reappraisal may be more beneficial when emotions are of low intensity, reappraisal is initiated early, or more time is provided to regulate the emotion. McRae (2016) argued in her review that reappraisal might take more time to be selected and implemented correctly, without the individual being overwhelmed by emotional intensity. Denny and Ochsner (2014) conducted a longitudinal study with four training sessions investigating the two reappraisal forms distancing and reinterpretation. Participants were asked to implement the required instructions while watching neutral or negative pictures. Results showed that both conditions led to decreased negative affect over the four sessions. In contrast, the effects were more pronounced for distancing, providing evidence for the long-term effectiveness of reappraisal.

McRae et al. (2010) contrasted regulating negative emotions elicited by pictures with reappraisal (reinterpretation) and with passive distraction and assessed the self-reported experience and neural correlates. Both ER strategies lowered negative emotions and decreased activation in the amygdala and prefrontal and cingulate brain regions associated with cognitive control. Reappraisal led to an increased activation in medial prefrontal and anterior temporal regions that have been linked to the processing of affective meaning. Distraction led to a more significant decrease in amygdala activation than reappraisal and increased activation in prefrontal and parietal regions associated with selective attention. The authors explained the more pronounced decrease in amygdala activation as a result of not attending to or not encoding emotional aspects during distraction. In this study, reappraisal reduced the experienced negative affect more profoundly than distraction, but the emotional intensity was not varied. A meta-analysis by Buhle et al. (2014) showed that reappraisal of negative affect mainly activates cognitive control areas (dorsomedial, dorsolateral, and ventrolateral PFC, posterior parietal lobe) and the lateral temporal cortex, indicating the use of cognitive control to alter semantic representations of an emotion, which in turn attenuates activation in the bilateral amygdala. It is noteworthy that Buhle et al. (2014) did not differentiate between reinterpretation and distancing as types of reappraisal.

In a more recent study and in line with previous findings (Sheppes et al., 2009; Sheppes & Meiran, 2007, 2008), Van Bockstaele et al. (2019) showed that participants who were given a choice to regulate low- or high-intensity negative emotions with either situation selection, distraction (active, neutral) or reappraisal (reinterpretation), chose situation selection and distraction for more intense and reappraisal for less intense negative emotions. Similarly, in a study by Moodie et al. (2020), participants could choose between the ER strategies reappraisal (reinterpretation), distraction, and distancing to regulate low and high negative emotions prompted by pictures while self-reported experience and neural activations were assessed. Results showed that reappraisal activated brain regions such as the dorsolateral PFC, supporting previous findings (Buhle et al., 2014). Most interestingly, this particular activation diminished with high emotional intensity levels, supporting the assumption that reappraisal becomes less effective with higher emotional intensity. For distraction, activations in the dorsolateral PFC, anterior insula, and the angular and supramarginal gyrus regions were observed, especially for high-intensity emotions, indicating that distraction adapted flexibly to the regulatory demands.

In the last two decades, acceptance has emerged in the ER research and has been compared to commonly investigated ER strategies such as distraction, reappraisal, or suppression (see 1.2.2.3). To compare ***acceptance with distraction***, Singer and Dobson (2007) induced negative mood with music combined with an autobiographical recall of negative mood-evoking events in remitted depressed participants. They randomly assigned participants to one of four groups: active distraction by thinking about something else (positive and neutral), acceptance comprising mindfulness and defusion elements, rumination, and a no training control group. Both distraction and acceptance significantly reduced the negative mood ratings compared to rumination and control without differing from each other. However, only acceptance reduced the negative attitude towards negative moods significantly compared to distraction and rumination. These results indicated that acceptance not only increased the tolerance of temporary sad mood but also decreased the negative mood equally to distraction. Kuehner et al. (2009) conducted a similar study but with a healthy sample and without a control group, in which only distraction but not acceptance led to reduced negative affect compared to rumination. In another similar design with remitted depressed patients, Huffziger and Kuehner (2009) found that both acceptance and distraction reduced negative mood compared to rumination. A study by Najmi et al. (2009) investigated the effectiveness of acceptance instructed by a defusion metaphor, distraction (active, positive), and suppression of unwanted intrusive thoughts in obsessive-compulsive disorder patients and healthy controls. They showed that acceptance and distraction both reduced distress after the task compared to suppression in the patient group but not the healthy control group. Moreover, only acceptance reduced the frequency of intrusive thoughts compared to distraction and suppression in the patient group.

The study by Hofmann et al. (2009) was the first study to compare ***acceptance with reappraisal*** directly in an ER context. Participants were asked to give an impromptu speech, a method to induce social anxiety, and received instructions about either acceptance, reappraisal (reinterpretation of the situation), or suppression. Results indicated that both acceptance and reappraisal decreased the HR relative to baseline measures compared to suppression. However, self-reported anxiety was only lower for reappraisal, whereas acceptance and suppression did not differ. The authors suggested that acceptance may be more beneficial for regulating physiological arousal rather than the experience. Wolgast et al. (2011) showed aversive film clips to participants and instructed them to either accept, reappraise (reinterpretation and distancing), or simply watch (control condition) them. They showed that acceptance and reappraisal lowered self-reported distress compared to the control group. Furthermore, physiological responses (SC, activity of corrugator supercilii) and behavioral avoidance to the film clips were reduced in these two groups compared to control. However, the authors did not find any differences between the two ER strategies. Szasz et al. (2011) induced anger via mental imagery and a frustration task in their study and asked healthy participants to either accept, reappraise (reinterpretation of the situation) or suppress their anger. The authors showed that the participants' anger decreased, and frustration tolerance increased over time for all three strategy groups, while the effects were most pronounced for reappraisal. Acceptance and suppression did not differ from each other. Asnaani et al. (2013) examined a healthy sample in a within-subjects design: participants were presented emotion-eliciting pictures (positive, negative, neutral) and should accept their emotions mindfully, reappraise them (distancing) or suppress them while an acoustic startle probe[4] was presented. The authors did not find any differences in the distress ratings between the strategies. However, suppression attenuated the eye-blink startle magnitude compared to acceptance and reappraisal irrespective of the picture valence. The authors suggested that participants might have used distancing or distraction strategies by redirecting their attention instead of suppressing them. Keng et al. (2013) induced sadness via music and autobiographical recall similar to Singer and Dobson (2007) in participants with elevated depressive symptoms. The researchers had instructed participants to either regulate their sadness with acceptance comprising mindfulness or reappraisal by reinterpreting the emotional stimuli, or no instructions were provided (control). Results indicated less sadness over time for both acceptance and reappraisal than the control group, but no differences between the two strategies. However, the interference scores measured by a Stroop task were lower for acceptance than reappraisal, indicating that acceptance was associated with reduced cognitive costs compared to reappraisal. Germain and Kangas (2015) investigated a sample with high trait anger and induced state anger with an anger recall task. Participants were randomly assigned to an acceptance, a reappraisal (reinterpretation), or a suppression group. Interestingly, reappraisal and suppression both reduced the state anger while acceptance even led to an increase of anger over the time course of the experiment. Unfortunately, the authors did not explain this unexpected

[4] The *probe startle reflex* is a primitive defensive reflex, reflected by the closure of the eyelids within 25-40 ms after a startle stimulus (Asnaani et al., 2013). The defensive reflex is potentiated when perceiving a threat and inhibited for appetitive cues or focused attention (Lang & Bradley, 2010). In the field of ER, startle magnitude has been shown to decrease when negative emotions are downregulated and to increase when they are upregulated (Asnaani et al., 2013; Jackson et al., 2000).

increase of state anger in the acceptance group any further. Instead, they only referred to contextual flexibility (Bonanno & Burton, 2013) to explain their findings. However, following this argument, the results indicate that acceptance might not be suitable as an effective ER strategy for high trait anxiety individuals. Another possible explanation is that the participants, in particular high trait anxiety individuals might be less familiar with the concept and use of acceptance and need more practice. In a more recent study, Goldin et al. (2019) presented healthy adults with either neutral or negative sentences, including autobiographical situations and negative self-beliefs. They asked the participants to either accept (including mindfulness), reappraise (reinterpretation), or react to (control condition) their negative self-beliefs while they assessed their autonomic and neural responses. Both reappraisal and acceptance conditions resulted in significantly less negative emotions and reduced respiratory rates compared to the control condition, suggesting a decreased emotional reactivity and increased focused attention. Moreover, both strategies led to greater activation in brain regions associated with cognitive control (PFCs), such as the dorsolateral and ventrolateral PFC, indicating goal-oriented ER selection and, again, the reduction of emotional reactivity. Negative emotions were even more reduced in the reappraisal compared to the acceptance condition, while HR was only lower for acceptance but not reappraisal compared to the control condition. However, reappraisal led to more brain activation in various areas (e.g., dorso-medial PFC) than acceptance and less activation in the amygdala, suggesting reappraisal to be more effective and more effortful than acceptance in downregulating negative emotions reflected by greater autonomic and neural activation.

Very few studies so far have compared ***acceptance, distraction, and reappraisal*** directly with each other in the ER context. In their meta-analysis, Kohl et al. (2012) contrasted acceptance as an ER strategy with various other ER strategies. They showed that acceptance was generally more effective than strategies labeled as maladaptive such as rumination or suppression (see 1.2.3, Aldao et al. (2010)). However, the comparison of acceptance with adaptive strategies such as distraction or reappraisal did not lead to clear conclusions. The authors suggested that the effectiveness of acceptance might depend on the regulatory goal. In studies where the goal was to reduce negative affect, acceptance seemed less or equally effective than other ER strategies. In studies where the goal was to endure negative feelings, acceptance seemed to be more effective. Thus, studies involving self-report measures such as ratings showed mixed results, whereas studies using tolerance tasks showed that acceptance was more effective than adaptive ER strategies. However, especially in the context of negative emotions, results were heterogeneous. Helbig-Lang et al. (2015) randomly assigned healthy and socially anxious individuals to one of three strategy groups: acceptance, including mindfulness, active distraction by completing a neutral crossword puzzle, and reappraisal by taking a realistic perspective (distancing). They induced anticipatory anxiety by announcing an impromptu speech. Anxiety and intensity ratings, as well as HR and blood pressure, were assessed. Surprisingly, all three strategies for both the clinical and healthy groups were equally effective in downregulating the anxiety during the speech's anticipation. Psychophysiology remained unaffected by strategy or sample. Interestingly, participants rated acceptance as more difficult and less successful to implement than distraction and reappraisal. The authors argue that acceptance probably requires more practice and a calm environment to be implemented appropriately. In a study by Volkaert et al. (2020), adolescents (age 9-13 years) were trained in either acceptance including mindfulness, reappraisal by reinterpreting their thoughts, active distraction, problem-solving, or were assigned to the rumination or cognitive task control group (passive distraction). Negative mood was induced by a sad film clip. Results showed that all ER strategy groups and the cognitive task control group significantly decreased negative emotions such as sadness and anxiety and increased positive moods such as adolescents' happiness. Only rumination led to an increase in negative emotions and maintained a low level of happiness. No long-term effects on the emotional well-being of the participants could be found.

In sum, ***distraction*** was effective in downregulating the self-reported experience of negative emotions, irrespective of the intensity or strategy onset (before or after emotion generation) (Moodie et al., 2020; Sheppes & Meiran, 2007, 2008; Thiruchselvam et al., 2011; Van Bockstaele et al., 2019). ***Reappraisal*** was only effective in downregulating negative emotions when emotional intensity was low, the strategy was initiated early, and more time was provided for the regulation process (McRae et al., 2010; Moodie et al., 2020; Sheppes & Meiran, 2007, 2008; Thiruchselvam et al., 2011; Van Bockstaele et al., 2019). When reappraisal was initiated late, more cognitive resources were consumed, which was evident in a Stroop task, and SC level was higher (Sheppes et al., 2009; Sheppes & Meiran, 2007). However, reappraisal is considered an effective long-term strategy (Denny & Ochsner, 2014), whereas distraction is speculated to be especially useful as a short-term strategy (Sheppes et al., 2009), adapting flexibly to the regulation demands.

Regarding the underlying mechanisms of distraction and reappraisal, both strategies were associated with brain regions reflecting cognitive control (Buhle et al., 2014; McRae et al., 2010; Moodie et al., 2020). Distraction also activated regions linked with selective attention, and reappraisal activated regions linked with the processing of affective meaning (McRae et al., 2010). Distraction was shown to impact memory (Sheppes & Meiran, 2007) and diminish amygdala activation compared to reappraisal, indicating that emotional aspects were not attended to or not encoded (McRae et al., 2010). Thus, reappraisal involves reinterpreting the affective meaning, while distraction does not process the affective meaning at all.

Most studies have shown that ***acceptance*** is equally effective in downregulating the experience of negative emotions as distraction (Huffziger & Kuehner, 2009; Najmi et al., 2009; Singer & Dobson, 2007), reappraisal (Asnaani et al., 2013; Goldin et al., 2019; Keng et al., 2013; Szasz et al., 2011; Wolgast et al., 2011) or both (Helbig-Lang et al., 2015; Volkaert et al., 2020). Few studies reported distraction (Kuehner et al., 2009) or reappraisal (Germain & Kangas, 2015; Goldin et al., 2019; Hofmann et al., 2009) as more effective than acceptance in the reduction of negative emotions. However, physiological measures such as HR, respiratory rate, or SC were consistently reduced for acceptance (Goldin et al., 2019; Hofmann et al., 2009; Wolgast et al., 2011), suggesting a robust effect of acceptance on physiological arousal rather than self-reported experience. Moreover, acceptance was associated with less cognitive costs than reappraisal (Keng et al., 2013). Some studies suggested that acceptance might be more efficient when tasks involve tolerating aversive experiences (Kohl et al., 2012) and when practiced more profoundly (Germain & Kangas, 2015; Helbig-Lang et al., 2015).

1.3.3. Effective regulation of pain with ER strategies

ER strategies have been widely investigated regarding their ability to alter emotions, but their ability to modulate the perception of pain also gained attention in the last decades. As pointed out in the first chapter, pain contains sensory and affective components, and its perception is highly subjective. The assumption that the perception of pain can be regulated similarly to emotions is therefore obvious. Furthermore, there is a high comorbidity between chronic pain and psychological disorders (Konietzny et al., 2016). As outlined in detail in chapter 1.2.3, emotion dysregulation is based on multiple factors and can result in psychological health problems. Emotion dysregulation can further result in the development and maintenance of chronic pain as well (Koechlin et al., 2018; Konietzny et al., 2016). Konietzny et al. (2016) outlined in their review, how pain and negative emotions are mutually dependent. Pain-related limitations in daily activities can lead to frustration and catastrophizing, which can in turn lead to even more focus on the pain. This vicious circle can result in a chronification of the pain in the long-term. Adaptive ER can facilitate goal-oriented behavior and help deal with the negative emotions and pain.

This section will review the current pain regulation literature on the ER strategies acceptance, distraction, and reappraisal. Again, the strategies will be categorized according to the taxonomy presented in chapter 1.3.1 if sufficient information is given in the literature.

1.3.3.1. Analgesic effects of distraction on acute but not chronic pain

Attentional deployment is the most researched cognitive strategy modulating the perception of pain. Wiech et al. (2008) outlined in their review how attention to or ***distraction*** from pain can increase or decrease the perceived pain intensity, respectively. While pain naturally attracts attention (Eccleston & Crombez, 1999) and can serve as a distractor from daily activities itself (Johnson, 2005), it can be challenging to engage in distraction from pain, depending on various factors such as the level of pain intensity (Buhle & Wager, 2010). Thus, regarding the self-reported perception of pain, results for distraction are somewhat inconclusive. However, distraction has been shown to attenuate brain activations in areas associated with sensory, affective, and cognitive areas of pain, such as the thalamus and the ACC (Bushnell et al., 2013; Wiech et al., 2008). When the emotional state was controlled, distraction only decreased the activation in the insula and the primary somatosensory cortex (Bushnell et al., 2013), modulating mainly the sensory aspects of pain. Bushnell et al. (2013) suggested that active, positive distraction might affect pain unpleasantness by targeting the emotional state, whereas neutral distraction could target pain intensity.

Two theories on the mechanisms underlying the distraction of acute pain are highlighted in the brief review by Birnie et al. (2017). The *capacity theory* states that the more cognitively demanding a distractor is and the more resources it requires, the more effective it is in reducing pain (Johnson, 2005). However, Johnson (2005) already noted in his review that there had been no clear evidence for the capacity theory; therefore, the multiple resource theory gained more popularity. The *multiple resource theory* proposes that the capacity of cognitive resources is limited, and the more the distractor competes with the same resource as used by pain, the more effective the distraction should be (Birnie et al., 2017; Van Ryckeghem et al., 2017).
Cioffi and Holloway (1993) conducted one of the earliest studies investigating the influence of distraction on pain. They investigated the effects of neutral distraction via an imaginary task and suppression from experimental pain induced by a cold pressor task (CPT). They could not show differences between ER strategies regarding pain tolerance or intensity. However, they found a more considerable rebound effect indicated by a greater unpleasantness during a harmless vibration after the pain induction for suppression compared to distraction. Goubert et al. (2004) induced pain via a lifting task in chronic back pain patients while they should either passively distract themselves with an attention-demanding tone-detection task or no further instructions were provided (control condition) in a within-subjects design. Results revealed no differences in pain intensity ratings between the distraction and the control condition and even showed elevated pain intensity ratings right after the distraction condition. In a related study by Verhoeven et al. (2011) healthy participants were either assigned to a distraction group, with a similar tone-detection task, or no instruction control group, and underwent a CPT. In contrast to Goubert et al. (2004), distraction led to reduced pain intensity ratings compared to the control condition. Interestingly, the authors also assessed the executive functions prior to the tasks, but no effect of executive functioning abilities on the pain perception during distraction could be found.

Buhle and Wager (2010) tested the relationship between pain and cognitive performance. Healthy participants were instructed to distract themselves passively via a working memory task with multiple difficulty levels and varying heat pain intensities. In a control condition, participants should passively view a serial letter mask while heat pain was administered. Results showed that participants experienced less pain during distraction with the working memory task than the control condition. Moreover, higher levels of heat pain reduced the performance in the working memory task and vice versa. That indicated a reciprocal relationship between pain and cognitive performance and shared limited cognitive resources. These results support the assumption that the effectiveness of a cognitive strategy such as distraction could diminish with higher pain intensity.
Van Ryckeghem et al. (2017) conducted a meta-analysis on attentional strategies. They did not find any effects of distraction on pain for chronic pain patients, regardless of the type of the distraction strategy or whether the pain was experimental or clinical. However, it should be noted that only ten studies could have been integrated into this meta-analysis. In one of these studies, Snijders et al. (2010) compared a

healthy control group with chronic pain patients and applied electrical stimuli. Participants were asked to either passively distract themselves from the pain with a cognitively demanding divided attention task or focus on the pain via selective attention. They showed that distraction increased the pain threshold and decreased the pain intensity only for the healthy control group, while pain intensity increased for the chronic pain patients. The authors assumed that chronic pain patients possessed a hypervigilance, or attentional bias, towards pain, making it harder to implement a distraction strategy effectively. This finding again supports the assumption of higher levels of pain leading to less effective distraction as the pain cannot be easily excluded from the attention due to limited cognitive resources (Van Ryckeghem et al., 2017). A study by Nouwen et al. (2006) – also part of the meta-analysis – compared focused attention on the pain by describing sensations to a passive, neutral distraction by naming forenames from the pain induced with a CPT. They found that participants in the distraction group initially had lower pain intensity ratings than focused attention. However, over time, pain intensity ratings increased for distraction for both healthy and chronic pain patients and even decreased for the focused attention group for chronic pain patients. Nevertheless, chronic pain patients still had higher pain intensity in the focused attention group than the healthy controls. These findings support the supposition made by the Ironic Process Theory by Wegner (1994) (see 1.2) that distraction is only effective in the short-term but loses effectiveness when pain duration is longer.

Van Damme et al. (2008) manipulated the threat value of a CPT by verbal information (describing the CPT as harmful vs. harmless). One-half of the healthy participants distracted themselves passively from the pain via a tone-detection task as used in previous research (Goubert et al., 2004), and the other half did not engage in a task (control group). Participants indicated after the pain task that distraction – compared to the control group – failed to attenuate the perceived pain intensity during the CPT. Moreover, there were no differences between the threat and the neutral group regarding pain intensity. However, participants in the threat group showed slower reaction times in the distraction group, indicating an effect of threat on cognitive performance. Lower cognitive performance in a distraction task could possibly impact the effectiveness of distraction, which this study could not demonstrate.

In a study by Rischer et al. (2020), participants took part in three tasks assessing their cognitive inhibition abilities. Afterward, they performed passive distraction tasks with high and low cognitive loads while receiving warm or painful thermal stimulation. They showed that pain intensity and unpleasantness ratings were significantly lower for high than low cognitive tasks, in line with the capacity theory. Furthermore, they found a correlation between one cognitive inhibition task and the pain intensity change score, meaning that better selection abilities were associated with more effective distraction. Surprisingly, this effect was moderated by average to high pain catastrophizing. The authors surmised that high pain catastrophizers could benefit more from distraction because they could have a higher motivation to direct their attention to non-threatening cues.

This overview shows that distraction from pain can have analgesic effects (Nouwen et al., 2006; Snijders et al., 2010; Verhoeven et al., 2011) but, under certain circumstances, might have no effect on the pain perception. Thus, it might not always be the strategy of choice for pain regulation, especially for chronic pain patients. Moreover, distraction can lose its effectiveness when pain duration is prolonged (Nouwen et al., 2006), cognitive resources are already limited, e.g., by higher pain intensity (Buhle & Wager, 2010; Snijders et al., 2010; Van Ryckeghem et al., 2017), or when the distraction is not enough cognitively demanding (Rischer et al., 2020). Perceiving pain as a threat appears to have either no effect on the effectivity of distraction (Van Damme et al., 2008) or might even serve as a higher motivator that could increase its effectivity (Rischer et al., 2020).

1.3.3.2. Reappraisal as an effective long-term pain regulation strategy

Reappraisal is one of the more complex ER strategies and has been proven effective in regulating pain, especially in the last decade. Moreover, reappraisal is already a key element of cognitive behavior therapies, including pain therapy (Konietzny et al., 2016).

One factor involved in modulating pain perception and outlined in the review by Wiech et al. (2008) is the degree of perceived control. When pain is perceived as controllable, more action is initiated to alter the pain. Such action can involve the ***reappraisal*** of the pain's meaning into less threatening. The ventrolateral PFC was shown to be involved in the controllability of pain and downregulation of pain intensity by reappraisal (Wiech et al., 2008). In a study by Denson et al. (2014), participants took part in a CPT and should either detach themselves from the pain (reappraisal group) or received no instructions (control group). The authors assessed pain ratings and pre- and post-CPT appraisals, capturing the evaluation of challenge, self-efficacy, and control over the pain. Moreover, they measured the HR and cortisol level. Results indicated that reappraisal did not affect the self-reported pain experience or HR in the reappraisal group compared to the control group. Even though participants did not evaluate the pain as less threatening in the reappraisal group, they perceived a higher self-efficacy and control over the pain pre- and post-CPT. Nevertheless, cortisol levels were marginally higher in the reappraisal than in the control group. The authors hypothesized that reappraisal might have activated more coping resources while being in pain, reflected by the higher self-efficacy and control appraisals. At the same time, reappraisal could have been more effortful because of its first-time implementation, reflected by heightened cortisol reactivity. They suggested that reappraisal might gain effectivity in the long-term by getting more automatic.

Hovasapian and Levine (2016) investigated the effects of reappraisal and distraction on anxiety sensitivity and memory bias on pain. Individuals with high anxiety sensitivity tend to perceive bodily sensations such as pain as more threatening and might have a greater memory bias for pain. The authors instructed healthy participants to either reinterpret the cold as healthy (reappraisal group), focus on a nearby computer screen (distraction group; active and neutral) or did not provide any instructions (control group) during CPT. Pain intensity ratings were gathered every 30 s throughout the CPT and directly afterward. Memory for pain and anxiety sensitivity were assessed three days later via online questionnaires. Results showed that pain intensity ratings did not differ between groups during CPT or for remembered pain. However, participants with higher anxiety sensitivity remembered the pain as more painful than they experienced during the CPT. Moreover, reappraisal but not distraction weakened this relationship. The authors suggested that even though both strategies failed to attenuate the experienced pain during the task, reappraisal led to the long-term benefit of modulating remembered pain. The capability to attenuate remembered pain could even be considered a protective factor against the development of chronic pain.

Lapate et al. (2012) conducted a longitudinal study to investigate the ER strategy reappraisal with three sessions, each about one year apart. In the first two sessions, participants should up- and downregulate negative emotions elicited by pictures by reinterpreting them as more catastrophic (e.g., a car accident with injuries) or distancing themselves (e.g., the car accident is just a movie), respectively. Electromyography (EMG) of the corrugator muscle was assessed in the first ER session, and neural correlates were assessed in the second ER session. In the last session, participants should either upregulate experimental heat pain by reappraising it to be life-threatening (e.g., pain caused by a fire) or downregulating it by imagining the sensation having a good outcome (e.g., being in a hot tub). The authors assessed unpleasantness ratings and neural correlates during the pain regulation sessions. They showed that pain unpleasantness increased and decreased accordingly to the up- and downregulation. Moreover, they calculated indices of regulation success (the difference between upregulation and downregulation condition) and regression analyses for the different variables. Results indicated that regulation success indexed by corrugator EMG during ER predicted regulation success indexed by unpleasantness ratings and bilateral amygdala activation during pain regulation. Modulation of the left amygdala during ER predicted pain regulation success indexed by pain unpleasantness. Lapate and colleagues concluded that success in emotion regulation could predict success in pain regulation. Therefore, the engagement of the amygdala reflects a *general regulatory ability* involved in the regulation of both emotions and pain. Moreover, Lapate et al. (2012) could demonstrate the stability of the individual regulatory ability over a time period of three years.

Woo et al. (2015) instructed healthy participants to up- and downregulate heat pain stimuli with different intensities via reappraisal (reinterpretation of the pain) and measured self-reported pain and brain activity. Pain intensity and unpleasantness were elevated for upregulation, lowered for downregulation, and varied according to the temperature. More interestingly, these effects of reappraisal were mediated by a brain pathway connecting the nucleus accumbens and ventromedial PFC, independently of the pain stimulus's intensity. In contrast, the neurologic pain signature – a brain activation pattern that includes sensory and affective aspects of pain – only mediated the effects of the heat pain intensity. These findings showed a distinct brain pathway activated by reappraisal apart from the neurologic pain signature (Bray, 2015).

Adamczyk et al. (2020) asked participants in a within-subjects design to up- and downregulate two different electrical pain intensities by reinterpreting (reappraisal condition) the pain as something dangerous or beneficial, respectively. In the control condition, they should maintain the pain by experiencing it naturally without changing it. In addition to pain ratings, they assessed the temporal dynamics of reappraisal via EEG. They could show that up- and downregulation led to significantly higher and lower pain intensity and unpleasantness ratings, respectively, compared to the control condition and with each other. Moreover, participants indicated that they were more efficient in downregulating moderate and upregulating higher electrical pain. Analysis of EEG revealed that reappraisal modulated pain processing at early (orbitofrontal cortex, amygdala) and late latency stages (insula), the earliest at approx. 100 ms after stimulus onset (ACC). However, the authors observed a general reduction in neural responses for reappraisal. They assumed that these neurological findings could result from a high cognitive demand rather than the reappraisal-specific change of evaluation. In a similar study design in a preceding study by Fardo et al. (2015), participants should also up- and downregulate electrical stimuli via reappraisal. Results showed that pain ratings increased and decreased accordingly as well. Furthermore, they assessed pain-related N2 potentials via EEG and showed that N2 amplitudes increased for downregulation and decreased for upregulation between 122 and 180 ms, indicating the reflection of cognitive expectations rather than the perception of pain.

This overview shows the complexity of reappraisal as a pain regulation strategy. The majority of studies has shown that reappraisal is able to modulate the self-reported perception of experimental pain, at least when pain is temporally limited (Adamczyk et al., 2020; Fardo et al., 2015; Lapate et al., 2012; Woo et al., 2015) contrary to a longer-lasting CPT (Denson et al., 2014; Hovasapian & Levine, 2016). The perceived controllability of pain is an essential underlying mechanism: Controllability of pain can foster the use of reappraisal strategies (Wiech et al., 2008) and reappraisal can foster perceived controllability (Denson et al., 2014). Moreover, reappraisal appears to modulate remembered pain by reducing the perceived threat and could even serve as a protective factor against chronic pain development in the long-term (Hovasapian & Levine, 2016). Besides, reappraisal might target not only cognitive change but also cognitive expectations (Adamczyk et al., 2020; Fardo et al., 2015). Due to a rather high cognitive demand, reappraisal could gain effectivity when automized in the long-term (Denson et al., 2014; Fardo et al., 2015).

1.3.3.3. Accepting chronic pain increases the quality of life

The benefits of the Acceptance and Commitment Therapy (ACT) for chronic pain patients have been demonstrated (see 1.2.2.1), but how does acceptance as a core process contribute to helping chronic pain patients to deal with their pain? The acceptance of chronic pain involves the active willingness to live with the pain and pursue valued goals and activities regardless of the pain (McCracken et al., 2004; McCracken & Eccleston, 2005). Accepting the pain leaves attempts of controlling or avoiding it aside so that it does not impair the quality of life (McCracken & Eccleston, 2005).

In a correlational study, Viane et al. (2003) found that fibromyalgia[5] patients who accepted their pain showed better mental health and engaged more strongly in regular daily life-activities independent of pain severity and pain catastrophizing. McCracken and Eccleston (2005) collected data on chronic pain patients and assessed the relationship between acceptance and patient functioning at two time points about four months apart. Results revealed that patients with higher acceptance of their pain at the first time point showed enhanced emotional, social, and physical functioning, less medication consumption, and better work status at the second time point. Interestingly, the level of pain and acceptance did not affect each other. In addition to acceptance, McCracken and Vowles (2008) measured values-based action, which means the engagement in activities according to personal goals instead of external circumstances such as pain. These two core ACT processes correlated negatively in chronic pain patients with pain severity, pain-related distress, anxiety and avoidance, depression and its impairment with functioning, and physical and psychosocial disability. De Boer et al. (2014) examined the relationship between acceptance, mindfulness, and pain-related catastrophizing in chronic pain patients. Acceptance and mindfulness were considered separate constructs (see 1.2.2.2) by using different questionnaires. Acceptance was associated with less pain catastrophizing, whereas mindfulness had no connection to it. Ramirez-Maestre et al. (2014) found a strong association between acceptance and resilience in chronic spinal pain patients. Moreover, acceptance was moderately and negatively correlated with impairment, anxiety, and depression and had a low association with pain intensity. In a longitudinal study, Jensen et al. (2016) investigated the role of acceptance in individuals with physical disabilities and pain, which are not necessarily seeking treatment. They found that higher acceptance of their pain predicted less pain intensity increase, less pain impairment, better physical function, less depression, and better sleep quality over 3.5 years.

In an experimental study by Vowles et al. (2007), patients with chronic low back pain underwent a physical impairment test before and after receiving instructions on either acceptance, pain control or continued practicing (control group). Patients in the acceptance group showed significantly less overall physical impairment than the other two groups, whereas pain intensity ratings did not differ between groups. Kohl et al. (2014) administered cold and heat pain stimuli to fibromyalgia patients who were told to accept the pain (including mindfulness and defusion), reappraise the situation, or listen to a newspaper article (control group). Accepting and reappraising heat pain equally increased pain tolerance compared to the control group. Reappraisal also increased the cold pain tolerance compared to the acceptance and the control group, both of which did not differ from each other. Pain intensity remained unaffected by group for heat and cold pain. Kratz et al. (2017) assessed acceptance in patients with spinal cord injuries. They collected data on momentary pain intensity and pain interference, and continuous physical activity over a period of seven days in daily life. They showed that acceptance moderated the momentary relationship between pain intensity and interference. Moreover, acceptance

[5] The fibromyalgia syndrome is a chronic pain disorder with widespread musculoskeletal pain (Giamberardino, 2008).

not only attenuated the affective pain component but general pain interference and physical activity. Patients with higher acceptance enjoyed and engaged in more activities despite higher pain levels.

This overview shows that acceptance undoubtedly helps individuals with chronic pain to cope even with higher pain levels and engage in daily life activities with fewer impairments. Nevertheless, the questions remain. Namely, what specific mechanisms underlie acceptance, under which circumstances is it most effective, and can it be adequately trained even without being a trait factor or having prior experience?

1.3.3.4. Effective regulation of acute pain with acceptance

To further detect underlying mechanisms of acceptance, basic research in controlled, experimental settings has been conducted with healthy participants and acute pain. One of the first studies investigating ***acceptance*** in the context of acute pain was the study by Hayes et al. (1999a). Here, Hayes and colleagues attempted to contrast control-based approaches reflecting behavioral therapy with acceptance-based approaches based on ACT. While control-based interventions seek to alter and regulate the form or frequency of individual events such as thoughts and feelings, acceptance-based approaches target the detachment of these events from behavior. They hypothesized that an acceptance-based intervention should lead to behavioral change, thus a greater pain tolerance, while a control-based intervention should lead to less self-reported pain experiences. The acceptance-based intervention incorporated the ACT core processes acceptance and defusion, aiming at not changing any sensations provoked by the pain. In contrast, the control-based intervention included techniques such as positive self-talk, controlled breathing, and distractions, targeting the control and modification of the pain. Before and after the intervention instructions, healthy participants underwent a CPT while pain ratings were gathered. As expected, the acceptance-based intervention led to a higher pain tolerance. Surprisingly, both interventions resulted in lower pain ratings in the post-intervention CPT. This result was the first indication of acceptance influencing the self-reported perception of pain, even though not targeted by the concept. A series of studies continued the research by Hayes et al. (1999a) and conducted further investigations with acceptance-based and control-based interventions or protocols, which will be reviewed in this paragraph.

Keogh et al. (2005) compared acceptance- and control-based protocols (comprising distraction and suppression) in a CPT similar to Hayes et al. (1999a) but briefer and as a within-subjects factor. Moreover, they investigated gender differences as a between-subjects factor. Surprisingly, they did not find any differences between acceptance- and control-based protocols regarding pain threshold and tolerance. However, pain intensity ratings were higher for the control-based compared to the acceptance-based protocol, independent of the gender. Pain unpleasantness was only lower for female participants in the acceptance- but not the control-based protocol, indicating that acceptance might be more beneficial in regulating affective pain for women.

Gutierrez et al. (2004) compared acceptance-based protocols with control-based protocols, similar to Hayes and colleagues, but focused more on specific elements rather than a combination of many strategies. In principle, participants received either instructions on acceptance or active, positive distraction after the first and before the second pain task consisting of multiple electrical pain stimuli with increasing magnitude. A motivational context was added to the pain tasks via a rewarded matching task to increase the participants' value to continue. Pain tolerance in the acceptance-based group increased significantly from the first to the second pain task, but not in the control-based group. Moreover, participants in the acceptance-based group reported more pain but continued to tolerate it longer. Pain intensity decreased significantly in the control-based but not the acceptance-based group from the first to the second pain task, contrary to Hayes et al. (1999a) and Keogh et al. (2005).

Roche et al. (2007) also used Hayes et al. (1999a) acceptance- and control-based interventions. Additionally, they varied the social demand (high vs. low) as a group factor. This factor included a variation of the distance and eye contact between experimenter and participant and a request to perform the best in the high-demand group. Roche and colleagues did not find any differences between the interventions regarding pain tolerance. Contrary to the previous studies, they could not show any differences for intervention or social demand for the pain experience. However, pain tolerance was increased for the high social demand group. Moreover, they could show a trend towards higher pain tolerance during acceptance than the control-based intervention for the high-demand group. Paez-Blarrina et al. (2008b) integrated the experimental design by Gutierrez et al. (2004) and used a similar acceptance protocol but incorporated suppression instead of distraction for the control-based protocol. Both protocols led to an increased pain tolerance and a decrease in experienced pain intensity from the first to the second electrical pain task and did not differ from each other. In a subsequent study with a similar design but an additional untrained control group, Paez-Blarrina et al. (2008a) showed that the pain tolerance was higher for the acceptance group than the remaining two control groups during the first pain task. Acceptance and suppression decreased equally the pain intensity ratings compared to the control group in the first pain task. There was an increase in pain tolerance for both protocols from the first to the second pain task contrary to the control group.

McMullen et al. (2008) used the experimental procedure by Gutierrez et al. (2004) and added a comparison of brief, simple instructions with more extensive instructions including relevant experiences and metaphors (full instructions) on acceptance and distraction. Moreover, they added a no instruction-control group, resulting in five groups. The only effect on the pain tolerance was yielded in the full acceptance group: pain tolerance increased from first to the second pain task. Contrary to Gutierrez et al. (2004), there were no differences between groups over time for pain intensity ratings. These findings highlight the importance of experiential exercises and metaphors ("crossing a muddy swamp", p. 125) for the effectiveness of acceptance-based strategies. Liu et al. (2013) showed that mindful acceptance including a metaphor ("Weather can change frequently and unpredictably, but it will not affect the nature of the sky", p. 201), and active, neutral distraction led to an increased pain tolerance during a CPT compared to a no-instruction control group. Only mindfulness decreased pain distress, whereas no effects on the pain intensity ratings could be observed. Evans et al. (2014) suggested that the brief acceptance instructions in the study by McMullen et al. (2008) only failed to modulate the pain tolerance because participants were not familiar with it. Thus, the authors compared mindful acceptance with the participants' own natural regulation strategies in a CPT. They showed that mindfulness decreased the pain tolerance and did not differ regarding pain intensity ratings compared to using familiar strategies. The authors assumed that acceptance could be more effective by becoming more automatic and less effortful through practice over time.

In addition to comparing entire interventions or protocols with each other in the context of pain, many studies have pursued the comparison of their core mechanisms (Gutierrez et al., 2004), meaning the specific ER strategies.

In a study by Masedo and Esteve (2007), participants should accept (including defusion), suppress, or spontaneously cope (control group) with the pain provoked by a CPT. Results revealed that participants in the acceptance group tolerated the pain longer than in the suppression and control groups. In contrast, suppression even led to a lower pain tolerance than spontaneous coping. Moreover, acceptance reduced the pain intensity and distress ratings compared to the other two groups. Suppression led to higher pain recovery ratings (30-60 s after the CPT) than the acceptance and the control group, whereas acceptance showed lower distress recovery ratings than the other two groups. Braams et al. (2012) administered a series of electrical pain stimuli before and after participants were instructed to accept or suppress the pain or received no further instructions (control group). In addition to pain unpleasantness and anxiety ratings, they assessed HR as a pain correlate. Acceptance and suppression led to lower pain unpleasantness ratings from pre to post instructions than the control group. Anxiety ratings decreased in all groups from pretest to posttest but the effects were more pronounced for acceptance than in the remaining groups. Furthermore, the HR (8 s after the electrical stimulus) decreased from pretest to posttest for the acceptance and the suppression group, but not the control group.

Jackson et al. (2012) instructed participants to accept (including defusion and mindfulness) the pain during a CPT or distract (active, positive) themselves via focusing on mental images, or they received instructions on pain education (control group). They further induced high or low threat by providing information labeling the CPT as dangerous or safe, respectively. The acceptance group showed a higher pain tolerance when the threat was low compared to the distraction and control group, which did not differ. When the threat was high, there were no differences between strategy groups. These findings suggest that acceptance and distraction failed to modulate pain tolerance as soon as the pain was perceived as highly threatening. Interestingly, distraction also failed when the pain was perceived as safe. The authors argued that generating images or memories might have been cognitively too demanding in the face of rather intense pain caused by the CPT. As outlined in chapter 1.3.3.1, threats should have no effect, let alone a motivating effect, on distraction. Prins et al. (2014) juxtaposed mindfulness and distraction by inducing heat pain stimuli. They integrated six core ACT processes (Hayes et al., 2006) in the mindfulness instructions: contact with the present moment, acceptance, defusion, and self as context (see 1.2.2.1). In the distraction group, participants listened to fairytales through headphones (passive distraction). Results indicated no differences between the two groups concerning pain tolerance and pain ratings. Nevertheless, for high pain catastrophizers, pain unpleasantness was lower in the mindfulness than the distraction group and vice versa for low pain catastrophizers. These findings show that acceptance can be beneficial for high pain catastrophizers as it counteracts catastrophic thinking. Distraction might be more effective with less pain catastrophizing. Moreover, acceptance could target the affective component of experiencing pain more strongly than the sensory, which is in line with its theoretical approach.

As mentioned in the preceding chapter, Kohl et al. (2012) could not draw clear conclusions in their meta-analysis regarding the effectiveness of acceptance compared to other adaptive strategies such as distraction and reappraisal in the ER context. However, results concerning studies investigating the regulation of pain provided more precise answers. In particular, they showed that acceptance was more effective in increasing pain tolerance than other ER strategies. Nevertheless, acceptance was not more successful in reducing the self-reported pain experience than other strategies. Kohl and colleagues explained their findings by referring to the ACT concept (see 1.2.2.1) and pointing out that acceptance does not aim at reducing any pain sensation but instead disconnects feelings and behavior, which might lead to participants being able to tolerate pain longer. Moreover, most studies investigating acceptance have used pain tolerance tasks that might impede the assessment of pain ratings. The study by Kohl et al. (2013) was the first and only study to compare acceptance and distraction with reappraisal by carrying out a heat pain tolerance task. They instructed participants to accept the pain (comprising mindfulness and defusion instructed by a "clouds in the sky"-metaphor), to distract themselves actively from the pain by imagining a pleasant scene, or to reappraise the pain by reinterpreting the situation. Pain tolerance was significantly higher in the acceptance than in the reappraisal group, whereas distraction did not differ from the other two groups. Pain intensity was experienced as significantly lower for distraction than acceptance, whereas reappraisal was not different from the remaining groups. These findings have shown that acceptance is more effective than distraction and reappraisal in tolerating pain longer.

Hampton et al. (2015) administered heat pain stimuli to participants while they either ignored any discomfort or sensations (suppression group), reinterpreted the heat pain into something positive (reappraisal group), or monitored it mindfully (acceptance group). Results showed that reappraisal significantly decreased the pain intensity and unpleasantness, and anxiety ratings after the heat pain administration and after a recovery period compared to suppression and acceptance. Moreover, pain intensity was lower in the suppression group than in the acceptance group, whereas the two did not differ from each other regarding the other ratings. Furthermore, reappraisal and suppression led to less facial activity during the heat pain administration compared to the acceptance group. These findings indicate that acceptance was less effective in downregulating the self-reported experience and expressive behavior of heat pain compared to reappraisal.

In sum, acceptance has proved to be an effective strategy for tolerating pain (Hayes et al., 1999a; Kohl et al., 2012; Liu et al., 2013; Roche et al., 2007) and appears to be even superior to distraction (Gutierrez et al., 2004; Jackson et al., 2012; Kohl et al., 2013; McMullen et al., 2008), reappraisal (Kohl et al., 2013), and suppression (Braams et al., 2012; Masedo & Esteve, 2007; Paez-Blarrina et al., 2008a; Paez-Blarrina et al., 2008b) in pain tolerance tasks. Pain ratings have been effectively decreased by acceptance compared to control conditions or in pre- to post-training comparisons (Braams et al., 2012; Keogh et al., 2005; Masedo & Esteve, 2007; Paez-Blarrina et al., 2008a). However, in comparison with distraction (Gutierrez et al., 2004; Kohl et al., 2013) or reappraisal (Hampton et al., 2015), acceptance seems to be less effective in modulating the self-reported pain perception, but findings are still unclear (Kohl et al., 2012). However, these findings are in line with the theoretical concept as acceptance does not target the modulation of a sensory experience but rather the detachment from behavior (Hayes et al., 1999b; Kohl et al., 2013; Masedo & Esteve, 2007; Prins et al., 2014).

Only one study so far assessed the effects of acceptance on a physiological pain correlate and showed an attenuated HR during acceptance (Braams et al., 2012). The use of additional metaphors and more extensive instructions proved to increase the effectiveness of acceptance (McMullen et al., 2008). More training or familiarity with acceptance could lead to effective results with brief instructions as well (Evans et al., 2014). On one hand, when the pain was perceived as highly threatening, acceptance lost its effectiveness (Jackson et al., 2012). On the other hand, acceptance was more effective than distraction for high pain catastrophizers (Prins et al., 2014). There might be a hint towards an even higher effectivity on pain tolerance with higher social demand (Roche et al., 2007), and women might benefit stronger from acceptance modulating the affective pain component (Keogh et al., 2005).

1.3.3.5. Prior experiences with regulation and trait influences

Emotion dysregulation is associated with various psychopathologies (see 1.2.3) and chronic pain development (Koechlin et al., 2018; Konietzny et al., 2016). Adaptive ER can serve as a protective factor against them (Aldao et al., 2010), but it depends on many factors, such as regulatory flexibility containing context sensitivity and repertoire of ER strategies (Bonanno & Burton, 2013; Troy et al., 2013). On the one hand, ER strategies such as the acceptance of pain can be actively trained in a treatment such as the Acceptance- and Commitment Therapy (see 1.2.2.1). On the other hand, acceptance and other ER strategies are labeled as trait factors as well. This means that the choice of the appropriate ER strategy requires not only selecting the right strategy in the proper context, but also certain personal dispositions, such as the individual's strategy repertoire. Whether these dispositions are fixed trait factors and can only be expanded to some extent or can be learned entirely is still debatable. However, every individual has their characteristics which determine how they habitually regulate emotions and pain in everyday life. Hence, the ***ER style*** has been proposed to affect the effectiveness of a regulatory attempt.

Previous studies suggested that matching the ER strategy to the individual ER style should lead to more effective pain management (Forys & Dahlquist, 2007). Forys and Dahlquist (2007) assessed participants' ER styles via questionnaires and assigned them to the strategy or control group. In the strategy group, participants should distract themselves from the pain caused by one CPT and monitor the pain during the other CPT. As hypothesized, pain threshold and pain tolerance increased for participants with a distracting ER style in the distraction condition compared to the monitoring condition. Participants with a monitoring ER style showed a higher pain threshold in the monitoring condition and, surprisingly, an increased pain tolerance in both strategy conditions. The authors assumed that the participants with a monitoring ER style could have greater regulatory flexibility than participants with a distracting ER style. Results indicated that the ER style does play a role in the effectiveness of an ER strategy. Moore et al. (2015) compared acceptance, including metaphors, and distraction by imagining something pleasant and measured the accepting / avoiding ER style. However, they did not assess participants' distracting ER style directly. Healthy participants underwent a pre- and post-intervention pain task consisting of multiple electrical pain stimuli (see 1.3.3.4, the study by Gutierrez et al. (2004), for a similar design). Pain tolerance remained unaffected by the two strategies. However, participants with an accepting ER style showed a higher pain tolerance in the acceptance group than in the distraction group. Nevertheless, participants reported that implementing distraction was easier than acceptance. These findings underline the importance of matching the ER style with the intervention. Moreover, they showed how complex implementing acceptance could be, suggesting that more training might be needed, at least in a laboratory setting with a non-clinical population. In a study by Zeidan et al. (2018), meditation-naive participants received heat pain stimuli while neural correlates and mindful ER styles were assessed. Highly mindful participants showed lower pain ratings, lower pain sensitivity, and greater deactivation of brain regions associated with attention and affective appraisals to sensory stimuli such as the dorsal posterior cingulate cortex and precuneus, compared to less mindful participants.

Contrary to the previous study, Hampton et al. (2015) did not find any interactions between reappraising or suppressing ER styles and performances in the strategy conditions with heat pain. The authors argued that participants could flexibly adapt to the assigned strategy irrespective of their habitual tendencies, indicating that ER strategies can be easily learned and do not need to be matched to individual ER styles. However, it is important to note that they did not assess any accepting ER styles.

As shown in this overview, very few experimental studies investigated the role of ER styles directly. Unfortunately, no studies have explored it systematically by actively assigning participants to their matching or mismatching strategy. These very few mixed results show that matching the ER style to the intervention or experimental manipulation could increase the ER strategy's effectiveness in diminishing the pain experience and behavior, but not necessarily. Another possibility is that some strategies might benefit from previous habitual use, others may not be affected. So far, it appears that adopting acceptance or mindfulness might benefit from prior experiences (Moore et al., 2015; Zeidan et al., 2018). Other strategies such as reappraisal (Hampton et al., 2015) or distraction (Moore et al., 2015) could be easier to adopt, either due to preexisting, comprehensive prior knowledge or a trait disposition.

Other trait factors have been linked to emotional and pain regulatory mechanisms. ***Optimism***, the tendency for positive expectations of the future (Basten-Günther et al., 2019), has been positively linked with problem-focused ER and the acceptance of stressful events (Scheier et al., 1986). It can be further considered a resilience factor protective of the development of chronic pain (Basten-Günther et al., 2019) . Higher trait optimism was associated with higher placebo analgesia (Geers et al., 2010), lower pain sensitivity (Hanssen et al., 2013), and less pain-induced impairments (Boselie et al., 2014). However, Hinkle and Quiton (2019) showed less pain inhibition for greater optimists. They suggested that optimistic individuals might engage more actively with a pain stimulus due to a more active ER style, which could lead to more pain perception.

Resilience is a positive personality trait, which helps with adaptation and coping with stressful events (Schumacher et al., 2005; Wagnild & Young, 1993). Resilience is described in the APA Dictionary as "the process and outcome of successfully adapting to difficult or challenging life experiences, especially through mental, emotional, and behavioral flexibility and adjustment to external and internal demands" (VandenBos & APA, 2015, p. 910). Research on resilience in the context of pain is promising and resilience is considered a protective factor (Goubert & Trompetter, 2017; Hemington et al., 2017). As noted earlier, resilience and acceptance have been shown to have a strong link and might lead to less impairments and pain intensity in chronic pain patients (Ramirez-Maestre et al., 2014).

A meta-analysis by Prati and Pietrantoni (2009) showed ***religious coping*** and reappraisal strategies were strong predictors of posttraumatic growth, meaning that traumatic events could have a positive impact on an individual's life. Optimism and ***spiritual coping*** showed medium effect sizes and acceptance was a small but significant predictor of posttraumatic growth. Vishkin et al. (2019) found that religiousness was associated with adaptive ER, especially the ER strategies reappraisal and acceptance, but not distraction.

The next and final chapter of the general introduction will provide an overview of the aims of this dissertation project, leading over to the research questions based on the theoretical and evidence-based revision so far.

1.4. Dissertation project

Past and current literature already demonstrated the efficiency of the ER strategies acceptance, distraction, and reappraisal in regulating emotions and pain. These strategies are considered adaptive and protective against the development of psychopathologies and potentially chronic pain syndromes (see 1.2.3 and 1.3.3), but other factors contribute to these qualities. Choosing the right ER strategy according to the context and one's goals are some of the qualities leading to adaptive ER (see 1.2.3). However, the intensity and the perceived controllability of the emotion or pain, as well as the duration, also play a role in whether a strategy proves to be effective. A trait-like disposition towards specific ER strategies or prior knowledge could either be beneficial or impede successful regulation (see 1.3.3.5).

Distraction has been shown to effectively reduce negative emotions and acute pain, especially in the short-term, irrespective of emotional intensity but only for lower pain intensities (see 1.3.2 and 1.3.3.1). When the pain lasted longer, was more intense, or was even chronic, distraction appeared to fail. Intense pain can disrupt attention (Eccleston & Crombez, 1999; Prins et al., 2014), which in turn explains the decreased effectiveness of distraction under these circumstances. An underlying mechanism of distraction could be the lack of attention to and encoding of the affective components.

Reappraisal effectively lowered negative emotions and pain, especially with lower emotional intensities, temporally limited pain, and enough time to engage in the regulatory process (see 1.3.2 and 1.3.3.2). Moreover, reappraisal appeared to consume more cognitive resources than distraction at first but seemed to gain effectivity as a long-term strategy with more training. The most critical underlying mechanisms were the reinterpretation of the affective meaning, the expectations, and the perceived controllability of pain.

Theoretically, these findings are in line with *Gross's process model of ER* (1998b) and also in line with the *process-specific hypothesis* (Sheppes & Gross, 2011) (see 1.2.1 and 1.2.4). Distraction starts earlier in the emotion-generative process, involves encoding less information, and is therefore cognitively easier to implement in the short term. However, it might prevent elaborated processing and understanding of information in the long run. Reappraisal starts rather late in the process and handles already ongoing evaluations, which is cognitively more challenging. However, when the regulation goal is long-term, and the cycle of the ER process repeats itself, ER becomes automatic and easier to implement. Sheppes and Gross (2011) pointed out that distraction and reappraisal are perfect candidates to investigate different time points in the emotion-generative process. Underlying mechanisms could be further investigated by altering the circumstances of the pain regulation, e.g., by varying the duration and modality of the pain stimulation. These two strategies are already established pain regulation strategies and therefore useful for the comparison with acceptance.

Acceptance has been proven especially effective in the treatment of chronic pain syndromes (see 1.3.3.3). So far, acceptance showed to effectively reduce negative emotions and pain, with inconsistent results regarding its comparison to distraction and reappraisal (see 1.3.2 and 1.3.3.4). However, acceptance demonstrated consistent reductions of psychophysiological correlates and stood out in tolerance tasks and with more training. As a recently introduced ER strategy, acceptance is still being discussed its position in the process model, whether it is an antecedent- or response-focused strategy (see 1.2.2.3). Acceptance has been suggested to consume less cognitive resources than reappraisal. Possible underlying mechanisms are not evaluating (mindfulness) the aversive event and counteracting avoidance (see 1.2.2.1). So theoretically, acceptance of pain does not target the reduction or control of pain but rather the detachment from the pain experience.

1.4.1. Overall aims and design

Several questions still remain to be investigated. Namely, under what circumstances is acceptance more or less effective than distraction and reappraisal in the context of pain? And where does it fit into Gross's process model of ER? Given the narrow and inconclusive results of the past and current research, this issue should be further investigated. Investigating these circumstances is crucial for adding to the search for resilience mechanisms that could be protective of the development of chronic pain disorders by fostering better pain management (Koechlin et al., 2018; Kröner-Herwig, 2017).

In order to find the underlying mechanisms and provide suggestions for the process model, we conducted fundamental research and compared the three strategies with each other in an experimental setting with acute pain, including possible temporal dynamics.

Only one study to date compared these three strategies with each other (Kohl et al., 2013), and two other studies compared acceptance with reappraisal (Hampton et al., 2015; Kohl et al., 2014) in a laboratory setting with acute, individually adjusted pain. Thus, this dissertation aimed at conducting experimental studies to ***compare the three strategies directly*** with each other ***under different pain regulation contexts*** by varying pain stimulus modality and duration. The main goal was to develop further insights into underlying mechanisms and temporal dynamics in the emotion-generative process. The pain modalities used in this project were heat and electrical pain stimuli as they are commonly used experimental pain induction methods (see 1.1.3.1).

Moreover, none of the reviewed studies have used within-subjects designs to compare specific ER strategies with each other, disregarding intraindividual differences in regulatory abilities and, if assessed, in autonomic measures (see 1.1.3.2). Within-subjects designs decrease sampling error and increase effect sizes in studies comparing ER strategies (Webb et al., 2012). Another aim of this dissertation was, therefore, to compare the ER strategies in a ***within-subjects design***.

Furthermore, many of the reviewed studies either used control conditions involving spontaneous coping (Evans et al., 2014; Forsyth & Hayes, 2014; Masedo & Esteve, 2007) or no instructions (Braams et al., 2012; McMullen et al., 2008; Paez-Blarrina et al., 2008a), reducing the internal validity. Some studies completely abandoned the use of control conditions (Gutierrez et al., 2004; Keogh et al., 2005; Kohl et al., 2013; Paez-Blarrina et al., 2008a) in order to avoid unsystematic strategy use, but also with the cost of an impaired internal validity regarding the effectiveness of the strategies. Webb et al. (2012) showed that ER strategies had larger effects when the emotions were instructed to be experienced naturally during the control condition instead of giving participants no instructions or instructions to regulate in a specific manner. They assumed that participants would regulate in their usual manner when the instructions did not explicitly exclude it. Therefore, we designed a ***neutral control condition*** without spontaneous coping and specific pain regulation for this dissertation. To ensure that participants did not try to regulate their pain experience, we included the note that they should not distract themselves, change or control their sensations in any way. This control condition was tested for the first time in the first study and later on implemented in all dissertation project studies.

Interestingly, only one study to date assessed autonomic measures as pain correlates when investigating effects of acceptance in acute pain (Braams et al., 2012). Consequently, this dissertation project enclosed ***cardiac and electrodermal pain correlates*** (HR and SC) (see 1.1.3.2) as psychophysiological measures of the pain experience in addition to the assessment of pain self-reports. Additionally, autonomic measures were assessed continuously to ***capture the temporal dynamics*** (see 1.2.4) of the pain regulation to be able to integrate a time factor into the analysis.
Moreover, data on ***ER styles*** were collected via questionnaires to capture habitual ER and investigate a possible effect on their performance in the experiments. Optimism, resilience, and religious coping were assessed as factors possibly altering pain regulation (see 1.3.3.5).

The ***distraction instructions*** were adapted from the distraction instructions used by Singer and Dobson (2007), where, for example, participants could distract themselves from a negative mood by visualizing to "walk the entire length of a shopping mall" (Singer & Dobson, 2007, p. 567) and the stores that they would pass on this walk. For this project, the visualization used as a distractor was supposed to be active and as neutral as possible (see 1.3.1) to avoid potential resemblance to the reappraisal strategy, where participants would reappraise the pain with a positive outcome. Additionally, participants received a list with five neutral visualizations to choose from, with the opportunity to suggest something on their own.
The ***reappraisal instructions*** were adapted from the instructions used in the study by Lapate et al. (2012), where participants reinterpreted the heat pain stimulation by imagining the heat representing a good outcome or a threat to their life. In this project, participants should only reappraise the heat as a positive outcome. Like the distraction instructions, participants received a list with five positive reappraisals and the possibility of selecting themselves.
The ***acceptance instructions*** were developed by incorporating and adapting several acceptance instructions used previously in research on emotion and pain regulation (Braams et al., 2012; Hayes et al., 1999a; Hofmann et al., 2009; Kohl et al., 2013). Thus, a broad acceptance concept (see 1.3.1) was established, including a combination of the core ACT processes (Hayes et al., 2006) *acceptance*, *mindfulness* (being present), and *defusion*. Participants additionally received a "clouds in the sky"-metaphor similar to the one used by Kohl et al. (2013) as an example of defusion, supporting the comprehension of the rather complex strategy.
The ***control condition instructions*** were created solely for this dissertation thesis and requested participants to try to sense the pain and react to it as it is without applying any regulation strategy.
All instructions were intended to match in length and wording as much as possible and differed regarding content. All strategy instructions were referred to as strategies in the summary of instructions.

1.4.2. Overall hypotheses

We hypothesized all three ER strategies distraction, reappraisal, and acceptance to reduce the participant's experience of heat and electrical pain, including its correlates, reflected by the autonomic measures HR and SC, compared to the control condition.

According to Gross's process model and past literature, distraction should be more effective in reducing brief, short pain stimulation than reappraisal, because it is initiated earlier in the emotion-generative process. When pain of a longer duration becomes more intense, distraction has been shown to lose effectiveness, while reappraisal becomes more effective. Thus, we hypothesized that distraction is more effective than reappraisal in downregulating short pain perception, but reappraisal is more effective than distraction in regulating longer pain stimulations. These effects should also be detectable in a temporal examination of the autonomic measures. Distraction should lead to earlier decreases in HR and SC than reappraisal. Because of the mixed results of acceptance in comparison to distraction and reappraisal, acceptance has been discussed different positions in Gross's process model. However, acceptance has proven to successfully reduce both short and longer pain as well as chronic pain. Therefore, we hypothesized that acceptance is at least as effective as reappraisal in downregulating a longer pain experience, and therefore more successful than distraction. Regarding short pain stimulations, acceptance is expected to be similarly effective as distraction and reappraisal. The impacts of acceptance in past research were especially reflected in the psychophysiology. Thus, we hypothesized that acceptance is more effective in decreasing autonomic measures compared to distraction and reappraisal.

Concerning ER styles and dispositions, we hypothesized that pain regulation during the experiment is more successful when the pain regulation strategy matches the habitually-used ER strategy. Moreover, we assumed that optimistic and resilient participants are more successful in pain regulation. We further hypothesized that a religious or spiritual orientation could also increase the success of regulating pain with acceptance and reappraisal.

2. Study 1: Regulating brief heat pain: Acceptance

2.1. Introduction

The concept of acceptance constitutes one of the six core processes of the Acceptance and Commitment Therapy (ACT) and targets psychological flexibility. Psychological flexibility refers to the ability to alter or continue goal-directed action by staying entirely and consciously in contact with the present moment (Hayes et al., 2006). Acceptance fosters psychological flexibility by actively embracing events without trying to change or control them or their frequency (Hayes et al., 2006; Hofmann et al., 2009). For further details, review sections 1.2.2.1 and 1.3.1.

Even though acceptance does not target the reduction or control of pain directly but rather the detachment from the pain experience, it has been considered a regulation strategy. However, the process model of emotion regulation by Gross (1998b) does not entail acceptance, so its position in the model is being discussed (Hofmann & Asmundson, 2008; Hofmann et al., 2009; Liverant et al., 2008; Wolgast et al., 2011). More precisely, the investigation of the mechanisms underlying acceptance is gaining attention. For example, acceptance has been suggested to consume less cognitive resources than reappraisal (Keng et al., 2013). Theoretically, other mechanisms would be not evaluating (mindfulness) the aversive event and counteracting avoidance.

In past and current research investigating emotion or pain regulation, concepts of acceptance have become more prominent, suggesting that acceptance could be a promising and adaptive regulation strategy. Studies frequently use a combination of several core ACT processes as the acceptance concept, usually incorporating the processes of mindfulness (being present) (Braams et al., 2012) and defusion (detachment from events) (Kohl et al., 2013).

Regarding pain regulation research, acceptance has been proven especially effective in the treatment of chronic pain syndromes by increasing daily life activities and diminishing impairments (Jensen et al., 2016; Kratz et al., 2017; Ramirez-Maestre et al., 2014; Vowles et al., 2007). Moreover, acceptance increased the pain tolerance of experimentally induced pain (Hayes et al., 1999a; Kohl et al., 2012; Liu et al., 2013; Roche et al., 2007) and proved to be even more successful in pain tolerance tasks than other ER strategies, such as distraction and reappraisal (Braams et al., 2012; Kohl et al., 2013; Masedo & Esteve, 2007). Even though effective in decreasing the self-reported pain experience when compared to control conditions or pre- to post-designs (Braams et al., 2012; Keogh et al., 2005; Masedo & Esteve, 2007; Paez-Blarrina et al., 2008a), acceptance appears to be less effective than other ER strategies (Gutierrez et al., 2004; Hampton et al., 2015; Kohl et al., 2013), but results are inconsistent (Kohl et al., 2012). However, in ER research, acceptance demonstrated consistent reductions in psychophysiological correlates (Goldin et al., 2019; Hofmann et al., 2009; Wolgast et al., 2011) and stood out with more training (Germain & Kangas, 2015; Helbig-Lang et al., 2015).

One of the main goals of this dissertation project was to find underlying mechanisms of the regulation strategy acceptance in an acute pain context and to highlight its effectiveness in pain reduction. So far, acceptance has been only compared to other ER strategies or control conditions, often involving spontaneous coping in between-factor designs (Braams et al., 2012; Kohl et al., 2013; Masedo & Esteve, 2007; McMullen et al., 2008). Consequently, the current and first study of the dissertation project aimed at introducing a within-subjects design to account for intraindividual differences in regulatory abilities. In addition, a neutral control condition without spontaneous coping or any regulation was developed to increase internal validity. For pain induction, we opted for heat pain as it activates the first and second pain (Staahl & Drewes, 2004) (see 1.1 for more details) and is a widespread method for inducing experimental pain. Our acceptance instructions were based on previous research investigating acceptance (Braams et al., 2012; Hayes et al., 1999a; Hofmann et al., 2009; Kohl et al., 2013) and constituted a broad concept, combining the core ACT processes acceptance, mindfulness, and defusion. The study by Braams et al. (2012) has been the only one so far showing that acceptance decreased an autonomic measure, namely the HR, compared to the pre-instruction measures. Thus, this study aimed at including the autonomic measures HR and SC as pain correlates (Treister et al., 2012) to expand their findings and capture the effectiveness of acceptance on a psychophysiological level. Additionally, pain intensity and unpleasantness ratings were gathered to assess the pain experience, and regulation ratings to capture the regulation experience.

We expected acceptance to be more effective in regulating the pain experience than the control condition, reflected by both pain ratings. Furthermore, as acceptance does not necessarily aim at reducing or controlling pain but rather detaching from the pain (Kohl et al., 2012), we hypothesized that the participants' success in regulating with acceptance would be more pronounced on the pain unpleasantness dimension than on the pain intensity dimension. Regarding the temporal dynamics, we expected the participants to perceive an improvement in their pain regulation over the time course of the experiment, as more training or familiarity with acceptance might improve the strategy's effectiveness (Evans et al., 2014). Furthermore, we assumed that the pain ratings would decrease for acceptance over time. We further expected the pain correlates HR and SC to be lower in the acceptance condition than in the control condition. We continuously recorded the autonomic measures to clarify the temporal dynamics of acceptance as there is a gap in current literature. Furthermore, we hypothesized that regulation with acceptance during the experiment would be more successful for participants with an accepting than a suppressing or reappraising ER style (Moore et al., 2015; Zeidan et al., 2018) and with higher psychological flexibility comprising acceptance. Moreover, we hypothesized that highly resilient participants would regulate better with acceptance (Ramirez-Maestre et al., 2014). Lastly, we assumed that optimistic and religious or spiritual participants would be more successful in pain regulation with acceptance (Prati & Pietrantoni, 2009; Scheier et al., 1986; Vishkin et al., 2019).

2.2. Methods

Part of the results of this study was published by Haspert et al. (2020) in the Journal Frontiers Psychology. However, the assessed data has been analyzed in a modified manner for this dissertation, consistent with the data analysis of the two subsequent studies. Christian Kaiser, a student from the University of Würzburg, supervised by Haspert, assisted in data collection and processing and used part of this data in his bachelor thesis.

2.2.1. Participants

Thirty-one participants between 18 and 41 years were recruited via the local online platforms Sona Systems (Sona Systems Ltd., Tallinn, Estonia) or Wuewowas (www.wuewowas.de). Exclusion criteria were the intake of central nervous or pain medication and chronic or pain-related conditions. Participants received 1.5 hours of course credit or 10 € for partaking in the study. An optimal sample size of 27 participants was calculated with the software G*Power (Faul et al., 2009), assuming a paired t-test analysis a priori (Haspert et al., 2020), with an expectation of medium to large effect sizes similar to Braams et al. (2012) (Cohen's $d = 0.5$) and estimated power and alpha-error ($1\text{-}\beta = .8$, $\alpha = .05$) from Kohl et al. (2013). We aimed for at least perceptible heat pain during the control condition trials, so we excluded two participants with an average pain intensity of less than five (VAS 0-100: $M = 0.33$;

M = 2.83) from further analyses. An exclusion criterion of above 3 *SD* was determined for outliers in the pain ratings. However, no outlier could be identified. Hence, the final sample consisted of 29 participants (15 females) between the age of 18 and 34 years (*M* = 25.41, *SD* = 3.36). Most of the participants were unmarried (93.1%), students (93.1%), right-handed (89.7%), and non-smoking (69%). All participants had at least Abitur as their highest education level. An overview of the sociodemographic information is shown in Table 2.1. The institutional review board of the medical faculty of the University of Würzburg approved the experimental procedure.

Participants were informed upon arrival about the details of the experiment, signed a written informed consent, and filled out a questionnaire on sociodemographic information (see Appendix A and Appendix B). The sociodemographic information survey retrieved information on age, sex, marital status, graduation, profession, education, first language, handedness, smoking habits, chronic conditions and allergies, chronic pain conditions, acute illnesses, menstruation, caffeine intake, and pain and other medication intakes. Additionally, participants were asked to indicate whether they had pain at the moment (yes/no) and, if so, they should specify the kind of pain. Subsequently, they were asked to "rate the intensity of your current pain using the scale below. To do this, mark the scale at the point that most closely corresponds to your current pain sensation" on a numeric rating scale (NRS 0-9; 0 = no pain, 9 = the strongest pain I can imagine). Further, they should rate their pain coping skills (NRS 0-9; 0 = cannot deal with it at all, 9 = have no problems dealing with pain), specified by the question "do you think you can cope with pain, or do you worry about being overwhelmed by the pain?". Lastly, they should answer whether they found pain of any kind unbearable (yes / no).

Table 2.1 Study 1: Sociodemographic information.

	Frequencies	*M (SD)*	*Min*	*Max*	*N*
Age		25.41 (3.63)	18	34	29
School degree					29
Abitur	29				29
Fachabitur	0				29
Realschule	0				29
First language					29
German	28				29
Other	1				29
Handedness					29
right	26				29
left	3				29
Smoked in the last 24 hrs	9				29
Caffeine in the last 24 hrs	22				29
Current pain intensity (NRS 0-9)		0 (0)	0	0	28*
Pain coping (NRS 0-9)		6.36 (1.25)	4	9	28*

Note. Frequencies of response and means (*M*) with standard deviations (*SD*) and minimal (*Min*) and maximal (*Max*) values. *Missing data.

Participants further completed several questionnaires on ER styles. Current literature suggests that ER strategies that are habitually used in everyday life might increase the effectiveness of pain regulation strategies when matched accordingly (Forys & Dahlquist, 2007; Moore et al., 2015) (see 1.3.3.5). The ***Emotion Regulation Questionnaire (ERQ)*** (Gross & John, 2003) measures the self-reported habitual use of the two ER strategies reappraisal and expressive suppression with a total of 10 items. The *reappraisal* subscale consists of 6 items (e.g., "I control my emotions by changing the way I think about the situation I'm in; When I want to feel less negative emotion (such as sadness or anger), I change what I'm thinking about"). The *suppression* subscale consists of 4 items (e.g., "I control my emotions by not expressing them; I keep my emotions to myself"). Participants indicate on a 7-point scale (1 = strongly disagree, 4 = neutral, 7 = strongly agree) how they control and regulate their emotional experience and expression (Abler & Kessler, 2009). The score for each subscale is calculated by averaging the corresponding items (Abler & Kessler, 2009). Higher scores indicate a more frequent habitual use of the respective ER strategy. Test-retest reliabilities across 3 months were .69 for both scales and the average Cronbach's $\alpha = .79$ for the reappraisal and $\alpha = .73$ for the suppression subscale (Gross & John, 2003). The German version of the ERQ (Abler & Kessler, 2009) showed an internal consistency between $\alpha = .68$ and $\alpha = .82$.

The ***Affective Style Questionnaire (ASQ)*** (Hofmann & Kashdan, 2010) consists of 20 items capturing the self-reported habitual tendency to use three ER strategies over others, namely concealing/suppression, adjusting/reappraisal, and tolerating/accepting (Graser et al., 2012). Participants are asked to indicate on a 5-point scale (1 = does not apply to me at all, 2 = applies a little bit, 3 = moderately, 4 = applies quite a bit, 5 = applies to me very strongly) how they usually experience and manage their emotions (Hofmann & Kashdan, 2010). The subscale *suppression* consists of 9 items (e.g., "I am good at hiding my feelings"), the subscale *reappraisal* consists of 5 items (e.g., "I can avoid getting upset by taking a different perspective on things"), and the subscale *accepting* consists of 6 items (e.g., "I am able to let go of my feelings") (Graser et al., 2012; Hofmann & Kashdan, 2010). The subscale scores are calculated by averaging the respective items. Higher scores indicate a more frequent habitual use of the respective ER strategy. The internal consistency of the German version of the ASQ (Graser et al., 2012) is $\alpha = .84$ for the suppression subscale, $\alpha = .75$ for the reappraisal subscale, and $\alpha = .72$ for the accepting subscale.

The ***Acceptance and Action Questionnaire-II (AAQ-II)*** (Bond et al., 2011) measures the self-rating unidimensional construct of psychological (in)flexibility and derives from the Acceptance- and Commitment Therapy (ACT) (see 1.2.2.1). Participants rate 7 items on a 7-point scale (1 = never true, 2 = very rarely true, 3 = rarely true, 4 = sometimes true, 5 = often true, 6 = almost always true, 7 = always true) how true the statements are to them. Examples of items are: "I'm afraid of my feelings; it seems like most people are handling their lives better than I am." The sum of all items constitutes the total score. Higher scores indicate greater levels of psychological inflexibility. The test-retest reliability of the German version (Hoyer & Gloster, 2013) for a healthy student population is $r = .85$, and the internal consistency is $\alpha = .97$.

Furthermore, participants completed several questionnaires on pain processing and pain influencing factors. As anxiety and fear have been linked to hyper- and hypoalgesia (Biggs et al., 2016; Rhudy et al., 2004; Rhudy & Meagher, 2000; Wieser & Pauli, 2016), respectively, we assessed a number of questionnaires on state and trait anxiety, pain catastrophizing, fear of pain, and pain sensitivity.

The ***State-Trait Anxiety Inventory (STAI)*** (Spielberger et al., 1983) measures the self-reported intensity of anxiety as an emotional state and individual differences in trait anxiety (Spielberger, 2009). Both subscales contain 20 items each. For *state anxiety*, participants were asked to rate their feelings of anxiety "right now, at this moment" on a 4-point scale (1 = not at all, 2 = a little, 3 = pretty much, 4 = very much) (Spielberger, 2009). Examples of state anxiety items are: "I am tense; I am worried" and "I feel calm; I feel secure." For *trait anxiety*, participants were asked to rate how they generally feel on a 4-point scale (almost never = 1, sometimes =2, often = 3, almost always = 4) (Spielberger, 2009). Examples of trait anxiety items are: "I worry too much over something that really doesn't matter" and "I am content; I am a steady person." For each subscale, reversed items were recoded, and the sum of all items was calculated. Higher scores indicate higher anxiety. Test re-test reliabilities of the German version are r = .77 to r = .90 for the trait anxiety subscale and r = .22 to r = .53 for the state anxiety subscale with α = .90 for both subscales (Laux et al., 1981).

The ***Pain Catastrophizing Scale (PCS)*** (Sullivan et al., 1995) measures the participants' self-reported catastrophizing thoughts and behaviors with 13 items. The questionnaire can be divided into three subscale scores: *helplessness* ("There is nothing I can do to reduce the intensity of the pain"), *magnification* ("I worry that something serious may happen"), and *rumination* ("I can't stop thinking about how much it hurts") (Sullivan et al., 1995). The total score is calculated by summing all items up, which we used for our study. Participants should indicate on a 5-point-scale (0 = not at all, 1 = to a small extent, 2 = to a moderate extent, 3 = to a large extent, 4 = all the time) the degree to which they experienced certain thoughts and feelings they have when in pain. Higher scores indicate a greater pain catastrophizing. The test-retest reliability of the German version (Meyer et al., 2008) is r = 0.80 and the Cronbach's α = .92.

The ***Fear of Pain Questionnaire-III (FPQ-III)*** (McNeil & Rainwater, 1998) assesses the self-reported fear of pain with 30 items, which can be divided into three subscales: *minor pain* ("getting a paper-cut on your finger"), *severe pain* ("breaking your arm") and *medical pain* ("receiving an injection in your mouth"). Participants rated on a 5-point-scale (1 = not at all, 2 = a little, 3 = a fair amount, 4 = very much, 5 = extreme) the intensity of their fear of certain events. We used the total score of the questionnaire in our study, which is the sum of all items. Higher scores indicate greater fear of pain. The English version of the FPQ-III total score has a test-retest reliability of r = .75 and Cronbach's α = .92 (McNeil & Rainwater, 1998), whereas a Cronbach's α = .90 is reported for the German version of the FPQ-III (Baum et al., 2013).

The ***Pain Sensitivity Questionnaire (PSQ)*** (Ruscheweyh et al., 2009) is a self-rating questionnaire with 17 items for assessing pain sensitivity that is similar to experimental pain sensitivity assessment.

Participants indicated how painful a situation would be for them on a numeric 11-point scale (from 0 = not painful at all, to 10 = worst pain imaginable) (Ruscheweyh et al., 2009). Fourteen of these items are considered as painful situations, such as “Imagine you bump your elbow on the edge of a table; imagine you trap your finger in a drawer”. Another three items served as a non-painful sensory reference, such as “Imagine you take a shower with lukewarm water” (Ruscheweyh et al., 2009). In our study, we used the total score of the PSQ by averaging the 14 painful items. It is also possible to calculate a moderate (equivalent to 4-6 on an NRS) or minor sub score (equivalent <4 on an NRS) by averaging the according items. Higher scores indicate a higher pain sensitivity. The test-retest reliability for the PSQ total score is r = .83 and Cronbach’s α = .92 (Ruscheweyh et al., 2009).

To capture factors that might contribute to and influence pain processing and regulation, we included questionnaires on optimism and pessimism, psychological resilience, and religious and spiritual coping in our study (see 1.3.3.5).
We obtained dispositional, self-reported optimism and pessimism with the ***Life-Orientation-Test Revised (LOT-R)*** (Scheier et al., 1994). The LOT-R consists of 10 items querying the opinion on various statements on a 5-point scale (0 = does not apply at all, 1 = barely applies, 2 = partly, 3 = applies somewhat, and 4 = does not apply at all). Three of the items form the *optimism* subscale (e.g., “I'm always optimistic about my future”) and another three the *pessimism* subscale (e.g., “If something can go wrong for me, it will”), whereas four items are used as filler items (e.g., “I enjoy my friends a lot”) (Scheier et al., 1994). The scales are calculated by summing up the corresponding items. The test-retest reliability is r = .59 for the LOT-R optimism scale and r = .65 for the pessimism scale. The internal consistency is Cronbach’s α = .69 for the optimism scale and Cronbach’s α = .59 for the pessimism scale.
We assessed self-rating psychological resilience with the ***Resilience Scale 11 (RS-11)*** (Wagnild & Young, 1993), which contains 11 items that should be rated on a 7-point scale (from 0 = no, I don’t agree, to 7 = yes, I agree completely). Examples for the items are: “I am determined; I can cope with several things at once.” The total score is a unidimensional scale and was calculated by summing all items up. Higher scores indicate a higher psychological resilience. The internal consistency of the German version (Schumacher et al., 2005) of the RS-11 is Cronbach’s α = 0.92 (Kocalevent et al., 2015).
With the ***Second Version of the Aspects of Spirituality Questionnaire (ASP 2.1)*** (Büssing et al., 2014) in German, we assessed self-reported aspects of spirituality[6] without conventional conceptual boundaries and institutional religiosity (Büssing et al., 2007). The questionnaire claims to avoid exclusive language and to operationalize non-formal aspects of spirituality in terms of relational

[6]Spirituality: “An attitude of search for meaning and purpose in life, which is based on the feeling or awareness of a ‘divine’ beginning/cause and an awareness of a connection with others, nature, the divine, etc. Due to this awareness, one strives to embody distinct teachings, experiences and insights; and this will impact the way of living and the ethical norms.” (Büssing & Ostermann, 2004; Büssing et al., 2007)

consciousness, particularly secular humanism and existential awareness (Büssing; Büssing et al., 2007). Participants should indicate in 25 items on a 5-point scale their agreement or disagreement with various statements on spirituality (0 = does not apply at all, 1 = does rather not apply, 2 = I cannot tell (neither yes nor no), 3 = rather applies, 4 = fully applies). The ASP questionnaire assesses four dimensions of spirituality: *Religious orientation* (e.g.,, "I trust in God and turn to Him; I pray for others; I read religious or spiritual writings"), *Search for Insight / Wisdom* (e.g.,, "I am trying to develop wisdom; My life is a search for answers"), *Conscious interactions* (e.g.,, "I interact consciously with my fellow human beings; I try to develop compassion"), and *Transcendence conviction* (e.g.,, "I am convinced that there is a rebirth of man (or his soul); I am convinced that man is a spiritual being"). Three items were used as filler items, such as "I meditate; I volunteer to help others". The transformed scale scores are calculated by multiplying the mean of the corresponding items of each dimension by 25, which can be interpreted in percent. Scores higher than 50% indicate higher agreement, while scores lower than 50% indicate disagreement. The internal consistency of the ASP 2.1 is Cronbach's α = .94 (Büssing et al., 2014). Mean questionnaire scores are shown in Table 2.2.

Table 2.2. Study 1: Mean questionnaire scores of the sample.

Questionnaires	*M (SD)*	*Min*	*Max*	*N*
AAQ-II				
Total	20.34 (6.22)	11	36	29
ASP				
Conscious interactions	71.03 (16.22)	25.00	95.00	29
Religious orientation	20.88 (15.72)	0	61.11	29
Search for Insight / Wisdom	57.14 (20.45)	10.71	92.86	29
Transcendence conviction	36.42 (23.69)	0	93.75	29
ASQ				
Suppression/concealing	2.93 (0.62)	1.67	4.22	29
Adjusting/reappraisal	3.16 (0.64)	1.40	4.20	29
Tolerating/accepting	3.75 (0.47)	2.83	4.50	29
ERQ				
Cognitive reappraisal	4.61 (0.88)	2.33	6.33	29
Expressive suppression	3.30 (1.01)	1.25	5.00	29
FPQ-III				
Total	76.93 (16.48)	42	103	29
LOT-R				
Pessimism	3.79 (2.06)	1	9	29
Optimism	9.17 (2.35)	3	12	29
PCS				
Total	14.93 (7.37)	2	31	29
PSQ				
Total	3.73 (1.23)	1.50	5.71	28*
RS-11				
Total	59.52 (7.78)	42	77	29
STAI				
State	38.48 (8.28)	21	51	29
Trait	36.93 (7.86)	22	54	29

Note. AAQ-II = Acceptance and Action Questionnaire II, ASQ = Affective Style Questionnaire, ERQ = Emotion Regulation Questionnaire, FPQ-III = Fear of Pain Questionnaire-III, PCS = Pain Catastrophizing Scale, PSQ = Pain Sensitivity Questionnaire, RS-11 = Resilience Scale 11, STAI = State-Trait Anxiety Inventory, LOT-R = Life-Orientation-Test Revised. Mean questionnaire scores (*M*) and standard deviations (*SD*), minimal (*Min*) and maximal (*Max*) scores and sample size (*N*). *Missing data.

At the end of the experiment, participants filled out a manipulation check survey (MCS), which assessed the participants' comprehensibility of the instructions and perceived success of their implementation. Participants were asked to indicate how clear and comprehensible the instructions for acceptance and the control instructions were (NRS 1-9; 1 = unclear, 9 = clear) and how well they succeeded in applying these instructions (NRS 1-9; 1 = not at all, 9 = very well). Furthermore, participants were asked to indicate whether they tried to distract themselves from the heat pain stimuli (NRS 1-9; 1 = not at all, 9 = a lot). For all these questions, there was also the opportunity to leave a comment and indicate further details. Find an overview of the comprehensibility and success information in Table 2.3. To assess religious beliefs, the participants indicated via checkboxes which religious denomination or community they were part of (Catholic, Protestant, other, none), whether they believed in a higher entity regardless of religious institutions (yes, no, not sure), which of the following described their belief system (spiritual, religious, atheist, agnostic, undefined, other) and how important spirituality or religiousness was currently in their personal life (not at all, little, moderate, considerable, very). Finally, participants could give feedback via open-ended questions on the pain stimuli or instructions, the experiment in general, and the supposed purpose of the experiment. An overview of religious and spiritual beliefs is shown in Table 2.4. See the complete MCS in the Appendix E.

Table 2.3. Study 1: MCS with comprehensibility and success of implementation.

Manipulation check item	Acceptance	Control	*p*
Comprehensibility of instruction (NRS 1-9)	**7.76**[a] (1.09)	**8.31**[a] (0.85)	**.001****
Min	6	6	
Max	9	9	
Success of implementation (NRS 1-9)	**6.83**[b] (1.39)	**7.93**[b] (1.19)	**.004****
Min	4	4	
Max	9	9	
Distraction from pain stimulus (NRS 1-9)	3.52 (2.10)		
Min	1		
Max	8		

Note. Means with standard deviations in parenthesis, minimal (*Min*) and maximal (*Max*) values. Pairwise t-tests were performed separately to compare comprehensibility of instructions and success of implementation between both conditions ($N = 29$). **$p < .01$. Significant differences (ps < .05) between conditions are marked in bold and specified by superscript letters. Participants perceived the control condition instructions as clearer, more comprehensible, and more applicable than the acceptance instructions.

Table 2.4. Study 1: MCS with religious and spiritual beliefs.

Manipulation check item	*f / M (SD)*
Religious denomination (*f*)	
Catholic	10
Protestant	9
Other	3
None	7
Believe in a higher entity (*f*)	
Yes	4
No	11
Not sure	14
Belief system (*f*)	
Spiritual	3
Religious	0
Atheist	6
Agnostic	14
Undefined	5
Other	1
Importance of spirituality / religiousness in personal life (1 = not at all, 5 = very)	
M (SD)	0.86 (0.99)
Min	0
Max	3

Note. N = 29. Frequencies (*f*) and means (*M*) with standard deviations (*SD*), minimal (*Min*) and maximal (*Max*) values.

2.2.2. Thermal Stimulation

Heat pain stimuli were delivered via a Somedic MSA thermal stimulator with an active thermode area of 25×50 mm (Somedic SenseLab AB, Sösdala, Sweden). The thermal stimulation was initiated and presented with the software Presentation® (Version 17.2, Neurobehavioral Systems Inc., Albany, CA, USA). Heat pain stimuli were controlled via the Software SenseLab (Version 5.2., Somedic SenseLab AB, Sösdala, Sweden). The thermode was attached to the non-dominant volar forearm and fixed with a Velcro strap. The position of the thermode was changed after the heat pain threshold procedure, after the practice trials, and after each heat pain block of six heat pain trials to avoid habituation or sensitization to the heat pain (Hollins et al., 2011; Jepma et al., 2014) and to avoid damages to the skin. Two different positions on the non-dominant volar forearm were alternated: position 1 on the upper half of the forearm near the wrist and position 2 on the lower half near the elbow pit. The order of the starting positions was counterbalanced between participants.

The *heat pain threshold* was calibrated with the method of adjustment (Horn-Hofmann & Lautenbacher, 2015). The heat pain threshold procedure started with instructions presented on the screen (resolution 1280 x 1024 pixels, background-color: RGB 132, 132, 132, font type = Arial bold, font size = 14, font color: RGB 255, 255, 255), presented via the software Presentation® (see above). Participants received the information that their individual pain threshold will be established by attaching the thermode to their forearm. They further received the instruction to set the temperature of the thermode with the arrow keys on the keyboard in front of them: "The temperature of the thermode will change slowly after each keypress. Do not press the arrow keys too fast and focus on the temperature change. With each keystroke, you will feel the thermode becoming either hotter (arrow key up) or cooler (arrow key down). Your task is to set the temperature exactly so that you perceive it as just painful. We ask you to alter the temperature up and down to set the exact point where you feel a change from HOT to just PAINFUL. We will repeat this process a few times to map your individual pain threshold as accurately as possible. All heat stimuli administered later during the experiment will be based on your established pain threshold." When participants had no further questions, the experimenter started the pain threshold procedure. The thermode was calibrated at a starting temperature of 35°C and could rise until a maximum of 49°C. The temperature rose or dropped by 0.5°C with each keystroke of the participants. During the whole procedure, the following instructions were presented on the screen: "Calibration of threshold: Please adjust the temperature by pressing the arrow keys up / down in a way that it starts to feel just painful. As soon as you feel the temperature is starting to be just painful, please let the experimenter know." As soon as the participants finished the first calibration of the thermode, the experimenter wrote down the corresponding temperature, cooled the thermode back down to 35°C, and started the procedure again. In total, the procedure was repeated three times, and the average threshold temperature was set as the individual pain threshold (M = 44.84°C, SD = 2.09, minimum value: 40.5°C, maximum value: 48°C). One participant reported the heat pain stimulus as not painful during the practice trials, so the threshold was increased by 1°C. Another participant perceived the stimulus as too painful during practice, so that it was decreased by 1.5°C. The practice trials were restarted after the new threshold adaption.

The *heat pain stimulus* for the practice trials and the experimental session was set as 1°C above the individual pain threshold. The heat pain stimulation was constructed as follows: First, the thermode started heating up from 10°C below the pain threshold (baseline temperature) to 1°C above the pain threshold (target temperature) with a rate of 5°C/s. As soon as the target temperature was achieved, it remained for 10 s continuously. Afterwards, the thermode cooled down to the baseline temperature with a rate of 5°C/s.

2.2.3. Measures

2.2.3.1. Ratings

Instructions on the ratings as well as the ratings themselves were presented on a screen (resolution 1280 x 1024 pixels, background-color: RGB 132, 132, 132, font type = Arial bold, font size = 16, font color: RGB 255, 255, 255) and programmed with the software Presentation® (Version 17.2, Neurobehavioral Systems Inc., Albany, CA, USA). Before the experiment, participants received instructions on the evaluation of the upcoming pain stimuli and the distinction between pain intensity and pain unpleasantness using the radio metaphor by Price and colleagues (Price et al., 1983): "Your task during the experiment will be, among other things, to evaluate heat stimuli in terms of their intensity and unpleasantness on two different scales. To help you understand the difference between unpleasantness and intensity of pain, imagine you are listening to the radio and the volume increases. I could ask you how loud you experience the radio, which would correspond to intensity/painfulness in the case of pain. But I could also ask you how annoying you find the sound of the radio, which would correspond to perceived unpleasantness in the case of pain and could be influenced by several factors. In summary, this means: intensity = how severe/how painful.... Unpleasantness = how irritating... ...you perceived the heat stimulus. To evaluate the heat stimuli, you should move a red marker to the right and left by pressing the arrow keys and confirming your decision with the space bar." After reading the instructions, the digitalized visual analog scales (VAS) for both pain intensity and unpleasantness were presented on the screen, so that participants could familiarize themselves with the scales and practice their handling with the keyboard. The pain intensity scale was described with the caption "How painful was the heat stimulus?". The ends of the scale ranged from "no pain" (left end = 0) to "maximum pain" (right end = 100). The pain unpleasantness scale was captioned "How unpleasant was the heat stimulus?", with the ends "not unpleasant at all" (left end = 0) to "extremely unpleasant" (right end = 100). Participants were asked to evaluate the *pain intensity* and *pain unpleasantness* (pain ratings) using the VAS right after each heat pain trial during the practice trials and the experiment.

After each heat pain trial in the acceptance condition, participants were additionally asked to give *regulation ratings*. For regulation ratings, a VAS with the caption "How well did you succeed in regulating the pain with the strategy?" was presented ranging from "not succeeded at all" (left end = 0) to "succeeded extremely well" (right end = 100).

The captions and the scales of all three VAS were presented in font size 16 in the middle of the screen, with white letters in Arial font and a grey background (see Appendix I). A red cursor (RGB 255, 0, 0) was presented at the left end of the scale and could be moved along the scale with the left and right arrow keys and confirmed by pressing the space bar. All given ratings were saved automatically in logfiles in .csv format. Trials were excluded from analyses in case the thermode did not heat up due to technical issues.

2.2.3.2. Psychophysiology

Heart rate (HR) and skin conductance (SC) were assessed as psychophysiological correlates of the pain perception, recorded continuously with the Brain Vision Recorder, V-Amp Edition 1.10 (Brain Products Inc, Munich, Germany) and processed with the Brain Vision Analyzer software (BrainProducts, Munich, Germany). To assess electrocardiography (ECG), the experimenter attached three electrodes to the torso of the participant (right collarbone, left lower costal arch, left lower side of the torso) (Haspert et al., 2020). The raw ECG signal was sampled with 250 Hz, using a V-Amp amplifier (Brain Products Inc., Munich, Germany) (Haspert et al., 2020). Afterward, the signal was filtered (High cut-off: 30 Hz, Notch filter: 50 Hz) (Haspert et al., 2020). R-waves were automatically detected and manually checked, the inter-beat intervals were calculated, and then converted into the continuous HR (Haspert et al., 2020; Koers et al., 1999). SC was recorded using two 8 mm Ag/AgCl surface electrodes (electrode gel: 0.5% NaCl) attached to the thenar and hypothenar eminence of the participant's non-dominant hand (Haspert et al., 2020). The SC signal was sampled with 250 Hz, with constant application of 0.5 V, and filtered (High cut-off: 1 Hz, Notch filter: 50 Hz) (Boucsein, 2012). HR and SC signals were both baseline-corrected relative to 1 s interval before visual cue onset.

To analyze the temporal dynamics, the whole heat pain trial (seconds 0-25) was divided into three phases according to the trial structure: cue (seconds 0-7), pain (seconds 7-17), and recovery of pain (seconds 17-25). HR, as well as the SC, were averaged into these three phases before being analyzed statistically, resulting in levels for SC (SCL). Trials were excluded from analyses in case the thermode did not heat up. Trials were also excluded from SC analysis when the SC signal was too noisy. One participant was excluded from HR and SC analyses due to technical issues during the psychophysiology recording. Another participant was excluded from SC analyses because they were defined as outliers (SC level during heat pain trial > 3 SD). Thus, the HR analyses were performed with a sample of 28 participants (N_{HR} = 28) and SC analyses with 27 participants (N_{SCL} = 27).

2.2.4. Instructions

Participants received all instructions on a computer screen with a resolution of 1280 x 1024 pixels, presented on a grey background (background-color: RGB 132, 132, 132) with white letters (font type = Arial bold, font size = 16, font color: RGB 255, 255, 255). For acceptance, participants received the following instructions on the screen:

> "Acceptance involves the allowing of thoughts, emotions, and other experiences without evaluating them. Acceptance is the willingness to take in an event or situation.
> If the word ACCEPT appears on the screen, you should try to fully experience and accept any feelings, sensations, and behavioral responses to the pain. Do not distract yourself. Do not change or control your sensations in any way.
> Example: Pain sensations and thereby feelings and thoughts provoked by them can be imagined as clouds in the sky that are certainly there but just passing by.
> Do not try to control your pain sensations or change them in any way. Let your feelings run their natural course and allow yourself to stay fully with your sensations."

For the control condition, participants received the following instructions on the screen:

> "If the word PERCEIVE appears on the screen, you should try to perceive any feelings and sensations to the pain. Try just to sense the pain and react to it as it is. Do not distract yourself. Do not change or control your sensations in any way, and above all, try not to use any strategies."

Participants obtained an overall summary of the instructions after reading the specific ones for each condition:

> "In summary, this means:
> The ACCEPT instruction involves the previously described strategy that you should apply as soon as the word appears on the screen. The PERCEIVE instruction involves no strategy use."

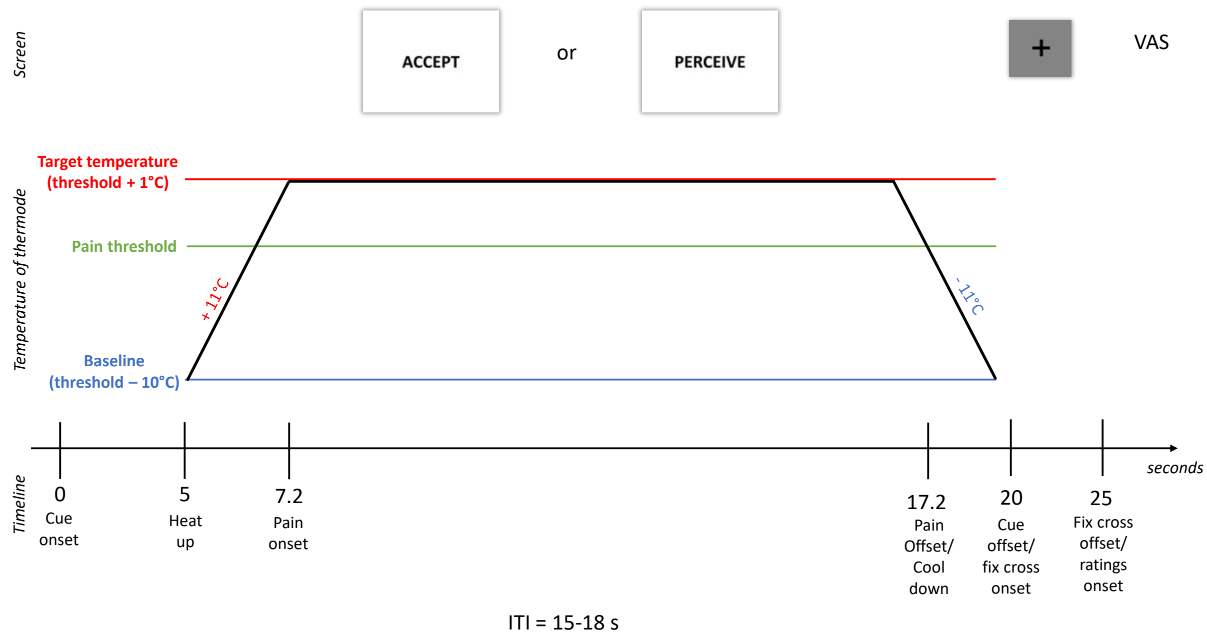
The experimenter reassured that the participants had no further questions. If there were any difficulties in comprehension, participants could read the instructions once again.
Visual instruction cues were image files created with Microsoft PowerPoint (Microsoft Corporation, Redmond, USA) with an image size of 960 x 720 pixels and white background. The text box was centered, with a position of 1.27 cm horizontal and 0 cm vertical, from the upper left corner. The cue word describing the respective condition (ACCEPT, or PERCEIVE) was centered and in capital, bold letters (font color black, font type Calibri, and font size 96). The margins inside the text box were 0.25 cm left and right, and 0.13 cm top and bottom.

2.2.5. Procedure

Participants sat down in front of the monitor and signed the written informed consent. Afterward, they filled out the questionnaire on sociodemographic information and questionnaires on emotion regulation (ASQ, ERQ, AAQ-II) and state-anxiety (STAI State). Then, the experimenter briefly explained the following procedures and began with the pain threshold procedure with standardized instructions presented on the screen. The pain threshold procedure, the practice trials, and the experimental procedure were controlled using the software Presentation® (Version 17.2, Neurobehavioral Systems Inc., Albany, CA, USA). After assessing the individual pain threshold, the experimenter turned off the monitor, took down the thermode, and asked the participants to wash their hands without soap. As soon as the participants returned, ECG and SC electrodes were attached. After that, the experimenter placed again the thermode on the participants' forearm according to the position order and turned on the monitor. Participants should read the instructions on the screen carefully and continue the experiment autonomously by pressing the space bar. Standardized instructions including the radio metaphor, examples of the VAS, and instructions regarding the two conditions followed on the screen. If there were no further questions, the practice trials followed. Each condition was practiced twice, pseudo-randomized. After the practice trials, the experimenter ensured that participants had no further questions regarding the experimental procedure. Then, the experimenter alternated the thermode to the next thermode position on the forearm and started the psychophysiology recordings. Participants were separated from the experimenter by a folding screen and interacted with the experimenter from this point on solely for the relocation of the thermode. Participants were instructed to address the experimenter if any questions about the VAS or the instructions about the conditions occurred. It was also pointed out that they could terminate the experiment at any time. Participants could then start the experiment by pressing the space bar.

Every heat pain trial started with the presentation of an instruction cue on the screen indicating the respective condition acceptance, distraction or control (cue onset, second 0). The instruction cue remained on the screen until the end of the heat pain administration (cue offset: second 20). Five seconds after cue onset, the thermode started heating up from the baseline temperature and reached the target temperature after 2.2 s (pain onset, second 7.2). Heat pain stimulation was delivered for 10 s and the thermode started cooling down (pain offset, second 17.2) to the baseline temperature in 2.2 s. After the cue offset, a fixation cross was presented in the middle of the screen for 5 s. As soon as the fixation cross disappeared, the VAS for pain intensity and unpleasantness appeared successively on the screen. Regulation ratings also appeared subsequently but only after acceptance trials. See Figure 1.2 for a schematic illustration of the heat pain trial. The interstimulus interval (ITI) was set between 15 to 18 s randomly in order to avoid anticipation effects and ensure enough time to recover from pain. The experiment consisted of 24 randomized heat pain trials, 12 per condition. No more than two trials of the same condition were presented in a row. The thermode position was changed after every 6 trials. After the experiment, participants filled out the remaining questionnaires on spirituality, resilience and pain-related variables (ASP, FPQ-III, LOT-R, PCS, PSQ, RS-11, STAI Trait) and answered the MCS.

Figure 2.1. Study 1: Schematic illustration of a short heat pain trial (10 s).



2.2.6. Statistical Analysis

IBM SPSS Statistics Version 25 (IBM Corp. Released 2017. IBM SPSS Statistics for Windows, Version 25.0. Armonk, NY: IBM Corp.) was used for all statistical analyses. Significance level was defined as $p < .05$.

Pain ratings (intensity and unpleasantness) were analyzed separately with repeated-measures ANOVAs with the within-factor *strategy* (2 levels: control condition vs. acceptance) and the within-factor *trials* (4 levels: trials 1-3, trials 4-6, trials 7-9 and trials 10-12) by averaging three consecutive trials per condition.

Analysis of regulation ratings was conducted with a repeated-measures ANOVA with the within-factor *trials* (4 levels: trials 1-3, trials 4-6, trials 7-9 and trials 10-12). Heart rate (HR) and skin conductance level (SCL) were analyzed separately with repeated-measures ANOVAs with the within-factor *strategy* (2 levels: control condition vs. acceptance), and the within-factor *phase* (3 levels: cue, seconds 0-7; pain, seconds 7-17, recovery, seconds 17-25).

Pain intensity and unpleasantness ratings were z-standardized across each participant, separately for each pain rating dimension. Difference scores were calculated from these z-standardized values by deducting the acceptance condition from the control condition. Pairwise t-tests were conducted with these z-standardized difference scores, comparing intensity vs. unpleasantness ratings.

Post-hoc pairwise t-tests or repeated contrasts were used to compare different factor levels. Difference scores were used to follow up on significant interactions when necessary. Partial eta-squared η_p^2 for ANOVAs and Cohen's *d* (Cohen, 1988; Lakens, 2013) for t-tests were used as measures of effect size. Greenhouse-Geisser correction was applied when the assumption of sphericity (Mauchly's test) was violated. P-value was Bonferroni-adjusted for multiple testing.

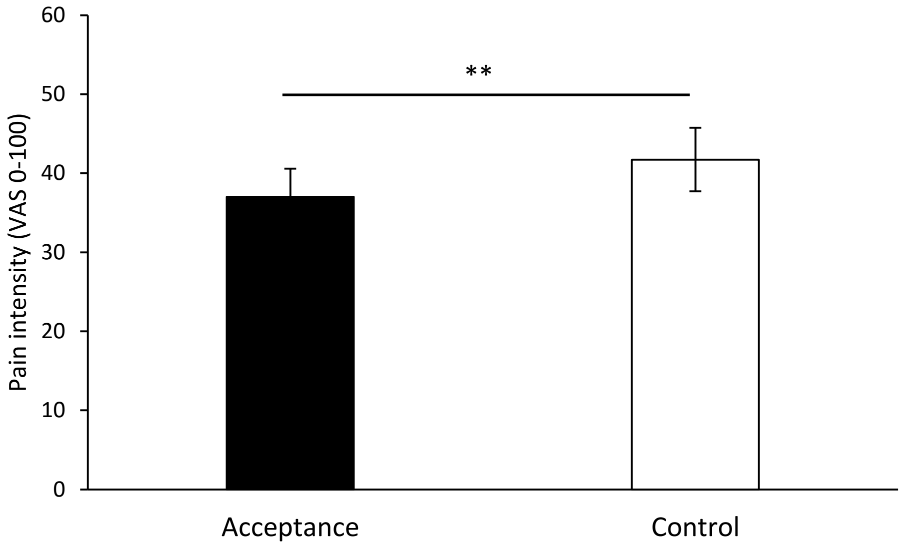
Two-tailed pearson correlations were performed to explore the association between strategy difference scores (control and acceptance condition) and ER questionnaire scores (ERQ, ASQ, AAQ-II) and RS-11, ASP and LOT-R scores as potential indicators of resilience.

2.3. Results

2.3.1. Pain intensity

Analysis of pain intensity ratings yielded a significant main effect of the within-factor *strategy* (Acceptance: $M = 37.02$, $SD = 19.10$; Control: $M = 41.73$, $SD = 21.64$), $F(1, 28) = 10.81$, $p = .003$, $\eta_p^2 = .278$, indicating higher pain intensity ratings during the control condition compared to the acceptance condition (see Figure 2.2). However, analysis did not reveal a significant main effect of the within-factor *trials,* $F(3, 84) = 0.09$, $p = .431$, $\eta_p^2 = .032$, nor a significant interaction between the within-factors *strategy* and *trials*, $F(3, 84) = 1.20$, $p = .313$, $\eta_p^2 = .041$.

Figure 2.2. Study 1: Heat pain intensity.

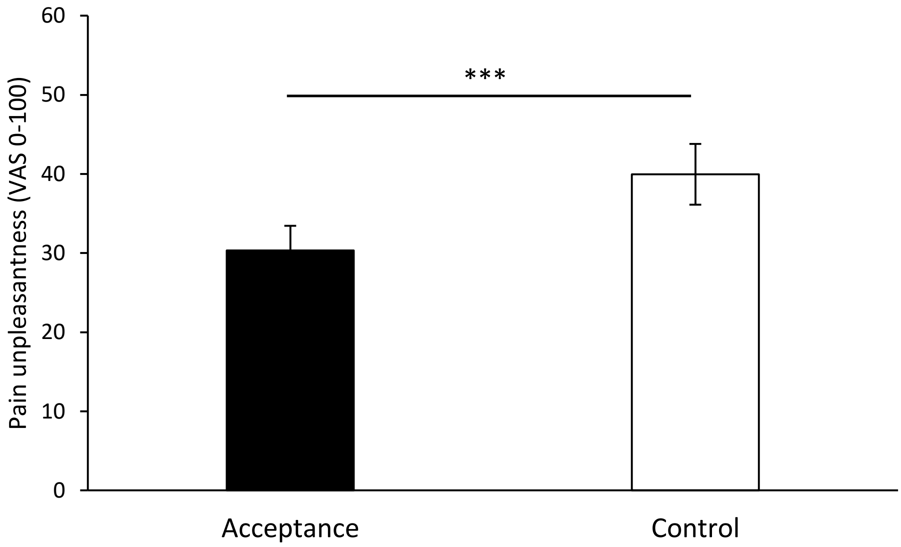


Note. Mean pain intensity ratings and SEMs of heat pain trials per strategy condition, $^{**}p < .01$.

2.3.2. Pain unpleasantness

Analysis of pain unpleasantness ratings revealed a significant main effect of the within-factor *strategy* (Acceptance: $M = 30.32$, $SD = 16.78$; Control: $M = 39.96$, $SD = 20.75$), $F(1, 28) = 30.38$, $p < .001$, $\eta_p^2 = .520$. Figure 2.3 shows the higher pain unpleasantness ratings during the control condition compared to the acceptance condition. No significant main effect of the within-factor *trials,* $F(2.36, 66.14) = 1.50$, $p = .228$, $\eta_p^2 = .051$, nor a significant interaction between the within-factors *strategy* and *trials*, $F(3, 84) = 1.22$, $p = .308$, $\eta_p^2 = .042$, could be found.

Figure 2.3. Study 1: Heat pain unpleasantness.

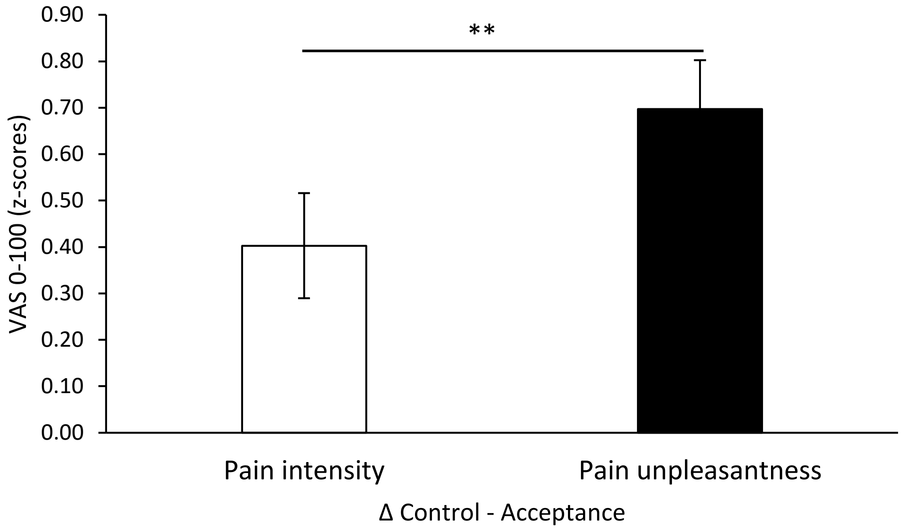


Note. Mean pain unpleasantness ratings and SEMs of heat pain trials per strategy condition, $^{***}p < .001$.

2.3.3. Pain intensity vs. pain unpleasantness

Analysis of the pain rating dimensions with the z-standardized difference scores (control – acceptance) revealed a significant difference between pain intensity (M = 0.40, SD = 0.61) and pain unpleasantness (M = 0.70, SD = 0.57) for acceptance difference scores, $t(28) = -3.12$, $p = .004$, $d = .580$. Figure 2.4 shows higher differences for the pain unpleasantness ratings than pain intensity ratings for acceptance difference scores.

Figure 2.4. Study 1: Comparison of heat pain intensity and unpleasantness.

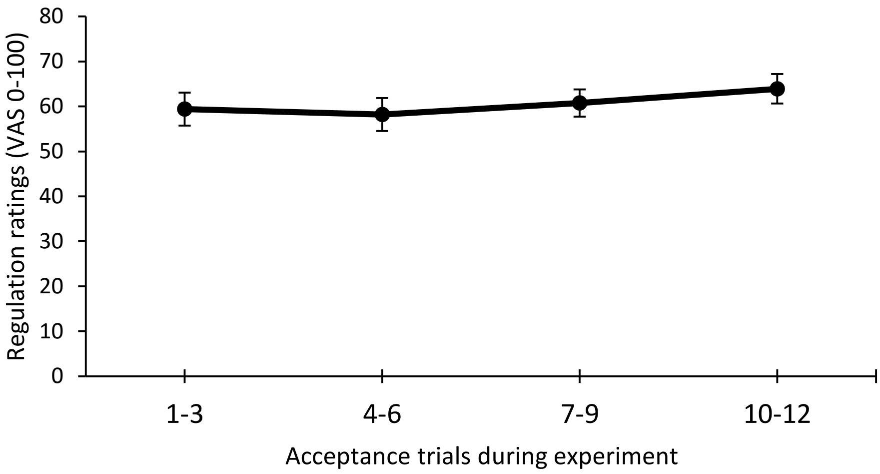


Note. Mean z-standardized difference scores of the strategy condition (control – acceptance) and SEMs of heat pain trials per pain rating dimension, $^{**}p < .01$.

2.3.4. Regulation ratings

Analysis of regulation ratings (M = 60.58, SD = 16.61) after the acceptance trials showed no significant main effect of the within-factor *trials*, $F(3, 84) = 2.07$, $p = .111$, $\eta_p^2 = .069$. Figure 2.5 shows the regulation ratings during the acceptance condition over time course of the experiment.

Figure 2.5. Study 1: Regulation ratings for acceptance over time.



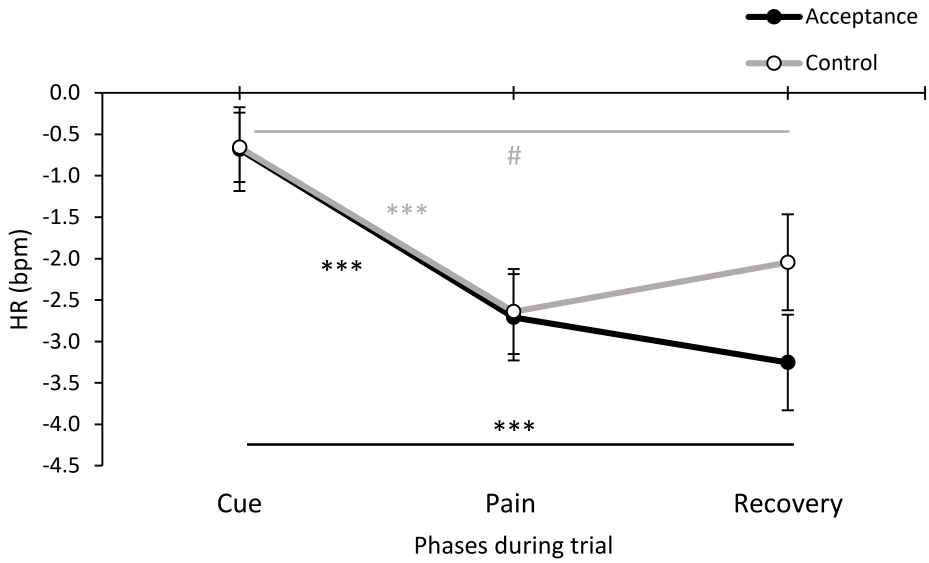
Note. Mean pain regulation ratings and SEMs of acceptance trials over the time course of the experiment.

2.3.5. Heart rate (HR)

Analysis of heart rate showed no significant main effect of the within-factor *strategy*, $F(1, 27) = 0.65$, $p = .427$, $\eta_p^2 = .023$. However, analysis yielded a significant main effect of the within-factor *phase*, $F(1.59, 42.80) = 20.06$, $p < .001$, $\eta_p^2 = .426$. Repeated contrasts with Bonferroni-corrected p-values (2 tests) showed a significant deceleration of HR from the cue phase ($M = -0.67$, $SD = 2.06$) to the pain phase ($M = -2.67$, $SD = 2.19$), $F(1, 27) = 50.27$, $p < .001$, $\eta_p^2 = .651$, while the pain phase and the recovery phase ($M = -2.65$, $SD = 2.63$) did not differ significantly, $p = 1$.

Moreover, there was a significant interaction between the within-factors *strategy* and *phase*, $F(2, 54) = 7.20$, $p = .002$, $\eta_p^2 = .211$. Post-hoc pairwise t-tests with Bonferroni-correction (9 tests) yielded a significant difference between the cue phase and the pain phase for both acceptance (cue: $M = -0.68$, $SD = 2.67$; pain: $M = -2.71$, $SD = 2.76$), $t(27) = 5.82$, $p < .001$, $d = 1.10$, and the control condition (cue: $M = -0.66$, $SD = 2.22$; pain: $M = -2.64$, $SD = 2.72$), $t(27) = 6.10$, $p < .001$, $d = 1.15$. Moreover, analysis revealed a significant difference between the cue phase and the recovery phase ($M = -3.25$, $SD = 3.06$) for the acceptance condition, $t(27) = 5.26$, $p < .001$, $d = 0.99$, and a close to significant difference between the cue phase and the recovery phase ($M = -2.04$, $SD = 3.06$) for the control condition, $t(27) = 2.97$, $p = .056$, $d = 0.56$. The remaining comparisons did not reach significance. Figure 2.6 shows the increase in HR from cue to pain phase during the control condition, while acceptance decreases continuously throughout the trial.

Figure 2.6. Study 1: HR over the course of the trial.



Note. Mean baseline-corrected (seconds -1 – 0) heart rate (HR) and SEMs per condition over the time course of the heat pain trial (phases), ***$p < .001$, #$p < .10$.

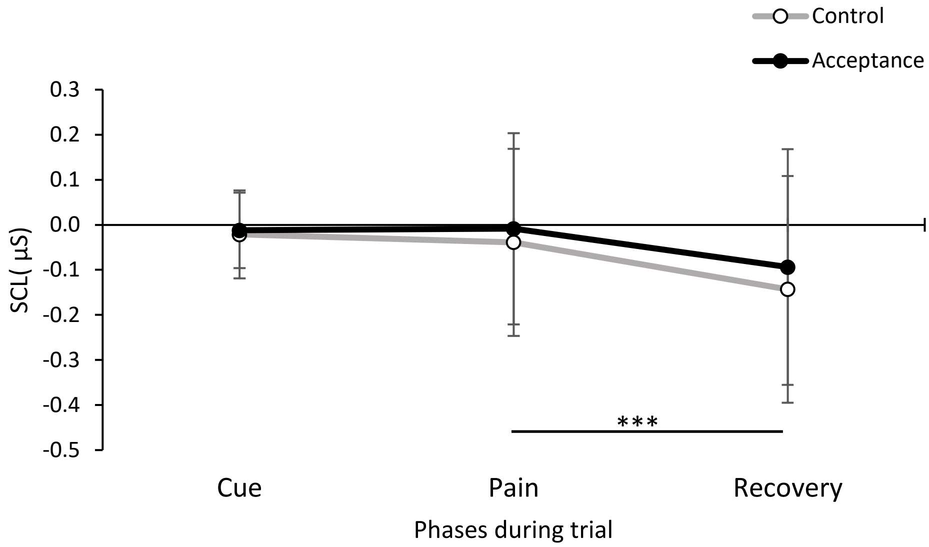
2.3.6. Skin conductance level (SCL)

Analysis of the skin conductance level (SCL) showed no significant main effect of the within-factor *strategy*, $F(1, 26) = 0.98$, $p = .330$, $\eta_p^2 = .036$.

However, there was a significant main effect of the within-factor *phase*, $F(1.35, 35.05) = 6.03$, $p = .004$, $\eta_p^2 = .188$. Repeated contrasts with Bonferroni-corrected p-values (2 tests) yielded a significant difference between the pain phase ($M = -0.02$, $SD = 0.19$) and the recovery phase ($M = -0.19$, $SD = 0.23$), $F(1, 26) = 16.55$, $p < .001$, $\eta_p^2 = .389$, while there was no significant difference between the cue phase ($M = -0.02$, $SD = 0.07$) and the recovery phase ($p = 1$), indicating a decrease of SCL at the end of the trial (see Figure 2.7).

There was no significant interaction between the within-factors *strategy* and *phase*, $F(1.45, 37.71) = 1.22$, $p = .295$, $\eta_p^2 = .045$.

Figure 2.7 Study 1: SCL over the course of the trial.



Note. Mean baseline-corrected (seconds -1 – 0) skin conductance level (SCL) and SEMs per condition over the time course of the heat pain trial (phases), ***p < .001. There were no significant differences between conditions or interactions.

2.3.7. Correlation analyses

Correlation analyses of heat *pain intensity* and *pain unpleasantness* difference scores (control condition – acceptance condition) revealed one significant positive correlation between the AAQ-II total score with the pain intensity difference score, and a close to significant correlation with the pain unpleasantness difference score. This result indicates that less psychological flexibility led to better regulatory outcomes for acceptance compared to the control condition on both pain dimensions. There was further a close to significant, positive relationship between the pain intensity and unpleasantness difference scores and the ASP conscious interactions subscale, implying that a more self-indicated conscious interaction led to a tendentially better regulatory outcome for acceptance on both pain dimensions. Table 2.5 shows the Pearson's coefficients with p-values from the pain intensity and unpleasantness analyses.

Table 2.5. Study 1: Correlation analyses of pain ratings and questionnaires.

	Pain intensity difference scores (control - acceptance)		Pain unpleasantness difference scores (control - acceptance)	
Questionnaires	*r*	*p*	*r*	*p*
AAQ-II				
Total	**.582**	**.001****	.355	.058#
ASP				
Conscious interactions	.333	.078#	.348	.064#
Religious orientation	-.020	.917	-.020	.916
Search for Insight / Wisdom	.097	.617	.071	.714
Transcendence conviction	.203	.290	.050	.797
ASQ				
Suppression / concealing	.061	.754	-.046	.813
Adjusting / reappraisal	-.156	.418	.007	.973
Tolerating / accepting	-.095	.622	.028	.885
ERQ				
Cognitive reappraisal	-.085	.622	-.030	.876
Expressive suppression	.095	.625	-.121	.531
LOT-R				
Pessimism	.286	.132	.044	.820
Optimism	-.165	.393	-.074	.704
RS-11				
Total	-.060	.755	-.210	.273

Note. $N = 29$. Pearson's r (*r*) with p-values (*p*) from two-tailed Pearson correlation analyses of pain intensity and pain unpleasantness difference scores (control – acceptance) with ER and resilience questionnaire scores. Significant correlations are marked in bold, $^{\#}p < .10$, $^{**}p < .01$.

2.4. Discussion

With the first study of the dissertation project, we introduced a within-subjects design and compared an acceptance ER strategy with a neutral control condition in an acute pain context. To this end, healthy participants were instructed to accept (*acceptance condition*) or not regulate (*control condition*) their pain experience induced by short heat pain stimuli. The pain experience was assessed via pain intensity and unpleasantness ratings while continuous heart rate (HR) and skin conductance (SC) were recorded. Participants further indicated how well they were able to regulate the pain with acceptance via regulation ratings. In addition, data of the participants' ER styles, optimism and pessimism, psychological resilience, and religious and spiritual coping was collected.

2.4.1. Acceptance reduces the pain experience

As hypothesized, acceptance significantly decreased the pain intensity and pain unpleasantness compared to the control condition. These results are similar to some previous findings that also included a control condition, however containing spontaneous coping. Braams et al. (2012) showed that acceptance decreased the pain unpleasantness of painful electrical stimuli compared to a control group. Masedo and Esteve (2007) found reduced pain intensity ratings during a CPT in the acceptance group compared to a control group. However, other studies (Kehoe et al., 2014; Reiner et al., 2016) did not find any differences in pain intensity ratings between acceptance and the control condition, contrary to our results. Their latter results are less surprising as, theoretically, acceptance does not aim at reducing the sensory experience but instead disconnects feelings and behavior (Hayes et al., 1999a; Kohl et al., 2013; Masedo & Esteve, 2007). This theory is also supported by our current finding that participants succeeded more in downregulating the pain unpleasantness than the pain intensity, also as hypothesized. Moreover, the study by Braams et al. (2012) has been the only one that assessed pain unpleasantness ratings and included a control condition in their study design. Therefore, we were able to replicate their findings and expand them to brief heat pain stimuli, showing that acceptance successfully reduces the self-reported pain unpleasantness. Unlike the theoretical approach and previous research, acceptance also reduced the self-reported pain intensity in our study. As the pain intensity and unpleasantness dimensions cannot be considered independent of each other (Price et al., 1987), the perception of the pain intensity naturally is affected by the reduced pain unpleasantness. Methodological differences could explain the disparity from previous studies. Kehoe et al. (2014) and Reiner et al. (2016) used tonic heat pain stimuli that can result in elevated pain unpleasantness compared to short pain stimuli (Rainville et al., 1992), which could have made the pain regulation more difficult. A comparison with different pain durations could clarify these further.

Contrary to our expectations, the participants' estimation of their regulatory success with acceptance via regulation ratings did not differ over the time course of the experiment. Accordingly, pain intensity and unpleasantness did not decline over time for acceptance. These findings show that participants already started the experiment with a relatively high estimation of their regulatory success with acceptance (see 2.3.4) that did not change over time. This result could be explained by the sample's habitual use of the acceptance ER strategy. According to the ASQ (see Table 2.2), participants in this study appeared to have a rather accepting ER style, possibly facilitating the implementation of acceptance from the beginning. In line with this result, participants in this study showed a relatively high psychological flexibility, indexed by low scores in the AAQ-II. However, comparing the regulation ratings with another strategy condition in the future could bring more insights on possible training effects.

2.4.2. Anticipatory heart rate deceleration

To analyze the temporal dynamics of the psychophysiology, we divided the total duration of the heat pain trial into three phases: the *cue phase* constituted of the first 7 s of the trial when the condition cue was already present on the screen, but no pain stimulus was apparent. This phase could also be considered as an anticipation phase. Subsequently, the *pain phase* proceeded with 10 s of heat pain, followed by 8 s of the *recovery phase* where the thermode cooled off, the cue disappeared from the screen, and the fixation cross appeared. Autonomic measures can show latencies in reaction; for example, SC can produce a latency of 1-4 s (Dawson et al., 2007), and Braams et al. (2012) found effects of acceptance on the HR 8 s after the electrical pain stimulus. Therefore, we recorded the recovery phase additionally after the pain stimulus.

Contrary to our hypotheses, there were no significant differences between the acceptance and the control condition for both autonomic measures HR and SCL. For HR, we found a significant deceleration from the cue to the pain phase in both conditions. Moreover, we found a significant interaction between the strategy condition and the HR over the time course of the trial. More precisely, acceptance led to a constant deceleration of the HR, specifically from the cue to the pain phase and from the cue to the recovery phase. In contrast, the HR during the control condition did not differ significantly from the cue to the recovery phase. Braams et al. (2012) showed a decelerated HR for acceptance from pre to post instructions in their study, which they interpreted as a reduced cardiac defense response and therefore less physiological costs during acceptance. They concluded that acceptance might be relatively easy to implement but suggested further testing with prolonged pain durations. In our study, both conditions led to a deceleration of HR from the cue to the pain phase, which could be interpreted as an anticipatory HR deceleration (De Pascalis et al., 1995). Participants anticipated the pain when the cue appeared and possibly prepared themselves to receive the pain stimulus. Mohammed et al. (2021) argued that HR deceleration could involve regulatory processes and reflect the downregulation of negative emotions. The participants in our study could have downregulated their negative emotions in anticipation of the heat pain stimulus. Descriptively, it appears that the HR further decelerated in the acceptance condition but slightly accelerated in the control condition in the recovery phase. Moreover, the HR deceleration was more pronounced in the acceptance condition than in the control condition throughout the trial, evident in the significant HR deceleration from the cue to the recovery phase in the acceptance condition only. Following the previous argumentation, participants appeared to have regulated their emotions not only while anticipating the heat pain but also while perceiving the pain stimulus in the acceptance condition. This finding could indicate a regulatory effort of acceptance during short heat pain stimuli reflected by HR deceleration. However, there was no significant difference between the two conditions in the recovery phase after the Bonferroni-correction. Possibly, acceptance could require more time to be fully initiated, which might have been undetected by the psychophysiology by using brief heat pain stimuli. This interpretation could also support the assumption of acceptance intervening somewhat late in the emotion-generative process (Gross, 1998b). However, Braams et al. (2012) found effects of acceptance in the HR even after phasic electrical stimuli that lasted only 200 ms. Nevertheless, the descriptive tendencies in the temporal dynamics could become more evident with a more prolonged pain stimulation.

For SCL, we only found a significant decrease from the pain to the recovery phase for both conditions equally, indicating that the SCL decreased for both conditions after the heat pain stimulus. Nickel et al. (2017) showed in their study that SC could be more related to the stimulus intensity than the perceived pain intensity. As we used moderate, individually adjusted heat pain stimuli, it could be possible that the SC only reflected the stimulus intensity in our study instead of functioning as a pain perception correlate.

Nevertheless, Loggia et al. (2011) argued that both autonomic measures should reflect the perceived intensity of painful stimuli, meaning the sensory component of the pain. As mentioned above, acceptance does not target the sensory experience but appears to have affected it in our study, as shown by the reduced pain intensity ratings. However, the decline in pain unpleasantness for acceptance was more pronounced so that HR and SC potentially did not detect the smaller reductions in perceived pain intensity.

2.4.3. Psychological flexibility impeding regulatory success?

In order to examine the regulatory outcome and, more specifically, the actual regulation success, we calculated the difference scores between the control and the acceptance condition for pain intensity and unpleasantness ratings. We hypothesized that regulatory success with acceptance would be higher with a more accepting ER style and higher psychological flexibility, which comprises acceptance. Unexpectedly, we could not confirm this hypothesis. There was no positive association between an accepting ER style and regulatory success for acceptance. Instead, we even found the opposite effect for psychological flexibility. More specifically, less psychologically flexible participants downregulated better with acceptance, reflected by both pain rating dimensions. This result is surprising as, theoretically, psychological inflexibility is the inability to persist or change value-based behavior (Hayes et al., 2006) and should entail experiential avoidance and counteract acceptance (see 1.2.2.1). Participants with high psychological inflexibility in this study possibly might have avoided the pain stimulus rather than accepting it and engaging in it. Experiential avoidance means the unwillingness to experience certain aversive emotions or sensations and the attempt to change their form or frequency even when harmful (Hayes et al., 2004; Hofmann & Asmundson, 2008). Thus, even though we instructed the participants to resist the attempt to alter or control their pain experience, they might have still tried to control the heat pain and regulated it successfully. However, following this argumentation, they seemed to have used avoidance or other strategies only during the acceptance condition but not during the control condition. This finding could lead to the assumption that participants did not understand the instructions entirely. According to the manipulation check survey (MCS) (see 2.2.1), participants indeed comprehended the control condition instructions better than the acceptance instructions. However, they still rated the acceptance instructions' comprehensibility as rather high (NRS 1-9: $M = 7.76$, $SD = 1.09$), with a minimum rating of 6. The MCS indicated less perceived success with implementing acceptance (NRS 1-9: $M = 6.83$, $SD = 1.39$) than the control condition. These results indicate that some participants might have had difficulties with implementing acceptance and therefore switched to other regulation strategies. Even though we assessed whether participants distracted themselves from the heat pain and excluded the high raters (NRS 1-9 = 9), we did not consider retrieving information on the use of other regulation strategies such as reappraisal or suppression in the MCS, which should be included in future studies.

Another consideration might be the small sample size ($N = 29$) used in this study. The a priori determination of the optimal sample size with G*Power (Faul et al., 2009) targeted the analyses of our main research questions performed with paired t-tests. An a priori analysis with G*Power (Faul et al., 2009) for a two-tailed correlational analysis with an estimated medium correlation of $r = .3$, $\alpha = .05$, and power of $1\text{-}\beta = .8$ would have resulted in an optimal sample size of 84. Due to the lack of studies conducting correlational analyses with pain regulation and ER styles, no parameters from other research were available for the optimal sample size analysis, so a lower but sufficient power was used. In their meta-analysis, Button et al. (2013) pointed out that small sample sizes can produce so-called "false positives", leading to an overestimation of the found effects due to low statistical power. Moreover, researchers (Hung et al., 2017; Malbec et al., 2022) have argued that small sample sizes could lead to random outcomes and have even recommended a minimal sample size of 150 for correlational analyses (Hung et al., 2017). On the other hand, Wilson et al. (2022) suggested that theory-focused research should aspire to intermediate sample sizes, as too big sample sizes produce false positives, too. According to a post-hoc analysis with G*Power (Faul et al., 2009), this study's correlational analysis of psychological flexibility achieved a statistical power of $1\text{-}\beta = 0.932$, sufficient to detect an actual effect and avoid a type II error. Thus, future studies should consider an a priori calculated optimal sample size to retrieve reliable correlational data.

We further expected that participants with a higher resilience would be more successful in pain regulation with acceptance. Unfortunately, we did not find any associations. The participants in this sample appeared to be averagely resilient (RS-11, NRS 0-7, maximum sum score = 77: $M = 59.52$, $SD = 7.78$). According to the normative data for the RS-11 (Kocalevent et al., 2015), the mean sum score in our sample is $M = 59.61$ ($SD = 10.65$), corresponding to a percentile rank of 47.5, which cannot explain the lack of associations. Our results are contrary to Ramirez-Maestre et al. (2014), who found a strong association between acceptance and resilience in chronic pain patients. However, they also found a negative correlation between acceptance and impairment, anxiety, and depression, which could have moderated their effect. We investigated healthy participants in our study, so possibly none of these moderating factors were present in our sample, weakening the link between acceptance and resilience. However, future studies should still incorporate resilience measures to verify whether there is a direct association between acceptance and resilience. Furthermore, our sample could have been too small to identify connections between acceptance and trait factors.

Finally, we further expected optimistic and religious or spiritual participants to be more successful in pain regulation with acceptance. This hypothesis could be confirmed partially. Close to significant tendencies suggested that participants with a more conscious interaction led to more regulatory success for acceptance on both pain dimensions. This supports the assumption that a higher spirituality might lead to better regulation with acceptance. However, there were no associations for optimism or religiosity with regulatory success with acceptance. These findings could be explained with a high percentage (69%) of agnostic or atheist individuals in the sample, while no participant identified as religious.

2.4.4. Conclusion and outlook

With this first study of the dissertation project, we successfully introduced a within-subjects design and compared an acceptance ER strategy with a neutral control condition with short heat pain stimuli. As expected, acceptance led to reduced pain intensity and unpleasantness ratings compared to the control condition. Moreover, the effects were more pronounced for pain unpleasantness, which aligns with the theoretical concept of acceptance. However, other studies (Kehoe et al., 2014; Reiner et al., 2016) suggested that accepting a tonic pain induction could fail to attenuate the self-reported pain intensity due to a higher pain unpleasantness and therefore impede a successful pain regulation. Therefore, future studies should incorporate different pain durations to clarify this assumption further.

Contrary to our hypothesis, we could not find any perceived training effects of acceptance over the time course of the experiment, reflected by the regulation ratings. This finding could be due to an already higher level of regulation ratings from the beginning of the experiment and a fairly accepting ER style within the sample. However, more conclusions could be drawn from the regulation ratings with other regulation strategies as a comparison.

Also contrary to our expectations, there were no differences between acceptance and the control condition regarding the autonomic measures. However, both conditions led to a deceleration of HR from the cue to the pain phase, which could be interpreted as an anticipatory HR deceleration (De Pascalis et al., 1995) or attempts to downregulate negative emotions prior to the heat pain (Mohammed et al., 2021). Descriptive findings pointed towards the assumption that the HR deceleration continued throughout the whole acceptance trial, indicating regulatory efforts of acceptance. This regulatory effort indicate a rather late onset of acceptance in the emotion-generative process (Gross, 1998b), which could be further investigated with longer pain durations. SCL only decreased for both conditions after the heat pain stimulus. Both autonomic measures are supposed to assess the sensory pain component (Loggia et al., 2011), so the absence of any differences between acceptance and the control condition is in line with the theoretical concept of acceptance. The effect on the self-reported pain intensity in our study could have been too weak to be detected by the SC. If this is true, there should be differences in SCL between acceptance and other regulation strategies, which should be included in future research. Moreover, a bigger sample could lead to clearer effects in the psychophysiology.

Unexpectedly and contrary to the theoretical approach, we found that higher psychological inflexibility led to a better regulatory outcome of acceptance for both pain rating dimensions. However, there were no effects of an accepting ER style. Reasons might be that participants either did not fully comprehend the acceptance instructions or had difficulties implementing acceptance, so they switched to other regulation strategies. Nevertheless, the manipulation check survey results did not indicate severe difficulties. Unfortunately, we did not include other strategies than distraction in the manipulation check survey. There were no associations with acceptance and the concepts of optimism, religiousness, and spirituality, and resilience. The small sample size of this study should be considered. A bigger sample could have resulted in clearer associations. However, these concepts should be included in further studies with larger samples to examine whether there is a connection to acceptance.

3. Study 2: Regulating heat and electrical pain: Acceptance vs. distraction

3.1. Introduction

In the previous and first study of the dissertation project (see 2), we successfully introduced a within-subjects design and compared an acceptance ER strategy with a neutral control condition with short heat pain stimuli. We showed that acceptance led to reduced pain intensity and unpleasantness ratings compared to the control condition. Moreover, we found a more pronounced reduction for pain unpleasantness than for pain intensity, in line with the theoretical model of acceptance behavior (Hayes et al., 1999a; Kohl et al., 2013; Masedo & Esteve, 2007) (see 1.2.2.1 for more details). The regulation ratings remained relatively high throughout the experiment, so no effects of training could be found. Furthermore, we found an anticipatory HR deceleration (De Pascalis et al., 1995) for both conditions and a descriptive deceleration for acceptance at the end of the heat pain trial, indicating a possible regulatory effort (Mohammed et al., 2021) of acceptance. SCL decreased for all conditions equally throughout the trial.

One of the aims of this dissertation project was to compare acceptance with two already established ER strategies from the process model of ER (1998b), namely distraction and reappraisal (see 1.4). These two strategies reflect different time points in the process model and are therefore ideal for comparing mechanisms and temporal dynamics (Sheppes & Gross, 2011). In this second study of the dissertation project, we extended the design of study 1 and included active, neutral distraction as another ER strategy. Distraction has been shown to effectively reduce negative emotions and acute pain, especially in the short-term (Nouwen et al., 2006; Snijders et al., 2010; Verhoeven et al., 2011). Bushnell et al. (2013) suggested that active, positive distraction might affect the pain unpleasantness by targeting the emotional state, whereas neutral distraction could target the pain intensity. However theoretically, distraction is initiated rather early in the emotion-generative process (Gross, 1998b) (see 1.2.1.), so it should encode less affective information (Sheppes & Meiran, 2007), and therefore affect the perceived pain unpleasantness less than strategies that are initiated later in the emotion-generative process. We constructed our active, neutral distraction instructions by adapting the visualization by Singer and Dobson (2007) to the pain context.

Another aim of this project was to further investigate different mechanisms by varying pain durations and modalities (see 1.4.1). To this end, we included the previously used brief heat pain stimuli and introduced very brief, phasic electrical pain stimuli to the design. We chose to oppose these pain modalities as they constitute different kinds of pain (Staahl & Drewes, 2004), and for the technical benefit that we could configure a very brief pain stimulation with electricity. Again, pain intensity and unpleasantness ratings as well as regulation ratings were gathered after every pain trial, and HR and SC were measured continuously.

We included the phasic electrical pain stimuli to capture possible temporal dynamics underlying distraction and acceptance. For example, if distraction intervenes earlier in the emotion-generative process than acceptance, the effects should be more pronounced for the electrical pain stimuli. On the other hand, both strategies might be fully initiated during the heat pain trial so that no differences would occur. Thus, we hypothesized that distraction and acceptance would reduce the self-reported pain intensity and unpleasantness compared to the control condition. Moreover, we expected distraction to be more effective than acceptance for the electrical pain stimuli but equally effective for the heat pain stimuli.

Following this argumentation and according to our first study, we expected a stronger reduction in pain unpleasantness than intensity for acceptance for both pain modalities. As distraction should target the pain intensity by not attending to the pain and should not encode any affective information, we expected that distraction would reduce the pain intensity and unpleasantness equally. Exploratively, we compared the pain ratings of the heat and electrical pain trials with each other to investigate further mechanisms regarding the pain modalities.

Regarding the regulation ratings, we still expected the participants to perceive an improvement in the estimation of their regulatory success with acceptance over the time course of the experiment. In comparison, distraction should be a more familiar regulation strategy, so we expected the regulation ratings to be higher for distraction than acceptance. Moreover, we assumed that the regulation ratings for distraction would remain the same over time. Accordingly, we expected that the pain ratings for acceptance but not distraction would decline over time.

In our previous study, there were no differences between acceptance and the control condition for autonomic measures. Therefore, we suggested that HR and SC reflected mainly the sensory pain component (Loggia et al., 2011), which acceptance did not affect. However, other regulation strategies targeting the sensory pain experience should differ from acceptance and the control condition. Thus, we hypothesized that distraction should decrease autonomic measures compared to acceptance and the control condition for both pain modalities.

Furthermore, we expected that regulation with acceptance would be more successful for participants with an accepting ER style, with higher psychological flexibility, more optimism, higher religiosity or spirituality, and more resilience. None of the ER questionnaires used in this project assessed distracting ER styles directly. However, there have been assumptions regarding less regulatory flexibility for people with distracting ER styles (Forys & Dahlquist, 2007). Thus, we considered regulatory flexibility as a part of psychological flexibility. Moreover, Moore et al. (2015) argued that the concept of psychological inflexibility, the inability to persist or change value-based behavior (Hayes et al., 2006), includes cognitive control, which is associated with distraction (Moodie et al., 2020). A high psychological inflexibility could therefore point towards a distracting ER style. Thus, we hypothesized that participants with higher psychological inflexibility might be better at regulating with distraction. We further expected optimistic participants to be also more successful in pain regulation with distraction.

3.2. Methods

Susanne Haridi, a student from the University of Würzburg, supervised by Haspert, assisted in data collection and processing and used part of this data in her bachelor thesis.

3.2.1. Participants

Forty participants were recruited via the local online platforms Sona Systems (Sona Systems Ltd., Tallinn, Estonia) or Wuewowas (www.wuewowas.de). Announced inclusion criteria were an age between 18 and 35 years and fluent in German language. Exclusion criteria were the intake of central nervous or pain medication, chronic pain or pain-related conditions. Two hours of course credit for psychology students or 15€ were granted for participation. Calculation of the optimal sample size was performed a priori via G*Power (Faul et al., 2009) for a repeated-measures ANOVA, following the studies by Braams et al. (2012) (effect size (f) = .25) and Kohl et al. (2013) ($1\text{-}\beta = .8$, $\alpha = .05$), resulting in an optimal sample size of at least 28 participants. Considering possible dropout, we recruited 40 participants in total. Participants who rated the heat and electrical stimuli less than VAS = 5 on the pain intensity scale (VAS 0-100) during heat and electrical pain trials in the control condition were excluded from further analyses. This criterion was established to ensure the perception of at least bearable pain during the experiment. In this study, one participant was excluded from analyses due to this criterion (heat pain intensity: $M = 3.17$; electrical pain intensity: $M = 4.00$). Another three participants were excluded due to their age (over 40 years old). No outliers (pain ratings, $SD > 3$) were identified. Thus, the final sample consisted of 36 participants (17 females). Participants were between 19 and 36 years old ($M = 25.92$, $SD = 4.66$), most of them were unmarried (88.9%), highest educational level was Abitur (88.9%), and they were mostly students (80.6%), right-handed (88.9%) and non-smokers (75.0%). An overview of the sociodemographic information is shown in Table 3.1. The institutional review board of the medical faculty of the University of Würzburg approved the experimental procedure.

Table 3.1. Study 2: Sociodemographic information.

	Frequencies	*M (SD)*	*Min*	*Max*
Age		25.92 (4.66)	19	36
School degree				
Abitur	33			
Fachabitur	0			
Realschule	3			
First language				
German	33			
Other	3			
Handedness				
right	32			
left	4			
Smoked in the last 24 hrs	8			
Caffeine in the last 24 hrs	21			
Current pain intensity (NRS 0-9)		0.3 (0.17)	0	2
Pain coping (NRS 0-9)		6.57 (1.27)	4.5	9

Note. $N = 36$. Frequencies of response and means (*M*) with standard deviations (*SD*) and minimal (*Min*) and maximal (*Max*) values.

Participants were informed about the specifics of the experiment, signed a written informed consent, and filled out a questionnaire on sociodemographic information (see Appendix A and Appendix C). Participants further completed a number of questionnaires on pain-related variables and constructs influencing pain processing and pain experience: the State-Trait Anxiety Inventory (STAI) (Laux et al., 1981; Spielberger et al., 1983), the Resilience Scale 11 (RS-11) (Schumacher et al., 2005; Wagnild & Young, 1993), the Life-Orientation-Test Revised (LOT-R) (Glaesmer et al., 2008; Scheier et al., 1994), the Pain Sensitivity Questionnaire (PSQ) (Ruscheweyh et al., 2009), the Pain Catastrophizing Scale (PCS) (Meyer et al., 2008; Sullivan et al., 1995), the Fear of Pain Questionnaire-III (FPQ-III) (Baum et al., 2013; McNeil & Rainwater, 1998) and the Aspects of Spirituality (ASP) (Büssing et al., 2007). They also completed a number of questionnaires on ER: the Emotion Regulation Questionnaire (ERQ) (Abler & Kessler, 2009; Sheppes & Gross, 2011), the Affective Style Questionnaire (ASQ) (Graser et al., 2012; Hofmann & Kashdan, 2010), and the Acceptance and Action Questionnaire-II (AAQ-II) (Bond et al., 2011; Hoyer & Gloster, 2013). Mean questionnaire scores are shown in Table 3.2.

Table 3.2. Study 2: Mean questionnaire scores of the sample.

Questionnaires	*M (SD)*	*Min*	*Max*	*N*
AAQ-II				
Total	17.00 (8.27)	7	39	36
ASP				
Conscious interactions	68.89 (19.93)	0	100	36
Religious orientation	37.19 (28.45)	0	88.89	36
Search for Insight / Wisdom	62.35 (20.71)	10.71	100	36
Transcendence conviction	45.49 (27.18)	0	87.50	36
ASQ				
Suppression/concealing	2.98 (0.77)	1.33	4.44	35*
Adjusting/reappraisal	3.27 (0.54)	1.80	4.00	36
Tolerating/accepting	3.69 (0.60)	2.67	4.67	36
ERQ				
Cognitive reappraisal	4.70 (0.99)	2.17	6.83	35
Expressive suppression	3.58 (1.24)	1.00	6.50	36
FPQ-III				
Total	79.36 (17.92)	46	131	36
LOT-R				
Pessimism	4.72 (2.15)	0	9	36
Optimism	8.50 (3.26)	0	12	36
PCS				
Total	17.50 (9.55)	0	45	36
PSQ				
Total	3.41 (1.61)	1.29	6.50	35
RS-11				
Total	60.50 (15.01)	42	138	36
STAI				
State	36.67 (9.52)	20	74	36
Trait	37.20 (10.57)	21	67	36

Note. AAQ-II = Acceptance and Action Questionnaire II, ASQ = Affective Style Questionnaire, ERQ = Emotion Regulation Questionnaire, FPQ-III = Fear of Pain Questionnaire-III, PCS = Pain Catastrophizing Scale, PSQ = Pain Sensitivity Questionnaire, RS-11 = Resilience Scale 11, STAI = State-Trait Anxiety Inventory, LOT-R = Life-Orientation-Test Revised. Mean questionnaire scores (*M*) and standard deviations (*SD*), minimal (*Min*) and maximal (*Max*) scores and sample size (*N*). *Missing data.

After the experiment, participants filled out a manipulation check survey (MCS), similar to the MCS in study 1 (see 2.2.1). In order to check for the comprehensibility of the instructions and perceived success of their implementation, they had to indicate how clear and comprehensible the instructions for the strategies acceptance and distraction and the control instructions were (NRS 1-9; 1 = unclear, 9 = clear) and how well they succeeded in using these instructions (NRS 1-9; 1 = not at all, 9 = very well). Participants should further indicate whether they tried to distract themselves from the pain stimuli (NRS 1-9; 1 = not at all, 9 = a lot). An opportunity to indicate further details was provided. Find an overview of the MCS information on comprehensibility and success in Table 3.3. Religious and spiritual beliefs were assessed in the same way as in study 1. Finally, the participants were asked via an open-ended question whether there was a pain modality (heat or electrical) they could regulate better with. If they affirmed this, they should indicate which strategy they could regulate the best with. They could also give feedback via open-ended questions on the pain stimuli or instructions, the experiment in general and the supposed purpose of the experiment. An overview of the MCS information on religious and spiritual beliefs, preferred pain modalities and strategies is shown in Table 3.4. See the complete MCS in the Appendix F.

Table 3.3. Study 2: MCS with comprehensibility and success of implementation.

Manipulation check item	Acceptance	Distraction	Control	*p*
Comprehensibility of instruction (NRS 1-9)	**7.42**[a,b] (1.63)	**8.53**[a] (0.91)	**8.19**[b] (1.14)	**< .001*****
Min	3	6	5	
Max	9	9	9	
Success of implementation (NRS 1-9)	**6.64**[c] (1.66)	**7.43**[c] (1.74)	7.25 (1.99)	.066$^{\#}$
Min	2	1	2	
Max	9	9	9	
Distraction from pain stimulus (NRS 1-9)	4.11 (2.35)			
Min	1			
Max	8			

Note. Means with standard deviations in parenthesis, minimal (*Min*) and maximal (*Max*) values. Repeated-measures ANOVAs were performed separately to compare comprehensibility of instructions and success of implementation between conditions ($N = 36$), $^{\#}p < .10$, $^{***}p < .001$. Post-hoc pairwise t-tests were performed to explore significant and close to significant condition differences. Significant differences ($ps < .05$) between conditions are marked in bold and specified by superscript letters. Distraction instructions ($p < .001$) and control condition instructions ($p = .019$) were clearer and more comprehensible than acceptance instructions. Participants felt more successful in applying distraction than acceptance ($p = .015$).

Table 3.4. Study 2: MCS with spiritual beliefs, preferred pain modality and strategy.

Manipulation check item	*f / M (SD)*	*N*
Religious denomination (*f*)		
Catholic	16	
Protestant	10	36
Other	3	
None	7	
Believe in a higher entity (*f*)		
Yes	16	
No	8	36
Not sure	12	
Belief system (*f*)		
Spiritual	5	
Religious	10	
Atheist	4	36
Agnostic	11	
Undefined	4	
Other	2	
Importance of spirituality / religiousness in personal life (1 = not at all, 5 = very)		
M (SD)	2.34 (1.26)	
Min	1	35
Max	5	
Better regulated pain modality (*f*)		
Heat pain stimulation	28	
Electrical pain stimulation	3	32
Both	1	
Better strategy (*f*)		
Acceptance	5	
Distraction	21	36
Both	1	
None	3	

Note. Frequencies (*f*) and means (*M*) with standard deviations (*SD*), minimal (*Min*) and maximal (*Max*) values, and sample size (*N*) because of partially missing values.

3.2.1.1. Exclusion of participants in specific analyses

Two of 36 participants were excluded from the statistical analyses of the heat pain trials as they indicated in the MCS to have used forms of reappraisal ("walking on hot sand"; "imagining a hot shower") during heat pain administration ($N_{heat} = 34$). Four participants were excluded from the skin conductance (SC) data analyses of both heat and electrical pain due to overall corrupted SC signals ($N_{SC\_electro} = 32$). Another three participants were excluded from SC analysis of heat pain ($N_{SC\_heat} = 27$) because they were defined as outliers (SC level during heat pain > 3 *SD*).

3.2.2. Pain stimulation

In this study, two different pain modalities were administered: heat pain and electrical pain. All pain stimuli were initiated and presented with the software Presentation® (Version 17.2, Neurobehavioral

Systems Inc., Albany, CA, USA). Heat pain stimuli were controlled via the Software SenseLab (Version 5.2., Somedic SenseLab AB, Sösdala, Sweden). Table 3.5 shows the mean target temperature and current used in the experiment.

Table 3.5. Study 2: Mean target temperature of heat pain and electric current of electrical pain.

	M (SD)	*Min*	*Max*	*N*
Target temperature, heat pain (°C)	44.17 (2.37)	39	46.5	34
Target current, electrical pain (mA)	3.40 (3.05)	0.9	7.2	36

Note. Mean (*M*) target temperature of heat pain and electric current of electrical pain with standard deviations (*SD*) and minimal (*Min*) and maximal (*Max*) values and sample size (*N*).

3.2.2.1. Heat pain stimulation

Heat pain stimuli were delivered similar to the previous study (see 2.2.2) via a Somedic MSA thermal stimulator with an active thermode area of 25×50 mm (Somedic SenseLab AB, Sösdala, Sweden). The heat pain threshold was calibrated with the method of adjustment (Horn-Hofmann & Lautenbacher, 2015). For this purpose, the thermode was attached to the non-dominant volar forearm (position depending on the order, see below) and fixed with a Velcro strap. The average threshold temperature of the three repetitions of this procedure was used as the individual pain threshold (M = 43.17°C, SD = 2.37). In case the heat pain stimuli were experienced as not painful during the practice trials, the pain threshold was increased by 2.5°C. This was the case for five participants. In case the heat pain stimuli were experienced as too painful after the practice trials, the target temperature was decreased by 1.5°C. This was the case for one participant. The practice trials were restarted after the new threshold adaption.

During the experiment, the thermode was attached again to the volar forearm of the non-dominant hand. The position of the thermode was changed after the heat pain threshold procedure, after the practice trials and after each heat pain block of six heat pain trials to avoid habituation or sensitization to the heat pain (Hollins et al., 2011; Jepma et al., 2014) and to avoid damages to the skin. Two different positions on the non-dominant volar forearm were alternated: position 1 on the upper half of the forearm near the wrist and position 2 on the lower half near the elbow pit. The order of the starting positions was counterbalanced between participants.

The heat pain for the practice trials and the experimental session was set as 1°C above the individual pain threshold. One heat pain stimulus lasted for 10 s continuously and was adjusted as in Study 1 (see 2.2.2). The mean target temperature with descriptive details is depicted in Table 3.5.

All heat pain trials were organized into blocks. One heat pain block during practice trials as well as during the experimental session consisted of six heat pain trials. Each block contained two trials of each condition (acceptance, distraction, or control condition), pseudo-randomized. No condition was presented twice or more in a row. Every heat pain block was announced with the following text in font size 24 on the screen: "You will only receive HEAT STIMULI via the thermode on your forearm in the next trials. You will not receive any electrical stimuli." This announcement was presented to ensure that the pain modality as well as the location are predictable and to reduce potential anticipatory anxiety (Schmitz & Grillon, 2012).

3.2.2.2. Electrical pain stimulation

Electrical pain stimuli were administered via the DS7A Current Stimulator (Digitimer Ltd., Hertfordshire, United Kingdom) with a constant current output of 400V and an electric conductance of 2000 µS. The electrical stimuli were delivered via a bar stimulating electrode consisting of two durable stainless-steel disk electrodes (8mm diameter with 30mm spacing) with a pulse width of 6. The electrode was attached to the medial left inner low leg (on the calf, musculus gastrocnemius) via a Velcro strap. The electrical pain for the experiment was calibrated by performing a threshold procedure with instructions on the screen. Participants were informed that the individual pain threshold procedure is intended to determine a suitable stimulus intensity and to familiarize the participant with the electrical stimuli. They were further informed that they will receive stimuli of varying intensity via the electrode on their lower leg, which will be announced by a tone. Some of the stimuli might be so weak that participants might not feel them. Their task was to tell the experimenter, how strong each stimulus was. For this purpose, participants could familiarize themselves with the rating scale before the threshold procedure started. The ratings scale was an 11-level numeric ratings scale (NRS) with the caption "How strong was the electrical stimulus?" with 0 = "not felt anything", 4 = "just perceptible pain", and 10 = "very strong pain". The caption was presented in font size 24 and the scale in font size 18 in the middle of the screen, with white letters in Arial font and a black background. If the participants had no further questions, the threshold procedure began. The experimenter set the electric current of the Current Stimulator according to the threshold scheme: the first stimulus was set to an electric current of 0 mA and the following stimuli were increased in 0.2 mA steps (e.g. 0 mA, 0.2 mA, 0.4 mA, 0.6 mA, etc.) until the participants rated a number higher than 4 on the NRS. Then, the last stimulus was presented again, and the following stimuli were decreased in 0.2 mA steps (e.g. 1.6 mA, 1.4 mA, 1.2 mA, etc.) until the participant rated a number lower than 4. Then, the last stimulus was repeated, and the experimenter started increasing the stimuli in 0.2 mA steps again, until the participant rated a number higher than 4. In sum, there were two sequences with stimuli increasing in electric current and one sequence in between with stimuli decreasing in electric current, all in 0.2 mA steps. The experimenter initiated each stimulus manually by pressing the space key, when 2 s afterwards a 524 ms tone followed while the screen was black. Immediately after the sound, a 20 ms electrical stimulus was presented with the electric current according to the scheme. Right afterwards, the NRS appeared on the screen and participants rated the stimulus intensity verbally. The experimenter wrote down the ratings for all presented stimuli in a threshold scheme template. The threshold currents for each sequence were specified as the last stimulus before a participant rated a number higher (for increasing sequences) or lower than 4 (for the decreasing sequence) on the NRS. For an example for the threshold scheme see Appendix H.

The average threshold of the three sequences constituted the individual electrical pain threshold. The target current for the practice and experimental trials was calculated by increasing the pain threshold by 50%. After the threshold procedure, participants received two electrical stimuli with the target current and should rate them on the NRS. If these ratings were below 5, the pain threshold was increased by 100% instead of 50%. Similarly, in case the electrical pain stimuli during the following practice trials were reported as not painful, the pain threshold was also increased by 100% instead of 50%. This was the case for nine participants. There was no case where participants reported the electrical stimuli as too painful. The mean target current with descriptive details is depicted in Table 3.4.

All electrical pain trials were organized into blocks. One electrical pain block during the *practice trials* consisted of two electrical pain trials of the same condition. One electrical pain block during the *experimental session* consisted of five electrical pain trials of the same condition. Each condition was presented five times in a row so that participants would be able to keep their engagement in the respective strategy for a prolonged period of time thus reducing interruptions caused by changing experimental conditions. Three electrical pain blocks were presented in a row with one of the three conditions each. Order of conditions was pseudo-randomized. Every electrical pain block was announced with the following text in font size 24 on the screen: "You will only receive ELECTRICAL STIMULI via the electrode on your calf in the next trials. You will not receive any heat stimuli." This announcement was presented to ensure that the pain modality as well as the location are predictable, and no anxiety is promoted (Schmitz & Grillon, 2012).

3.2.3. Measures

3.2.3.1. Ratings

Instructions about the ratings as well as the ratings themselves were presented on a screen (resolution 1280 x 1024 pixels, background-color: RGB 132, 132, 132, font type = Arial bold, font size = 16, font color: RGB 255, 255, 255) and programmed with the software Presentation® (Version 17.2, Neurobehavioral Systems Inc., Albany, CA, USA). As in the previous study, participants learned about the pain ratings and the distinction between pain intensity and pain unpleasantness using the radio metaphor by Price and colleagues (Price et al., 1983). As in Study 1, participants could familiarize themselves with the digitalized visual analogue scales (VAS) and practice their handling with the keyboard before the experiment. During the experiment, participants were asked to give ratings right after each heat and electrical pain trial using the VAS for ***pain intensity*** and ***pain unpleasantness*** **(**pain ratings). The pain intensity scales were described with the captions "How painful was the heat stimulus?" / "How painful was the electrical stimulus?", respectively. The ends of the scale ranged from "not painful at all" (left end = 0) to "extremely painful" (right end = 100). The pain unpleasantness scale was captioned "How unpleasant was the heat stimulus?" / "How unpleasant was the electrical stimulus?", respectively, with the ends "not unpleasant at all" (left end = 0) to "extremely unpleasant" (right end = 100). After each heat pain trial / electrical pain block in both strategy conditions, participants were further asked to give ***regulation ratings***, similar to the ones from study 1 (see 2.2.3.1). Regulation ratings were presented after each heat pain trial and after each electrical pain block consisting of five electrical pain trials. The captions, scales and cursor had the same properties as in study 1 (see Appendix I for an example VRS). All given ratings were saved automatically in logfiles in .csv format. Trials were excluded from analyses in case the thermode did not heat up.

3.2.3.2. Psychophysiology

Electrodes for the measurement of both the electrocardiography (ECG) and the skin conductance (SC) were attached, and heart rate (HR) and SC were recorded continuously with the Brain Vision Recorder, V-Amp Edition 1.10 (Brain Products Inc, Munich, Germany) and processed with the Brain Vision Analyzer software (BrainProducts, Munich, Germany) the same way as in the studies before (see 2.2.3.2).

To analyze the temporal dynamics of the psychophysiology, the whole heat pain trial (seconds 0-25) was divided into three phases according to the trial structure: cue (seconds 0-7), pain (seconds 7-17) and recovery of pain (seconds 17-25). HR as well as the SC were averaged into these three phases before analyzed statistically.

The electrical pain trial (seconds 0-9) was divided into two phases to analyze the temporal dynamics of the HR: cue (seconds 0-5.5), pain (seconds 5.5-9). HR was averaged into these two phases and analyzed statistically.

For SC analyses of the electrical pain trials, only the first skin conductance response (SCR) after the brief electrical stimulus (at 5.5 s after cue onset) was used. This first SCR was defined as follows: the reaction should start between 6.3 s – 9 s and (minimal value) and should peak between 8.3 s – 10 s (maximal value) after cue onset (for further information on this method see "EDR type 3, evaluation method C", in Boucsein (2012)). This method was applied by using the macro "Export Marker Amplitude and Latency" (developed by Andreas Mühlberger & Mathias Müller, Version 06/2005, University of Würzburg, Würzburg, Germany) in Brain Vision Analyzer but corrected manually. Trials with no visible reaction in SC were marked manually and set to a value of 0 after data export. Amplitudes of the minimal and maximal values were exported into an excel sheet. Differences between maximal and minimal values were calculated and values below 0.01 µS were defined as non-responder trials and set to 0. These differences were logarithmized and constitute the final SCR values that were used for statistical analysis.

Trials were excluded from analyses in case the thermode did not heat up or markers were not sent during electrical pain application. Trials were also excluded from SC analysis when the SC signal was too noisy.

3.2.4. Instructions

Participants received all instructions on a computer screen with a resolution of 1280 x 1024 pixels, presented on a grey background (background color: RGB 132, 132, 132) with white letters (font type = Arial bold, font size = 16, font color: RGB 255, 255, 255). The instructions for the control and acceptance condition were the same as in Study 1 (see 2.2.4). For distraction, participants received the following instructions on the screen:

> "When the word IMAGINE appears on the screen, you should try to focus on a neutral, everyday thought. To do this, imagine the way from your home to a place of your choice. In doing so, you select an imagination with which you can identify the best and in which you can put yourself the best. Here are some examples:
>
> Select an imagination that is good for you and maintain it throughout the whole experiment:
>
> a. I am walking to work / the university.
> b. I am walking to the supermarket / bakery.
> c. I am walking to the marketplace.
> d. I am walking to the town hall.
> e. I am walking to the central station.
> f. I am walking to … (own suggestion)
>
> Please let the experimenter know now which imagination you have chosen.
>
> SUMMARY:
> In summary this means:
> The ACCEPT and IMAGINE instructions are the previously described strategies that you should apply when the word appears on the screen. You should not use a strategy when the PERCEIVE instruction appears."

See Table 3.6 for the frequencies of the imaginations selected for distraction. Own suggestions were, e.g., "walking home from here", "walking to the bank", or "walking my daughter to school". The experimenter reassured that the participants had no further questions. If there were any difficulties in comprehension, participants could read the instructions once again.

Table 3.6. Study 2: Frequencies of selected imaginations for the distraction strategy.

Imagination	Frequency (N = 36)
Work / university	16
Supermarket / bakery	6
Market place	0
Town hall	0
Central station	4
Own suggestion	10

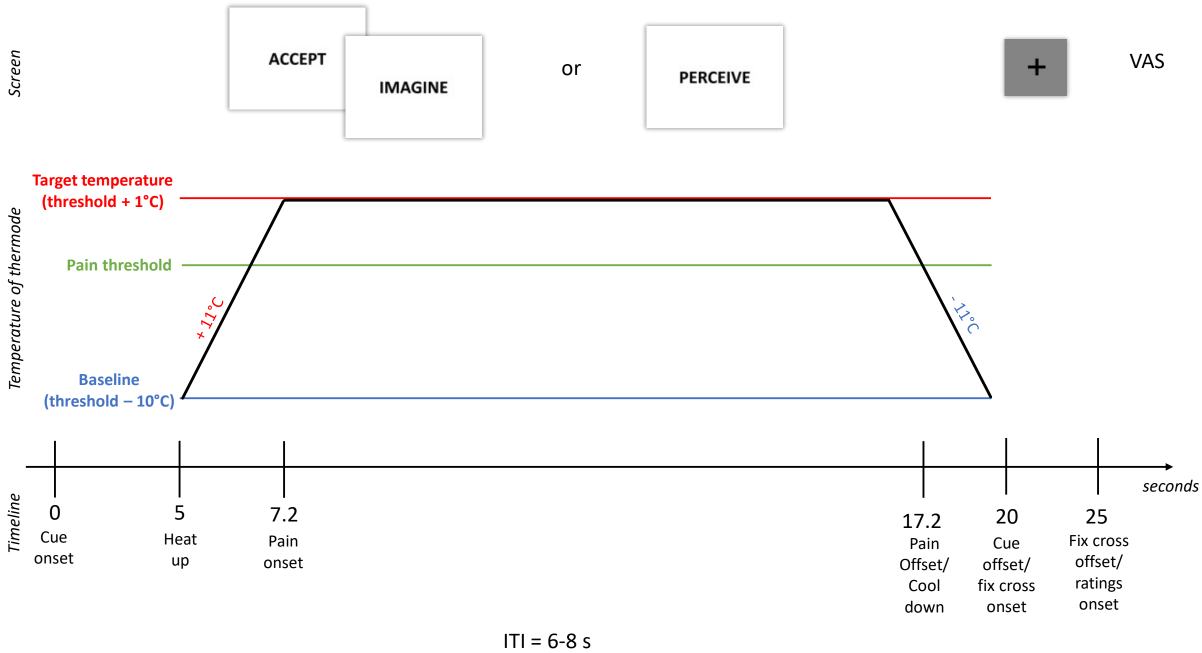
Visual instruction cues were image files created with Microsoft PowerPoint (Microsoft Corporation, Redmond, USA) with the same properties as in study 1 (see 2.2.4). The cue word describing the respective condition (ACCEPT, IMAGINE, or PERCEIVE) was centered and in capital, bold letters (font color black, font type Calibri and font size 96).

3.2.5. Procedure

Participants sat down in front of the monitor and signed the written informed consent. Afterwards, they filled out the questionnaire on sociodemographic information and questionnaires on emotion regulation (ASQ, ERQ, AAQ-II) and trait anxiety (STAI Trait). The experimenter summed up the subsequent procedures briefly and asked the participants to wash their hands without soap. As soon as they returned, the thermode was placed on the forearm according to the position order and the electrode for the electrical stimuli was placed on the left inner calf. Afterwards, the pain threshold procedures started with standardized instructions presented on the screen. Both pain threshold procedures as well as the experimental procedure were controlled using the software Presentation® (Version 17.2, Neurobehavioral Systems Inc., Albany, CA, USA). Whether the experimenter started with the electrical or the heat pain threshold assessment was counterbalanced across participants. After the individual pain threshold was assessed, the experimenter turned off the monitor and removed the thermode. The experimenter attached the ECG and SC electrodes. Thereafter, the thermode was placed again on the participants' forearm according to the position order. Participants should read the instructions on the screen carefully and continue the experiment autonomously by pressing the space bar. Standardized instructions including the radio metaphor, examples of the VAS and instructions regarding the three conditions followed on the screen. Participants selected one specific strategy for the distraction condition (imagination, see Table 3.6) from a list and informed the experimenter. If there were no further questions, the practice trials followed. Each condition was practiced twice for each pain modality (see 3.2.2). Whether an electrical or a heat pain block started first was counterbalanced across participants. After the practice trials, the experimenter made sure that participants had no further questions regarding the experimental procedure. The monitor was turned off, the thermode removed and participants filled out the STAI State questionnaire. Thereafter, the experimenter placed the thermode back on the respective thermode position on the forearm, turned on the monitor and started the psychophysiology recordings. Participants were separated from the experimenter by a folding screen and interacted with the experimenter from this point solely for the relocation of the thermode. Participants were instructed to address the experimenter in case there were any questions left regarding the VAS or the instructions about the conditions. It was also pointed out that they could terminate the experiment at any time. Participants could then start the experiment by pressing the space bar.

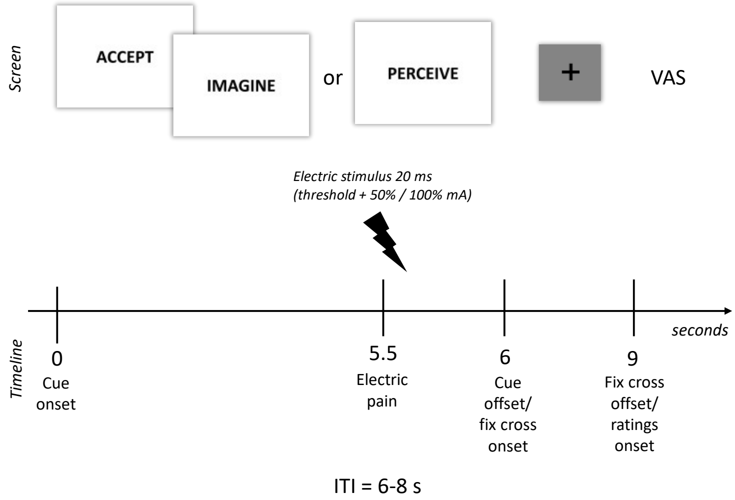
Every heat pain trial started with the presentation of an instruction cue on the screen indicating the respective condition acceptance, distraction or control *(cue onset, second 0)*. The instruction cue remained on the screen until the end of the heat pain administration *(cue offset: second 20)*. Five s after cue onset, the thermode started heating up from the baseline temperature and reached the target temperature after 2.2 s *(pain onset, second 7.2)*. Heat pain stimulation was delivered for 10 s and the thermode started cooling down *(pain offset, second 17.2)* to the baseline temperature in 2.2 s. After the cue offset, a fixation cross was presented in the middle of the screen for 5 s. As soon as the fixation cross disappeared, the VAS for pain intensity and unpleasantness appeared successively on the screen. Regulation ratings also appeared subsequently but only after acceptance and distraction trials. See Figure 3.1 for a schematic illustration of the heat pain trial.

Figure 3.1. Study 2: Schematic illustration of a short heat pain trial (10 s).



Every electrical pain trial started with the presentation of the instruction cue respective to the condition acceptance, distraction or control *(cue onset, second 0)* on the screen, similar to the heat pain trial. The instruction cue remained on the screen until after the electrical pain administration *(cue offset: 6)*. The electrical stimulus of 20 ms was delivered 5.5 s after cue onset. After the cue offset, a fixation cross was presented in the middle of the screen for 5 s. As soon as the fixation cross disappeared, the VAS for pain intensity and unpleasantness appeared successively on the screen. Regulation ratings appeared subsequently but only after electrical pain blocks (i.e., after every five electrical pain trials) in the acceptance and distraction condition. See Figure 3.2 for a schematic illustration of the electrical pain trial.

Figure 3.2. Study 2: Schematic illustration of a phasic electrical pain trial (20 ms).



The interstimulus interval (ITI) was set between 6 to 8 s randomly in order to avoid anticipation effects and ensure enough time to recover from pain. The experimental session comprised three heat pain blocks á six heat pain trials (= 18 heat pain trials in total) and nine electrical pain blocks á five electrical pain trials (= 45 electrical pain trials in total). Three electrical pain blocks were always presented in a row. So, heat pain blocks alternated with three inextricably linked electrical pain blocks. Order of blocks and conditions was pseudo-randomized. Thus, there were six different orders of the experimental session, counterbalanced across participants. After the experiment, participants filled out the remaining questionnaires on spirituality, resilience, and pain-related variables (ASP, FPQ-III, LOT-R, PCS, PSQ, RS-11) and answered the MCS.

3.2.6. Statistical Analysis

IBM SPSS Statistics Version 25 (IBM Corp. Released 2017. IBM SPSS Statistics for Windows, Version 25.0. Armonk, NY: IBM Corp.) was used for all statistical analyses. Significance level was defined as $p < .05$.

Analyses of heat pain trials was performed as follows: Pain ratings (intensity and unpleasantness) were analyzed separately with repeated-measures ANOVAs with the within-factor *strategy* (3 levels: control condition vs. acceptance vs. distraction) and the within-factor *trials* (2 levels: trials 1-3, trials 4-6) by averaging three consecutive trials per condition.

Analyses of regulation ratings was conducted with a repeated-measures ANOVA with the within-factor *strategy* (2 levels: acceptance vs. distraction) and the within-factor *trials* (2 levels: trials 1-3, trials 4-6). Heart rate (HR) and skin conductance level (SCL) were analyzed separately with repeated-measures ANOVAs with the within-factor *strategy* (3 levels: control condition vs. acceptance vs. distraction) and

the within-factor *phase* (3 levels: cue, seconds 0-7; pain, seconds 7-17, recovery, seconds 17-25).
Analyses of electrical pain trials was performed as follows: Pain ratings (intensity and unpleasantness) were analyzed separately with repeated-measures ANOVAs with the within-factor *strategy* (3 levels: control condition vs. acceptance vs. distraction) and the within-factor *trials* (3 levels: trials 1-5, trials 6-10, and trials 11-15) by averaging five consecutive trials per condition. Analyses of regulation ratings was conducted with a repeated-measures ANOVA with the within-factor *strategy* (2 levels: acceptance vs. distraction) and the within-factor *block* (3 levels: block 1, block 2, block 3), as regulation ratings were only obtained after each block of five electrical pain trials. Heart rate (HR) was analyzed with a repeated-measures ANOVA with the within-factor strategy (3 levels: control condition vs. acceptance vs. distraction) and the within-factor *phase* (2 levels: cue, seconds 0-5.5; pain, seconds 5.5-9). Skin conductance response (SCR) was analyzed with a repeated-measures ANOVA with the within-factor *strategy* (3 levels: control condition vs. acceptance vs. distraction) and the within-factor *trials* (3 levels: trials 1-5, trials 6-10, and trials 11-15).

Pain intensity and unpleasantness ratings were z-standardized across each participant, separately for each pain rating dimension and pain modality. Difference scores were calculated from these z-standardized values by deducting the strategy condition from the control condition. Pairwise t-tests were conducted with these z-standardized difference scores, comparing intensity vs. unpleasantness ratings for both strategy conditions. This analysis was conducted for heat and electrical pain separately. Pairwise t-tests with these z-standardized difference scores were also conducted to compare heat vs. electrical pain for both pain intensity and unpleasantness ratings and both strategy conditions.

Post-hoc pairwise t-tests or repeated contrasts were used to compare different factor levels. Difference scores were used to follow up on significant interactions when necessary. Partial eta-squared η_p^2 for ANOVAs and Cohen's *d* (Cohen, 1988; Lakens, 2013) for t-tests were used as measures of effect size. Greenhouse-Geisser correction was applied when the assumption of sphericity (Mauchly's test) was violated. P-value was Bonferroni-adjusted for multiple testing.

Pearson correlations were performed to explore the association between strategy difference scores (control and strategy conditions) and ER questionnaire scores (ERQ, ASQ, AAQ-II) and RS-11, ASP and LOT-R scores as potential indicators of resilience.

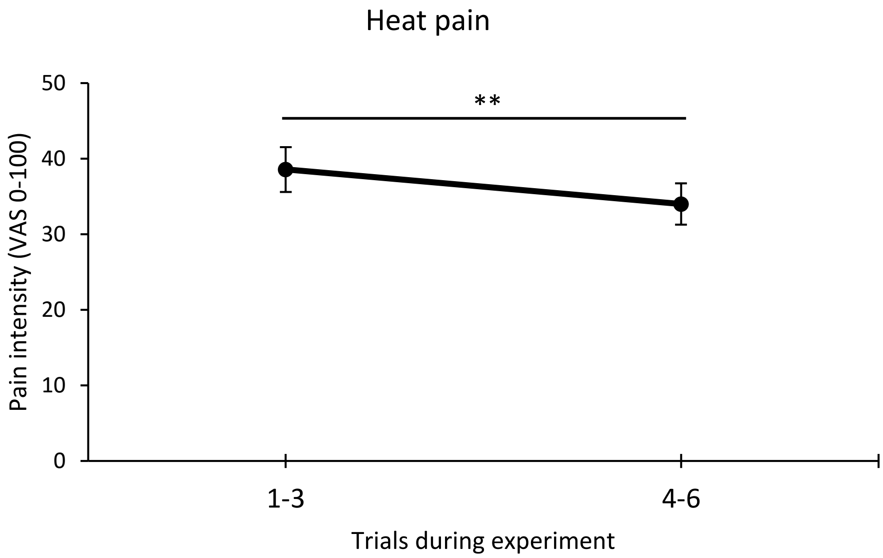
3.3. Results

3.3.1. Heat pain trials

3.3.1.1. Pain intensity

Analysis of pain intensity ratings of the heat pain trials yielded no significant main effect of the within-factor *strategy* (Acceptance: $M = 36.34$, $SD = 15.92$; Control: $M = 37.25$, $SD = 16.38$, Distraction: $M = 35.12$, $SD = 17.86$), $F(2, 66) = 1.88$, $p = .161$, $\eta_p^2 = .054$. However, there was a significant main effect of the within-factor *trials*, $F(1, 33) = 12.64$, $p = .001$, $\eta_p^2 = .277$, indicating higher heat pain intensity ratings in the first half (M = 38.58, SD = 17.30) of the experiment compared to the second half (M = 34.00, SD = 16.03) (see Figure 3.3). There was no significant interaction between the within-factors *strategy* and *trials*, $F(2, 66) = 0.50$, $p = .610$, $\eta_p^2 = .015$.

Figure 3.3. Study 2: Heat pain intensity over time.

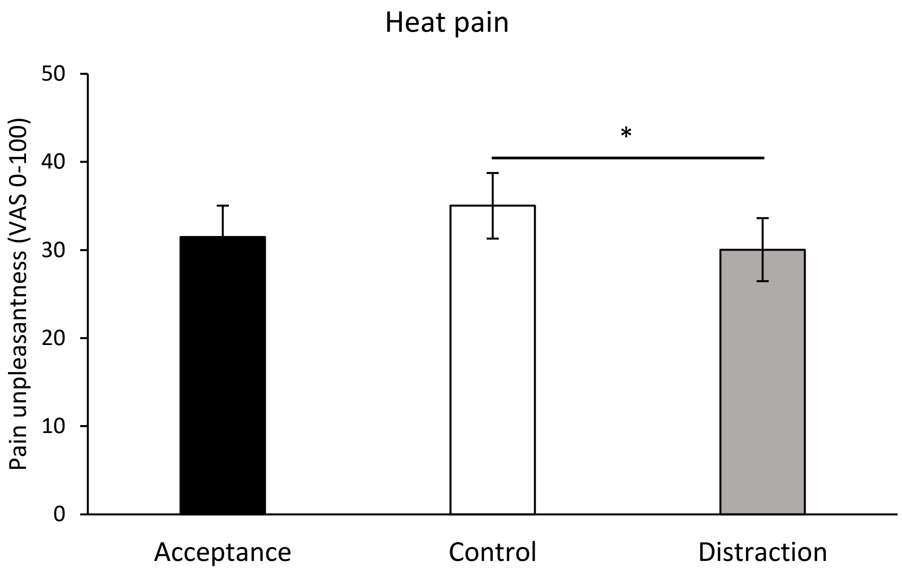


Note. Mean pain intensity ratings and SEMs of heat pain trials over the time course of the experiment, $^{**}p < .01$.

3.3.1.2. Pain unpleasantness

Analysis of pain unpleasantness ratings of the heat pain trials revealed a significant main effect of the within-factor *strategy*, $F(2, 66) = 4.10$, $p = .021$, $\eta_p^2 = .111$. Post-hoc pairwise t-tests using Bonferroni-corrected p-values (3 tests) showed a significant difference between distraction (M = 30.03, SD = 20.89) and the control condition (M = 35.02, SD = 21.61), $t(33) = -2.60$, $p = .042$, $d = 0.45$, whereas acceptance (Acceptance: M = 31.48, SD = 20.74) and the control condition, $t(33) = -1.79$, $p = .248$, $d = 0.31$, and acceptance and distraction, $t(33) = 1.02$, $p = .953$, $d = 0.17$, did not reach significance. Figure 3.4 shows the lower pain unpleasantness ratings for distraction compared to the control condition, while acceptance did not differ from the two conditions. There was no significant main effect of the within-factor *trials* and no significant interaction between the within-factors *strategy* and *trials*, all ps > .198.

Figure 3.4. Study 2: Heat pain unpleasantness.

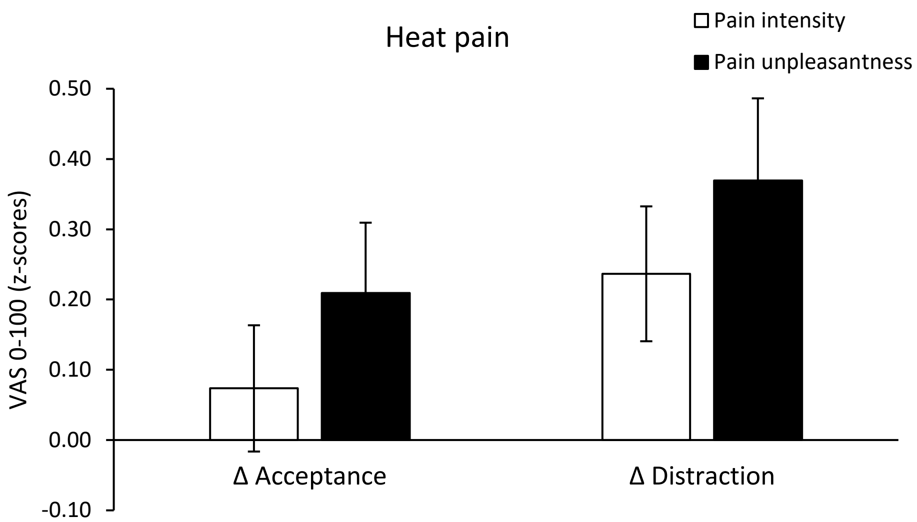


Note. Mean pain unpleasantness ratings and SEMs of heat pain trials per strategy condition, $*p < .05$.

3.3.1.3. Pain intensity vs. pain unpleasantness

Analysis of the pain rating dimensions for each strategy (2 tests) with the z-standardized difference scores (control – strategy) yielded no significant differences between pain intensity ($M = 0.07$, $SD = 0.52$) and pain unpleasantness ($M = 0.21$, $SD = 0.58$) for acceptance difference scores, $t(33) = -1.77$, $p = .170$, $d = .30$, and no significant differences between pain intensity ($M = 0.24$, $SD = 0.10$) and pain unpleasantness ($M = 0.37$, $SD = 0.12$) for distraction difference scores, $t(33) = -1.64$, $p = .222$, $d = .28$ (see Figure 3.5).

Figure 3.5. Study 2: Comparison of heat pain intensity and unpleasantness.

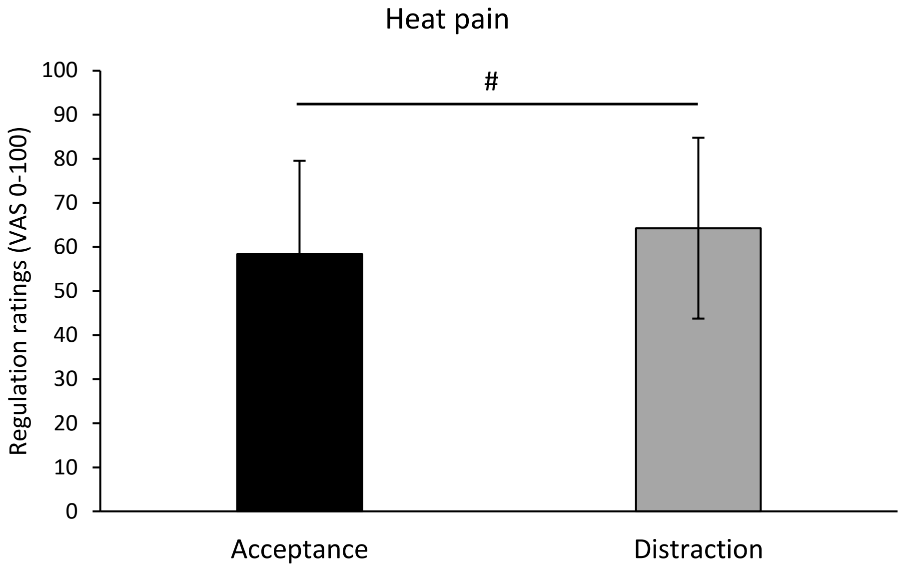


Note. Mean z-standardized difference scores of the strategy condition (control – strategy) and SEMs of heat pain trials per pain rating dimension.

3.3.1.4. Regulation ratings

Analysis of regulation ratings of the heat pain trials showed a close to significant main effect of the within-factor *strategy*, $F(1, 33) = 3.59$, $p = .067$, $\eta_p^2 = .098$, indicating a tendency that participants indicated that they could regulate better with distraction ($M = 64.26$, $SD = 20.54$) than with acceptance ($M = 58.35$, $SD = 21.19$). Figure 3.6 shows the slightly higher regulation ratings for distraction compared to acceptance. There was no significant main effect of the within-factor *trials* and no significant interaction between the within-factors *strategy* and *trials*, all *p*s > .487.

Figure 3.6. Study 2: Heat pain regulation ratings.

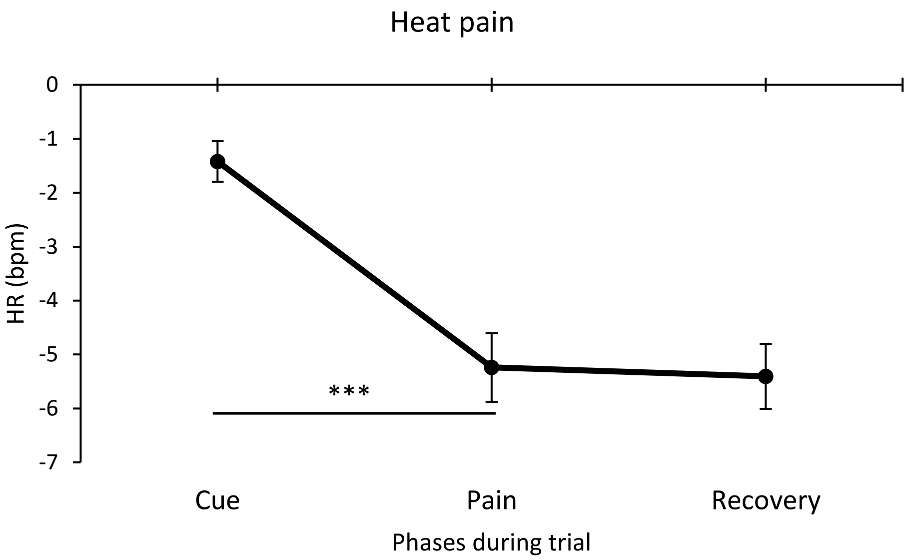


Note. Mean pain regulation ratings and SEMs of heat pain trials per strategy condition, #$p < .10$.

3.3.1.5. Heart rate (HR)

Analysis of heart rate during the heat pain trials revealed no significant main effect of the within-factor *strategy*, $F(2, 66) = 0.68$, $p = .512$, $\eta_p^2 = .020$. However, analysis yielded a significant main effect of the within-factor *phase*, $F(2, 66) = 73.29$, $p < .001$, $\eta_p^2 = .690$. Repeated contrasts with Bonferroni-corrected p-values (2 tests) showed a deceleration of HR from the cue phase ($M = -1.42$, $SD = 2.20$) to the pain phase ($M = -5.24$, $SD = 3.70$), $F(1, 33) = 78.59$, $p < .001$, $\eta_p^2 = .704$, while the pain phase and the recovery phase ($M = -5.40$, $SD = 3.51$) did not differ significantly, $p = 1$ (see Figure 3.7). There was no significant interaction between the within-factors *strategy* and *phase*, $p = .413$.

Figure 3.7. Study 2: HR over the course of the heat pain trial.

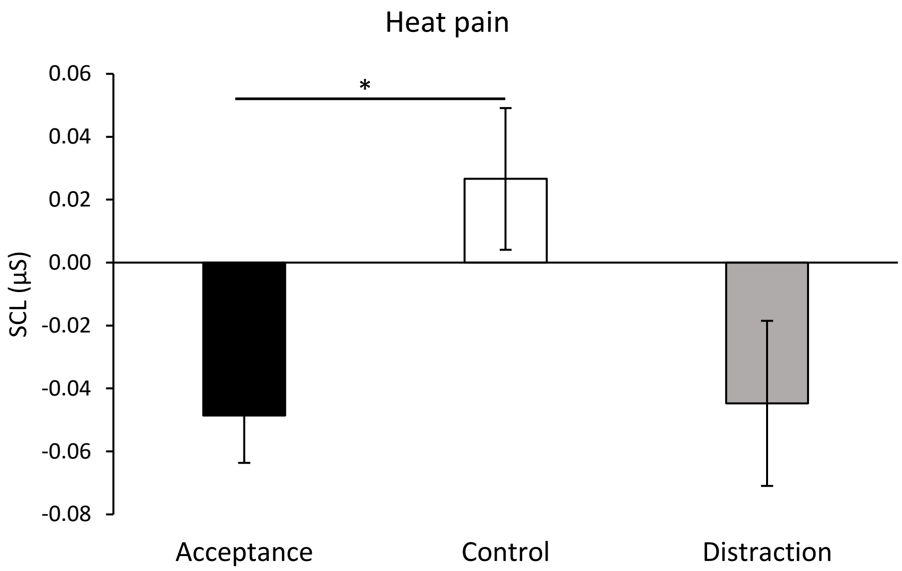


Note. Mean baseline-corrected (seconds -1 – 0) heart rate (HR) and SEMs of heat pain trials over the time course of the trial (phases), ****p* < .001.

3.3.1.6. Skin conductance level (SCL)

Analysis of the skin conductance level (SCL) during the heat pain trials revealed a significant main effect of the within-factor *strategy*, $F(1.64, 42.62) = 4.62$, $p = .021$, $\eta_p^2 = .151$. Post-hoc pairwise t-tests with Bonferroni-adjusted p-values (3 tests) yielded a significant difference between acceptance ($M = -0.05$, $SD = 0.08$) and the control condition ($M = 0.03$, $SD = 0.12$), $t(26) = -2.91$, $p = .022$, $d = 0.56$. There were no significant differences between distraction and the control condition, $t(26) = -2.14$, $p = .126$, $d = 0.412$, and distraction and acceptance, $t(26) = -0.17$, $p = 1$, $d = 0.032$. Figure 3.8 shows the lower SCL for acceptance compared to the control condition, while distraction did not differ from both conditions.

Figure 3.8. Study 2: SCL of heat pain trials.

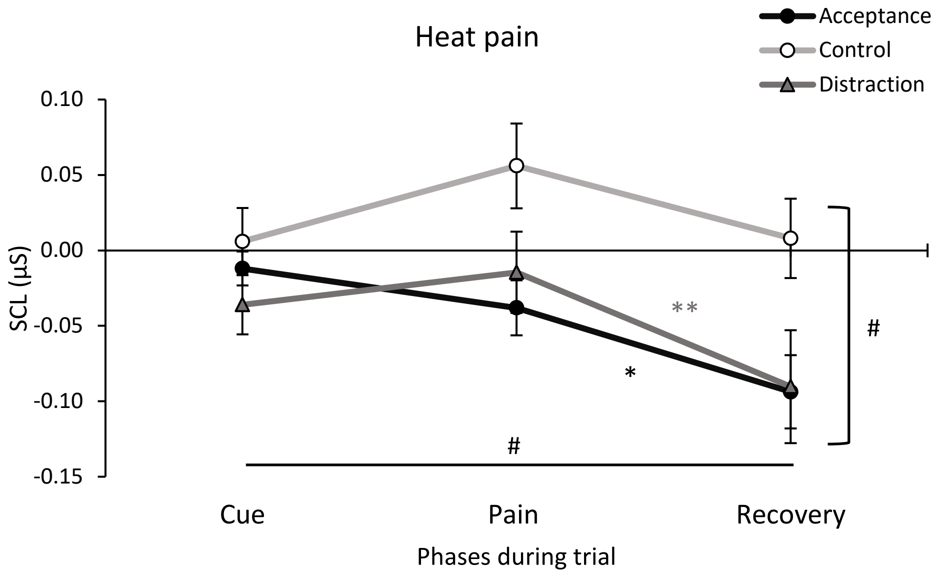


Note. Mean baseline-corrected (seconds -1 – 0) skin conductance level (SCL; seconds 0-25) and SEMs of heat pain trials per strategy condition¸$*p < .05$.

Moreover, there was a significant main effect of the within-factor *phase*, $F(1.65, 42.77) = 7.21$, $p = .003$, $\eta_p^2 = .217$. Repeated contrasts with Bonferroni-corrected p-values (2 tests) yielded a significant difference between the pain phase ($M = 0.00$, $SD = 0.08$) and the recovery phase ($M = -0.06$, $SD = 0.12$), $F(1, 26) = 16.09$, $p < .001$, $\eta_p^2 = .382$, while there was no significant difference between the cue phase ($M = -0.01$, $SD = 0.11$) and the recovery phase, $F(1, 26) = 1.21$, $p = .564$, $\eta_p^2 = .044$, indicating a decrease of SCL at the end of the trial.

Furthermore, the interaction of the within-factors *strategy* and *phase* was significant, $F(1.79, 46.46) = 3.71$, $p = .037$, $\eta_p^2 = .125$. Post-hoc pairwise t-tests with Bonferroni-correction (18 tests) yielded a close to significant difference between acceptance ($M = -0.09$, $SD = 0.13$) and the control condition ($M = 0.01$, $SD = 0.14$) in the recovery phase, $t(26) = -3.21$, $p = .063$, $d = 0.62$. Moreover, there were significant differences between the pain phase ($M = -0.04$, $SD = 0.09$) and recovery phase for acceptance, $t(26) = 3.33$, $p = .047$, $d = 0.77$, the pain phase ($M = -0.01$, $SD = 0.14$) and recovery phase ($M = -0.09$, $SD = 0.19$) for distraction, $t(26) = 4.01$, $p = .008$, and a close to significant difference between the cue phase ($M = -0.01$, $SD = 0.06$) and the recovery phase for acceptance, $t(26) = 3.30$, $p = .051$, $d = 0.63$. The remaining comparisons did not reach significance, all *p*s > .107. Figure 3.9 shows the drop of SCL for both strategy conditions from the pain to recovery phase while the control condition remains unchanged throughout the trial. In the recovery phase only, SCL tends to be lower during acceptance than the control condition.

Figure 3.9. Study 2: SCL over the course of the heat pain trial.



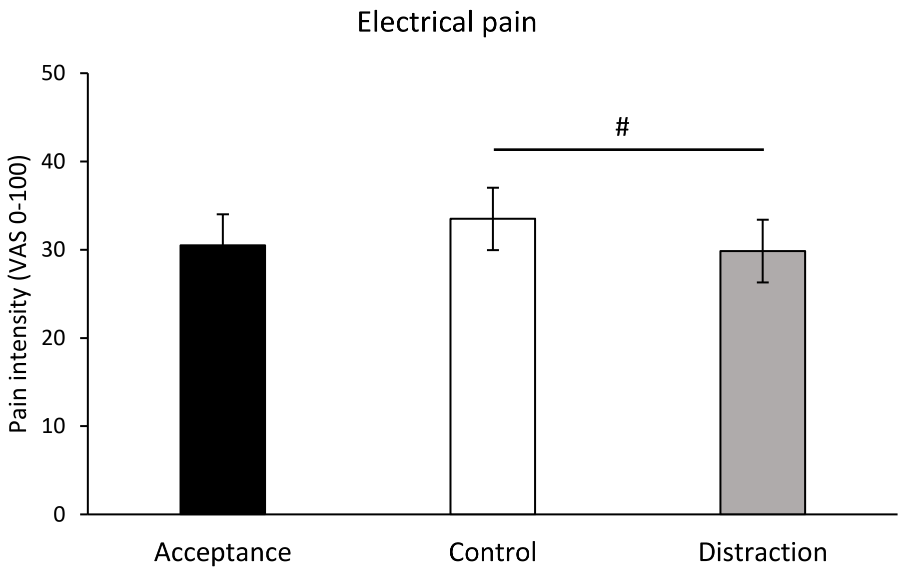
Note. Mean baseline-corrected (seconds -1 – 0) skin conductance level (SCL) and SEMs of heat pain trials over the time course of the trial (phases) per strategy condition, #$p < .10$, *$p < .05$, **$p < .01$.

3.3.2. Electrical pain trials

3.3.2.1. Pain intensity

Analysis of pain intensity ratings of the electrical pain trials revealed a significant main effect of the within-factor *strategy*, $F(1.53, 53.51) = 4.16$, $p = .030$, $\eta_p^2 = .106$. Post-hoc pairwise t-tests with Bonferroni-adjusted p-values (3 tests) showed a close to significant difference between the distraction ($M = 29.86$, $SD = 21.30$) and control condition ($M = 33.51$, $SD = 21.24$), $t(35) = -2.30$, $p = .083$, $d = 0.38$, whereas acceptance ($M = 30.50$, $SD = 21.28$) and the control condition, $t(35) = -2.14$, $p = .117$, $d = 0.36$, and acceptance and distraction, $t(35) = 0.64$, $p = 1$, $d = 0.11$, did not differ from each other (see Figure 3.10). There was no significant main effect of the within-factor *trials*, $F(1.46, 50.91) = 0.16$, $p = .783$, $\eta_p^2 = .005$.

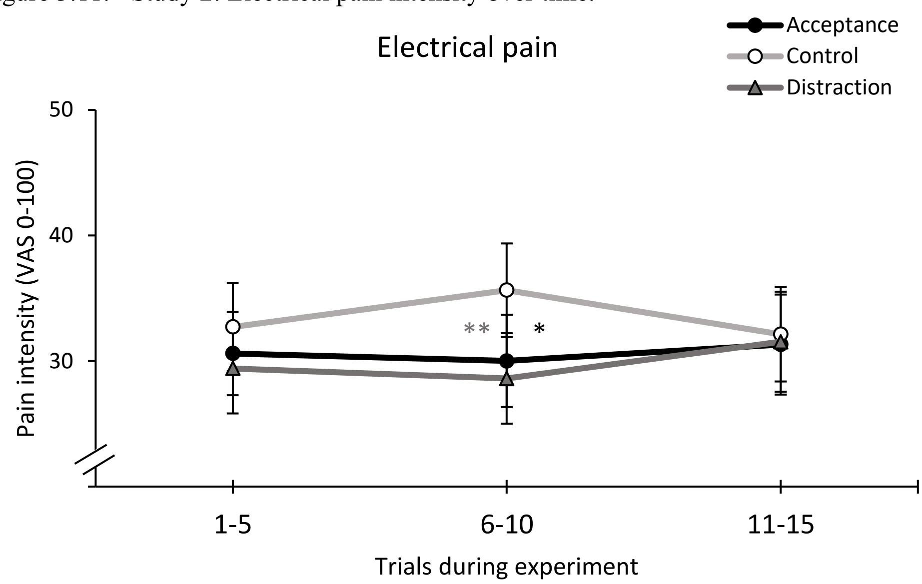
Figure 3.10. Study 2: Electrical pain intensity.



Note. Mean pain intensity ratings and SEMs of electrical pain trials per strategy condition, #$p < .10$.

However, analysis yielded a significant interaction between the within-factors *strategy* and *trials*, $F(3.19, 111.47) = 2.88$, $p = .036$, $\eta_p^2 = .076$. Post-hoc pairwise t-tests with Bonferroni-corrected p-values (18 tests) revealed significant differences for trials 6-10 between acceptance ($M = 30.02$, $SD = 22.07$) and the control condition ($M = 35.65$, $SD = 22.34$), $t(35) = -3.47$, $p = .026$, $d = 0.58$, and distraction ($M = 28.62$, $SD = 21.61$) and the control condition, $t(35) = -3.97$, $p = .006$, $d = 0.66$. The remaining comparisons did not reach significance, all *ps* > .747. Figure 3.11 shows the differences of the strategy conditions compared to the control condition during trials 6-10, whereas there were no differences between conditions during the other trials.

Figure 3.11. Study 2: Electrical pain intensity over time.

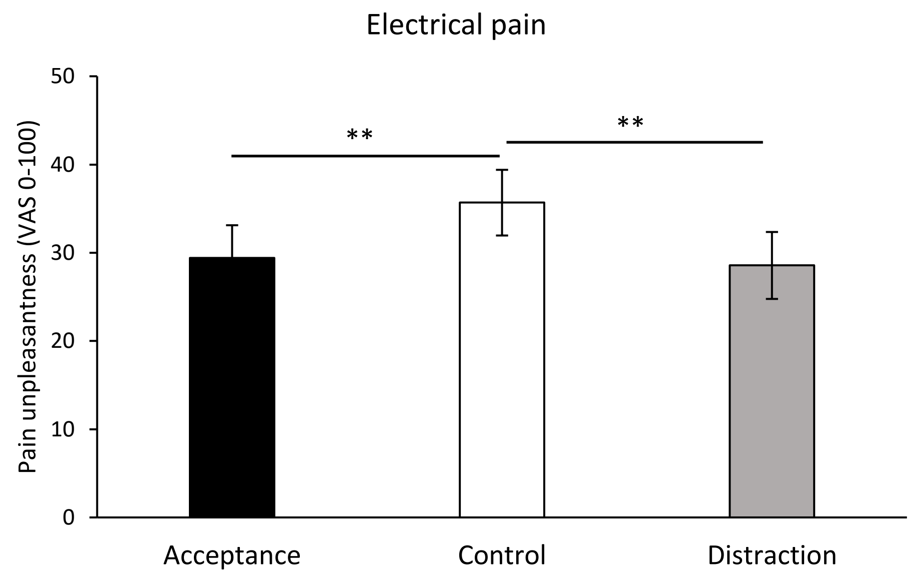


Note. Mean pain intensity ratings and SEMs of electrical pain trials per strategy condition over the time course of the experiment, *$p < .05$, **$p < .01$.

3.3.2.2. Pain unpleasantness

Analysis of pain intensity unpleasantness of the electrical pain trials showed a significant main effect of the within-factor *strategy*, $F(1.64, 57.32) = 10.67$, $p < .001$, $\eta_p^2 = .234$. Post-hoc pairwise t-tests with Bonferroni-adjusted p-values (3 tests) showed a significant difference between acceptance ($M = 29.43$, $SD = 22.10$) and the control condition ($M = 35.69$, $SD = 22.33$), $t(35) = -3.58$, $p = .003$, $d = 0.60$, and distraction ($M = 28.58$, $SD = 22.77$) and the control condition, $t(35) = -3.69$, $p = .002$, $d = 0.62$, while acceptance and distraction did not differ significantly from each other, $t(35) = 0.64$, $p = 1$, $d = 0.11$. Figure 3.12 shows the lower pain unpleasantness ratings for both strategy conditions compared to the control condition. There was no significant main effect of the within-factor *trials*, $F(1.58, 55.21) = 0.70$, $p = .469$, $\eta_p^2 = .020$.

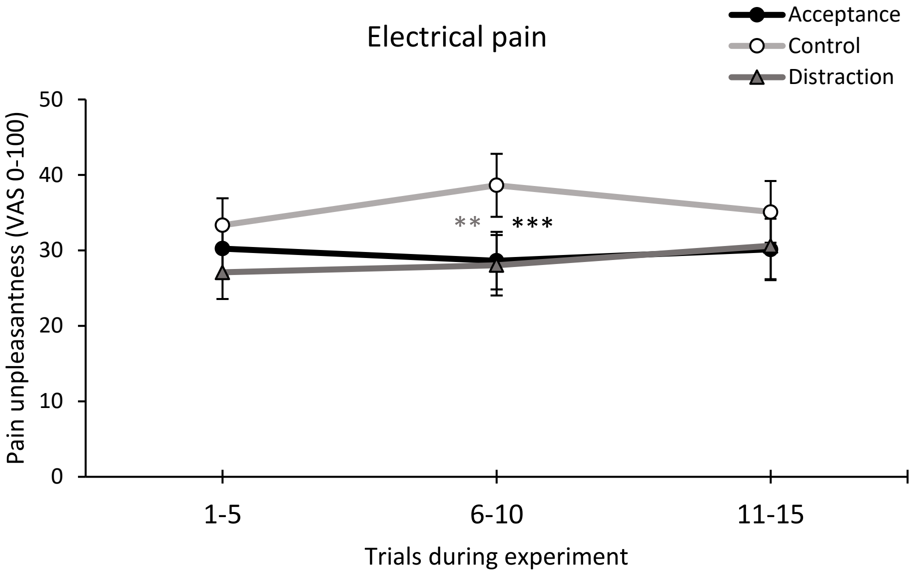
Figure 3.12. Study 2: Electrical pain unpleasantness.



Note. Mean pain unpleasantness ratings and SEMs of electrical pain trials per strategy condition, $^{**}p < .01$.

Moreover, analysis yielded a significant interaction between the within-factors *strategy* and *trials*, $F(3.23, 112.92) = 2.75$, $p = .042$, $\eta_p^2 = .073$. Post-hoc pairwise t-tests with Bonferroni-corrected p-values (18 tests) revealed significant differences for trials 6-10 between acceptance ($M = 28.64$, $SD = 22.85$) and the control condition ($M = 35.09$, $SD = 24.54$), $t(35) = -5.06$, $p < .001$, $d = 0.84$, and distraction ($M = 28.03$, $SD = 24.08$) and the control condition, $t(35) = -4.71$, $p = .001$, $d = 0.78$. The remaining comparisons did not reach significance, all ps > .232. Figure 3.13 shows the differences of both strategy conditions compared to the control condition during trials 6-10, while there were no differences between conditions during the other trials.

Figure 3.13. Study 2: Electrical pain unpleasantness over time.

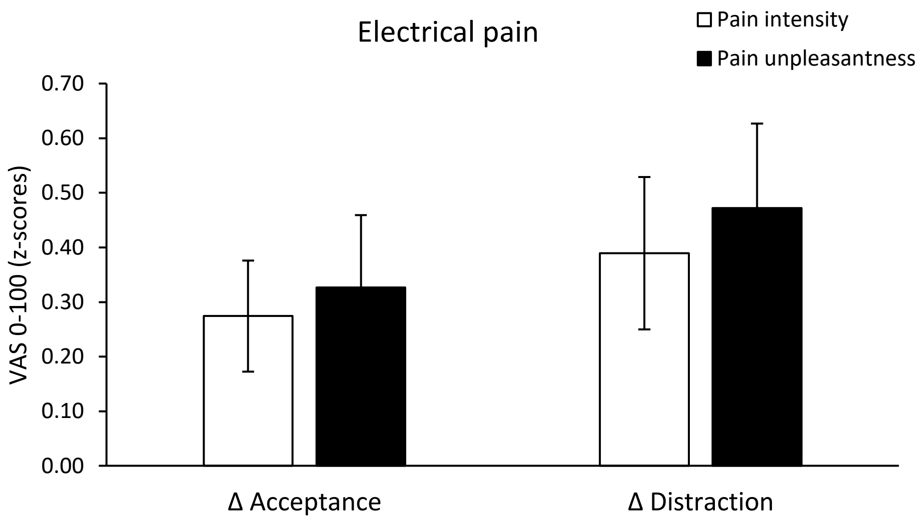


Note. Mean pain unpleasantness ratings and SEMs of electrical pain trials per strategy condition over the time course of the experiment, $**p < .01$, $***p < .001$.

3.3.2.3. Pain intensity vs. pain unpleasantness

Analysis of the pain rating dimensions for each strategy (2 tests) with the z-standardized difference scores (control – strategy) yielded no significant differences between pain intensity ($M = 0.27$, $SD = 0.61$) and pain unpleasantness ($M = 0.33$, $SD = 0.80$) for acceptance difference scores, $t(35) = -0.54$, $p = 1$, $d = .09$, and no significant differences between pain intensity ($M = 0.39$, $SD = 0.84$) and pain unpleasantness ($M = 0.47$, $SD = 0.93$) for distraction difference scores, $t(35) = -0.69$, $p = .985$, $d = .12$ (see Figure 3.14).

Figure 3.14. Study 2: Comparison of electrical pain intensity and unpleasantness.

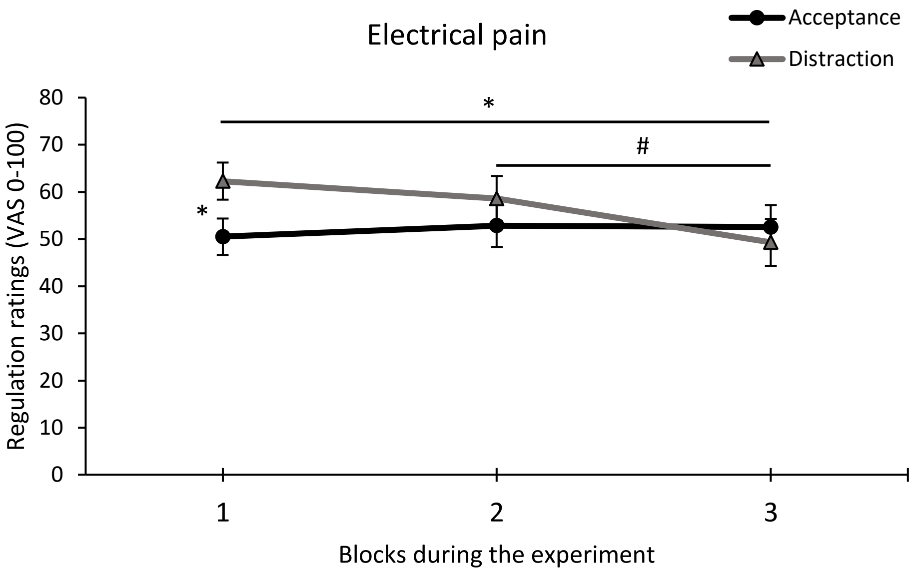


Note. Mean z-standardized difference scores of the strategy condition (control – strategy) and SEMs of electrical pain trials per pain rating dimension.

3.3.2.4. Regulation ratings

Analysis of regulation ratings of the electrical pain trials showed no main effect of the within-factor *strategy* (Acceptance: $M = 51.95$, $SD = 22.54$; Distraction: $M = 56.72$, $SD = 24.03$), $F(1, 35) = 1.82$, $p = .186$, $\eta_p^2 = .049$, and no main effect of the within-factor *block*, $F(1.63, 57.00) = 2.02$, $p = .150$, $\eta_p^2 = .055$. However, there was a significant interaction between the within-factors *strategy* and *block*, $F(2, 70) = 4.65$, $p = .013$, $\eta_p^2 = .117$. Post-hoc pairwise t-tests with Bonferroni-adjusted p-values (9 tests) revealed a significant difference for distraction between blocks 1 ($M = 62.28$, $SD = 23.70$) and block 3 ($M = 49.31$, $SD = 29.93$), $t(35) = 3.31$, $p = .020$, $d = 0.55$, and a close to significant difference between block 2 ($M = 58.58$, $SD = 28.71$) and block 3, $t(35) = 2.81$, $p = .073$, $d = 0.47$. Furthermore, there was a significant difference between acceptance ($M = 50.50$, $SD = 23.07$) and distraction after the first block, $t(35) = -2.97$, $p = .048$, $d = 0.50$. The remaining comparisons did not reach significance, all *p*s = 1. Figure 3.15 shows the decline of the regulation ratings of distraction over the time course of the experiment, while acceptance does not change over time.

Figure 3.15. Study 2: Electrical pain regulation ratings over time.

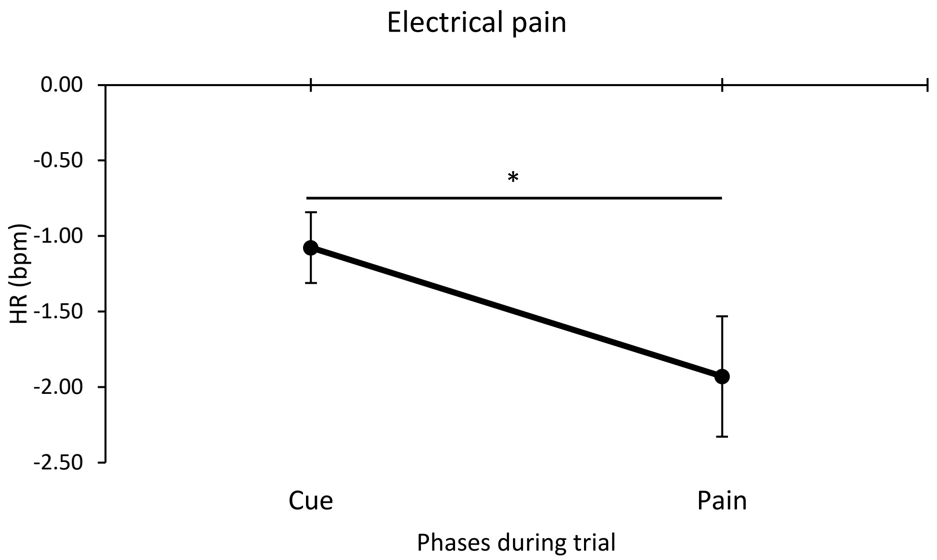


Note. Mean regulation ratings and SEMs of electrical pain trials per strategy condition over the time course of the experiment (blocks), #$p < .10$, *$p < .05$.

3.3.2.5. Heart rate (HR)

Analysis of HR during the electrical pain trials revealed no significant main effect of the within-factor *strategy*, $F(1.70, 59.47) = 0.65$, $p = .523$, $\eta_p^2 = .018$. However, analysis yielded a significant main effect of the within-factor *phase*, $F(1, 35) = 7.12$, $p = .011$, $\eta_p^2 = .169$, indicating a declaration of heart rate from the cue phase ($M = -1.08$, $SD = 1.40$) to the pain phase ($M = -1.93$, $SD = 2.39$) (see Figure 3.16). There was no significant interaction between the within-factors strategy and *phase*, $p = .418$.

Figure 3.16. Study 2: HR over the course of the electrical pain trial.

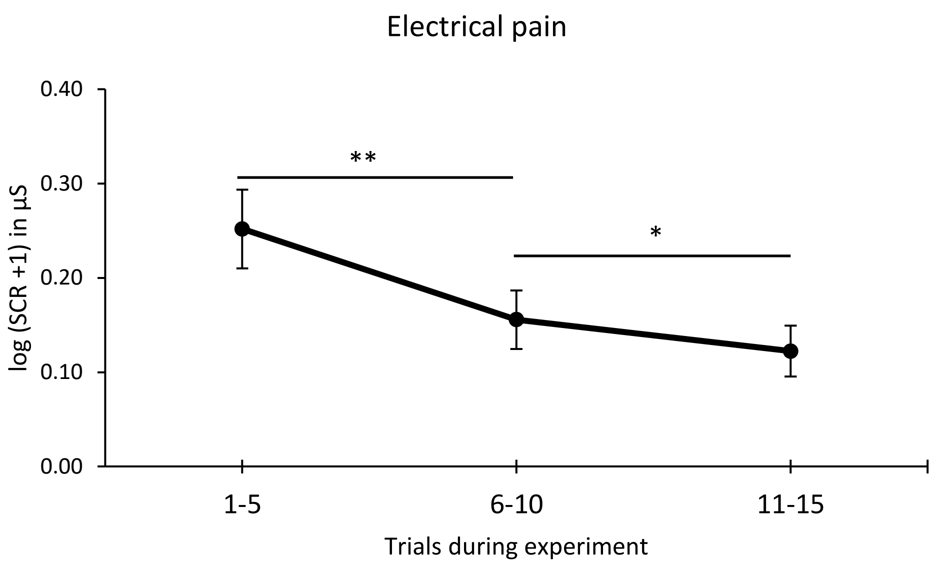


Note. Mean baseline-corrected (seconds -1 – 0) heart rate and SEMs of electrical pain trials over the time course of the trial (phases), $*p < .05$.

3.3.2.6. Skin conductance response (SCR)

Analysis of the skin conductance response (SCR) during the electrical pain trials showed no significant main effect of the within-factor *strategy*, $F(2, 62) = 0.80$, $p = .453$, $\eta_p^2 = .025$. However, there was a significant main effect of the within-factor *trials*, $F(1.27, 39.33) = 17.04$, $p = .453$, $\eta_p^2 = .025$. Repeated contrasts with Bonferroni-adjusted p-values (2 tests) revealed significant differences between trials 1-5 ($M = 0.25$, $SD = 0.24$) and trials 6-10 ($M = 0.16$, $SD = 0.18$), $F(1, 31) = 11.15$, $p = .004$, $\eta_p^2 = .265$, and trials 6-10 and trials 11-15 ($M = 0.12$, $SD = 0.15$), $F(1, 31) = 7.55$, $p = .020$, $\eta_p^2 = .196$. Figure 3.17 shows the decrease of SCRs over the time course of the experiment. Analysis yielded no significant interaction between the within-factors *strategy* and *trials*, $F(2.73, 81.94) = 0.72$, $p = .577$, $\eta_p^2 = .024$.

Figure 3.17. Study 2: SCR of electrical pain time.

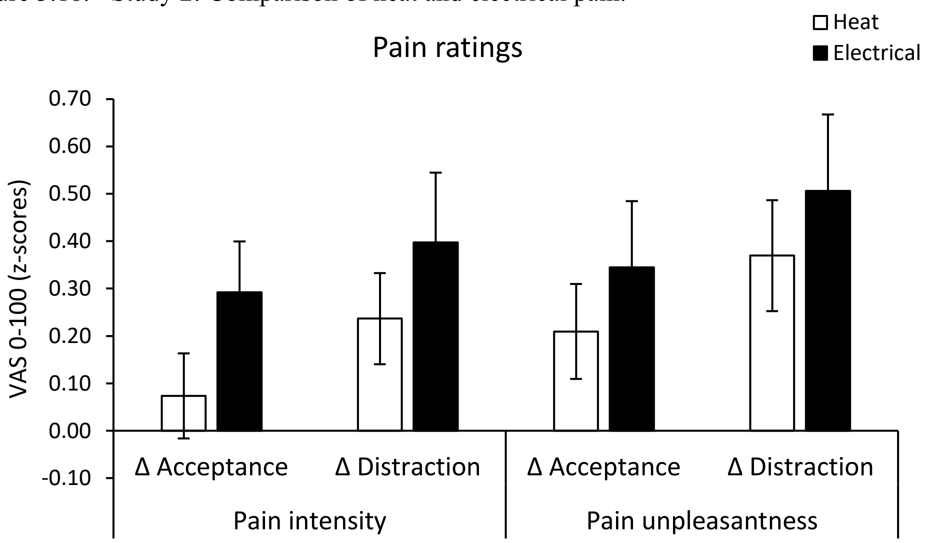


Note. Mean skin conductance response (SCR) and SEMs of electrical pain trials over the time course of the experiment (trials), **p* < .05, ***p* < .01.

3.3.3. Heat vs. electrical pain trials

Comparison of pain modalities (heat vs. electrical) with z-standardized difference scores (control – strategy) for both strategy conditions with Bonferroni-adjusted p-values (4 tests) showed no significant differences between heat and electrical pain trials neither for pain intensity nor pain unpleasantness, all *p*s > .334. Figure 3.18 shows the difference scores of the strategy condition per pain rating dimension and per heat and electrical pain.

Figure 3.18. Study 2: Comparison of heat and electrical pain.



Note. Mean z-standardized difference scores of the strategy condition (control – strategy) and SEMs of heat and electrical pain trials per pain modality (heat vs. electrical) and pain rating dimension.

3.3.4. Correlation analyses

3.3.4.1. Heat pain trials

Correlation analyses of heat *pain intensity* and *pain unpleasantness* difference scores (control condition – strategy condition) revealed one significant negative relationship with the ERQ expressive suppression subscale and the pain unpleasantness difference score of acceptance. Moreover, there were close to significant negative correlations between the pain unpleasantness difference score for acceptance and the AAQ-II total score and the ASQ suppression subscale, and a positive association with the LOT-R optimism subscale. These correlations indicate that less habitual use of suppression and, descriptively, more trait optimism and psychological flexibility led to better regulatory outcomes for acceptance on the affective pain dimension. There was further a close to significant and positive relationship between the pain unpleasantness difference score of distraction and the ASP conscious interactions subscale, implying that a more self-indicated conscious interaction led to tendentially a better regulatory outcome for distraction on the affective pain dimension. Table 3.7 shows the Pearson's coefficients with p-values and number of subjects from the pain intensity and unpleasantness analyses.

Table 3.7. Study 2: Correlation analyses of pain ratings and questionnaires (heat).

	Pain intensity difference scores (heat)				Pain unpleasantness difference scores (heat)				
	Acceptance		Distraction		Acceptance		Distraction		
Questionnaires	*r*	*p*	*r*	*p*	*r*	*p*	*r*	*p*	*N*
AAQ-II									
Total	-.005	.978	.067	.705	-.316	.068#	-.198	.261	34
ASP									
Conscious interactions	-.134	.451	.171	.334	.154	.384	.288	.099#	34
Religious orientation	.091	.610	.117	.508	-.119	.501	-.034	.848	34
Search for Insight / Wisdom	.114	.521	-.082	.643	.103	.561	-.056	.755	34
Transcendence conviction	.082	.644	.027	.878	.043	.808	.045	.803	34
ASQ									
Suppression / concealing	-.110	.542	.098	.589	-.299	.091#	-.033	.855	33
Adjusting / reappraisal	-.176	.320	.114	.522	-.182	.302	.129	.466	34
Tolerating / accepting	.062	.726	.074	.676	.195	.269	.197	.265	34
ERQ									
Cognitive reappraisal	.025	.888	.008	.967	-.008	.967	-.169	.347	33
Expressive suppression	-.193	.274	.015	.935	**-.398**	**.020***	-.127	.474	34
LOT-R									
Pessimism	.030	.864	.021	.905	-.269	.125	-.099	.579	34
Optimism	-.050	.777	-.006	.974	.320	.065#	.106	.549	34
RS-11									
Total	.047	.794	.065	.716	.216	.219	.273	.118	34

Note. Pearson's r (*r*) with p-values (*p*) and number of subjects (*N*) from two-tailed Pearson correlation analyses of pain intensity and pain unpleasantness difference scores (control – strategy) of heat pain trials with ER and resilience questionnaire scores. Significant correlations are marked in bold, $^{\#}p < .10$, $^{*}p < .05$.

3.3.4.2. Electrical pain trials

Correlation analyses of electrical *pain intensity* and *pain unpleasantness* difference scores (control condition – strategy condition) revealed significant positive associations of the pain intensity and unpleasantness of acceptance difference scores with the LOT-R optimism subscale. Furthermore, there was a negative correlation for the pain unpleasantness difference score of acceptance with the LOT-R pessimism subscale. These correlations suggest that less trait pessimism resulted in better regulatory outcomes for acceptance on the sensory and affective pain dimension. Trait optimism also led to a better affective pain regulation for acceptance. Moreover, there was a close to significant negative correlation between the pain unpleasantness difference score of acceptance with the AAQ-II total score, implying a slightly better regulatory outcome with more psychological flexibility. There was further a close to significant and positive relationship between the pain unpleasantness difference score of distraction and the ASP conscious interactions subscale, indicating a descriptively better regulatory outcome for distraction on the affective pain dimension with more self-administered conscious interaction. Table 3.8 shows the Pearson's coefficients with p-values and number of subjects from the pain intensity and unpleasantness analyses.

Table 3.8. Study 2: Correlation analyses of pain ratings and questionnaire (electrical).

	Pain intensity difference scores (electrical)				Pain unpleasantness difference scores (electrical)				
	Acceptance		Distraction		Acceptance		Distraction		
Questionnaires	*r*	*p*	*r*	*p*	*r*	*p*	*r*	*p*	*N*
AAQ-II									
Total	-.226	.184	-.044	.798	-.314	.062#	-.139	.417	36
ASP									
Conscious interactions	.039	.819	.189	.269	.102	.553	.311	.065#	36
Religious orientation	-.018	.919	.067	.698	-.009	.960	.080	.642	36
Search for Insight / Wisdom	.009	.957	.169	.324	-.061	.726	.101	.558	36
Transcendence conviction	-.007	.967	.068	.693	.058	.737	.152	.376	36
ASQ									
Suppression / concealing	.013	.942	-.146	.403	-.119	.495	-.170	.328	35
Adjusting / reappraisal	-.266	.117	-.265	.118	-.204	.232	-.099	.564	36
Tolerating / accepting	.088	.608	.197	.250	.106	.540	.241	.156	36
ERQ									
Cognitive reappraisal	.223	.197	.264	.125	.080	.648	.174	.319	35
Expressive suppression	-.042	.808	-.221	.195	-.151	.380	-.188	.271	36
LOT-R									
Pessimism	-.278	.100	-.208	.222	**-.343**	**.041***	-.238	.162	36
Optimism	**.382**	**.021***	.182	.288	**.439**	**.007****	.196	.251	36
RS-11									
Total	.209	.222	.139	.418	.227	.184	.196	.253	36

Note. Pearson's r (*r*) with p-values (*p*) and number of subjects (*N*) from two-tailed Pearson correlation analyses of pain intensity and pain unpleasantness difference scores (control – strategy) of electrical pain trials with ER and resilience questionnaire scores. Significant correlations are marked in bold, # < .10, **p* < .05, ***p* < .01.

3.4. Discussion

In the second study of this dissertation project, we expanded the within-subjects design of the first study by introducing another regulation strategy, namely distraction. Moreover, we added another pain modality so that participants received brief heat pain and phasic electrical pain. Participants were instructed to distract themselves (*distraction condition*), accept (*acceptance condition*), or not regulate (*control condition*) their pain experience. As in the first study, we assessed the participant's pain experience via pain ratings (intensity and unpleasantness), their perceived regulation via regulation ratings, and recorded autonomic measures continuously (HR and SC). Again, data of the participants' ER styles, optimism and pessimism, psychological resilience, and religious and spiritual coping was collected.

3.4.1. Less electrical pain perception during distraction and acceptance

Regarding the pain ratings, we hypothesized that distraction and acceptance would reduce the self-reported pain intensity and unpleasantness compared to the control condition. For ***heat pain*** trials, we expected both strategies to be equally effective compared to the control condition. Contrary to our expectations and our previous study, there were no significant differences in pain intensity ratings between conditions. Heat pain intensity only declined over the time course of the experiment for all conditions equally, probably indicating habituation to the sensory component of the heat pain. However, distraction significantly reduced the heat pain unpleasantness compared to the control condition, while acceptance did not differ from both conditions.

The result concerning acceptance is surprising, considering the significant reduction in pain ratings in our first study. The high standard deviations implicate a relatively high distribution of the pain ratings, assuming different levels of pain regulation success. However, study 1 also revealed high standard deviations for ratings. In this dissertation project, we excluded participants from the analysis with a standard deviation above 3. Possibly, a stricter exclusion criterion regarding outliers might provide a solution. Moreover, more extensive strategy training could lower this variance in future research.

As we did not find any time effects in study 1, we concluded that acceptance was equally effective throughout the entire experiment. Therefore, we assumed that similar effects would occur with fewer trials in the current study. Thus, one of the main methodological differences and limitations in this study is that there were only six heat pain trials per condition, while the first study contained twelve. However, a too small number of trials can impact the statistical power considerably (Forrester, 2015). Notably, effect sizes turned out smaller in this study than in study 1, even though we included a big enough sample to detect at least medium effect sizes (see 3.2.1). Analysis of the within-factor strategy in study 1 yielded very large effect sizes of $\eta_p^2 = .278$ and $\eta_p^2 = .520$, while the current study showed small to medium effect sizes (Aron et al., 2013; Lenhard & Lenhard, 2016) of $\eta_p^2 = .054$ and $\eta_p^2 = .111$ for pain intensity and unpleasantness, respectively. Thus, the statistical power loss and lack of findings might have been due to the small number of trials. Future studies should consider calculating the optimal combination of number of trials and sample size a priori (Forrester, 2015).

Distraction only reduced the heat pain unpleasantness significantly compared to the control condition. One explanation might be that the distraction task was cognitively not demanding enough to catch the participants' attention to affect the sensory component of the pain experience (Birnie et al., 2017). Interestingly, distraction decreased the affective component more profoundly, even though neutral distraction should target the sensory experience instead. However, theoretically, distraction should prevent the affective information from being encoded (Sheppes & Meiran, 2007), which could have been the case here.

Moreover, it could be argued that switching between three different conditions might have been confusing and effortful for the participants, which might have led to a loss in effectiveness for both strategies. According to the multiple resource theory (Birnie et al., 2017; Van Ryckeghem et al., 2017), distraction might lose effectivity when the pain stimulus is too intense or cognitive resources are limited. The average pain intensities were moderate (44.17°C) and perceived as moderate in the control conditions (VAS 0-100: $M = 35.12$), so it is unlikely that the heat pain was too intense. However, switching between conditions might have been cognitively too demanding, which could have impeded the implementation of both strategies and led to a partial loss in effectiveness. Therefore, future studies might use a mixed within-between-subjects design to prevent too much cognitive demand without forgoing the advantages of a within-subjects design.

Regarding the heat pain regulation ratings, we expected the participants to perceive an improvement in their pain regulation and a decline in their pain experience with acceptance over the time course of the experiment. Unexpectedly, we did not find any significant differences between the strategies for the regulation ratings and no time effects for the pain and regulation ratings. However, we found a tendency that participants felt like they could regulate somewhat better with distraction than acceptance. A greater familiarity with distraction could explain this tendency. In line with this assumption are the regulation ratings for distraction that did not change over time.

For ***electrical pain***, we expected distraction to be more effective than acceptance and both strategies to be more effective than the control condition. However, the significant interaction with time revealed that acceptance and distraction significantly decreased the electrical pain intensity and unpleasantness compared to the control condition in the middle (trials 6-10 out of 15) of the experiment only. Contrary to our hypothesis, distraction was not more effective than acceptance. This result questions the allocation of the strategies in the process model by Gross (1998b) by indicating a similar timing for distraction and acceptance. Thus, acceptance might be initiated earlier in the emotion-generative process than previously assumed. Descriptively, pain intensity and unpleasantness of electrical stimuli seemed to have increased in the control condition over time but decreased during the strategy conditions. Perhaps, these results indicate a training effect over time for both strategies, reflected by the increased effectiveness from the beginning to the middle of the experiment. At the end of the experiment, the pain ratings during the control condition tended to decrease, which could indicate a habituation to the

electrical stimulus.
Contrary to our assumption, we found a significant decline in ***regulation ratings*** over the time course of the experiment for distraction only. This finding suggests that the participants indicated that they regulated worse over time with distraction but not acceptance. However, the estimated regulatory success of acceptance remained at a moderate level ($M = 51.95$) throughout the whole experiment, similar to study 1.

We expected a stronger reduction for pain unpleasantness than intensity ratings. Therefore, we compared z-standardized difference scores of both pain modalities. Contrary to our hypothesis, we could not find more robust reductions for the pain unpleasantness than intensity for acceptance. This result is not in line with our first study, where participants succeeded more in downregulating the pain unpleasantness than the pain intensity with acceptance. Acceptance seems to have affected both pain dimensions equally, which raises the question of whether acceptance targets the sensory or affective component of pain or both. For distraction, we did not expect any differences, which was confirmed. However, descriptively, the pain unpleasantness was more successfully reduced than pain intensity for both strategies in both pain modalities. For distraction, this indication also could confirm the assumed mechanism of not encoding affective information. These effects could become more evident with more trials and a larger sample. In this study, we limited the number of heat pain trials because of an already elaborated and rather long within-subjects design, including different conditions and pain modalities. However, future studies should include these variables in other study designs without cutbacks, such as a mixed design.

Finally, the explorative comparisons of the heat and electrical pain stimuli did not yield any differences, indicating that distraction and acceptance modulated both pain modalities equally. However, pain durations should also be varied apart from modalities to explore possible underlying mechanisms further.

3.4.2. Regulatory efforts of acceptance reflected by the skin conductance

Regarding the autonomic measures, we expected distraction to decrease autonomic measures compared to acceptance and the control condition for both pain modalities, as we did not find any differences between acceptance and the control condition in our previous study. Therefore, we included an analysis of the temporal dynamics similar to the first study for the heat pain trials. For electrical pain trials, we divided the trial into two phases for HR analyses: the cue phase consisted of the first 5.5 s before the electrical stimulus, and the pain phase started with the electrical stimulus and included another 3.5 s afterward to capture the latencies of autonomic measures (Dawson et al., 2007). For SC, analyses with SCR instead of SCL were performed to capture the first reaction to the very brief electrical stimulus.

Similar to the first study, we found an anticipatory ***HR*** (De Pascalis et al., 1995) for all conditions marked by a deceleration in HR from the cue phase to the pain phase for both heat and electrical pain stimuli. Contrary to our expectations, there were no differences between conditions, so the assumption of distraction decreasing the HR could not be confirmed. However, we could show again that acceptance did not affect the HR, at least for phasic and brief pain stimuli. We did not find any indications of a regulatory effort of acceptance as in study 1, but the question remains whether more tonic pain durations could reveal that.

For ***SCL*** during heat pain trials, we found a significant interaction between the strategy conditions and the phases of the trial timing. More specifically, we found a decrease in SC from the pain to the recovery phase during acceptance and distraction but not during the control condition. This finding indicates a probable effect of regulation reflected by the SC in later phases. Interestingly, there was a close to significant decline in SCL for acceptance compared to the control condition during the recovery phase, probably explaining the significant main effect of the strategy condition. This result also points towards a later influence of acceptance on the SC, which might be better detectable with a longer pain duration. Even though we did not expect acceptance to affect the SCL but only distraction, this finding suggests an effect of acceptance on the SC but questions the findings of the previous study. Nevertheless, it remains inconclusive whether autonomic measures can reveal regulatory efforts of distraction.

Contrary to our assumption, ***SCR***s of the electrical pain trials did not differ between conditions. We could only show a significant decrease in SCR over the time course of the experiment, possibly indicating habituation to the electrical pain stimulus. Therefore, assessing SC for phasic electrical stimuli probably was not very yielding. This is in line with Breimhorst et al. (2011) who showed that the SCR differentiated reliably between different pain intensities of mechanical and heat pain stimuli but failed for painful electrical stimulation.

3.4.3. High optimism facilitates pain regulation with acceptance

We expected that pain regulation with acceptance and distraction would be more successful for participants with more optimism. In this study, we could confirm these hypotheses partially. In the electrical pain condition, high optimistic participants regulated better their self-reported pain experience with acceptance, while there was no effect on distraction. For heat pain, there was a close to significant relationship between optimism and downregulating the pain unpleasantness with acceptance. This association between optimism and acceptance is in line with previous research.

Scheier et al. (1986) already showed a positive relationship between the acceptance of stressful events and optimism. Hinkle and Quiton (2019) argued that optimistic individuals might engage more actively with the pain stimulus, corresponding to the theoretical concept of accepting the pain and engaging in it. However, the authors found less pain inhibition with more optimism. One reason could be that they induced pain with a CPT, which could have led to a feeling of less controllability.

Basten-Günther et al. (2019) argued in their meta-analysis that a healthy, optimistic sample would shift their attention away from negative aspects, which would lead to pain inhibition, as the participants are aware of the safe, controllable, and temporally limited experimental setting. Optimistic individuals facing a threatening pain condition, on the other hand, might instead focus on their pain while expecting improvement. In turn, optimistic chronic pain patients would be more likely to use distraction or active coping strategies, such as acceptance. Basten-Günther et al. (2019) further reviewed that optimistic individuals flexibly adapt their coping styles to their circumstances (Geers et al., 2008). Interestingly, the connection between optimism and acceptance became weaker in the heat pain condition of our current study, suggesting that pain duration could have contributed to this effect. Moreover, as instructed, participants could have simply engaged more in the heat pain stimulus, which might have been more difficult for the phasic electrical stimulus. Surprisingly, higher optimists did not regulate better with distraction in our current study, indicating that distraction might not have been the appropriate strategy for optimists in this context. To further clarify the reasons, future studies should investigate the relationship between optimism and distraction in different pain regulation contexts, e.g., by varying variables such as controllability and pain duration.

Our assumption that participants with higher psychological flexibility and an accepting ER style would regulate better with acceptance did not yield a significant association. However, we found a close to significant relationship between acceptance and psychological flexibility for both pain modalities. More specifically, high psychologically flexible participants downregulated their pain unpleasantness better with acceptance. Contrary to our first study, the directions of this association were as expected and in line with the intertwined concepts of psychological flexibility and acceptance (Hayes et al., 2006). In our previous study, we assumed that the negative association resulted from participants having difficulties using acceptance and therefore switching to other regulation strategies due to being rather psychologically inflexible. When comparing the total scores of psychological inflexibility measured by the AAQ-II (Bond et al., 2011) from both studies, one might notice that, descriptively, psychological inflexibility was higher in the sample of study 1 (AAQ-II, NRS 1-7, maximum total score = 49: $M = 20.34$, $SD = 6.22$) than in this study ($M = 17.00$, $SD = 8.27$). Thus, the higher psychologically flexible sample in this study might have produced the expected association by having fewer difficulties implanting acceptance. Nevertheless, these effects of psychological flexibility and acceptance should be investigated systematically, e.g., by opposing high and low psychologically flexible groups. Another explanation of this opposite effect to the previous study might be the slightly bigger sample size. However, according to G*Power (Faul et al., 2009), this study should have also included 84 participants (see 2.4.3) for the correlation analysis, so the sample was still too small. Moreover, the statistical power of the current association is smaller ($1\text{-}\beta_{Heat} = 0.454$, $1\text{-}\beta_{Electrical} = 0.472$) than in the previous study ($1\text{-}\beta = 0.932$), making a clear conclusion difficult. A bigger sample size should clarify this ambiguity conclusively.

Interestingly, there were no associations with the ASQ subscale “tolerating/accepting”, neither in the current nor the previous study. Thus, it could be possible that the questionnaire is not sensitive enough to assess an accepting ER style. We could only reveal one significant, negative relationship between a suppressing ER style and regulatory success with acceptance for pain unpleasantness. Conceptually this finding makes sense as acceptance opposes suppression by targeting response-focused strategies and counteracting them (Hofmann & Asmundson, 2008). Furthermore, we assumed that participants with higher psychological inflexibility might be better at regulating with distraction. In contrast to our hypothesis, psychological inflexibility did not affect the regulatory success with distraction, indicating that distraction is not necessarily the strategy of choice of psychologically inflexible individuals. Another possible explanation is that our sample did not contain many participants with a distracting ER style, at whom we directed our hypothesis initially. None of the questionnaires we used contained the assessment of a distracting ER style, so future studies should include these to clarify the connection between distraction and psychological inflexibility.

We further expected highly religious or spiritual participants to be better at pain regulation with acceptance. Contrary to our first study, we found a close to significant association with conscious interaction and regulatory success with distraction but not acceptance for pain unpleasantness for both pain conditions. This finding is surprising, considering the tendential effects between acceptance and conscious interaction in our first study. Moreover, consciously interacting with the surroundings facilitated the regulation of both heat and electrical pain with distraction tendentially. This finding is contrary to Vishkin et al. (2019), who did not find an association between religiosity and emotion regulation. However, conscious interaction rather refers to spirituality than religiosity. Taking the current and the previous studies into account, spirituality could improve pain regulation with both strategies, but the effect remains relatively weak and needs further investigation. Furthermore, no indications of connections with religiosity could be found for either strategy. In this study, agnostic or atheist individuals constituted 41,7%, and spiritual or religious individuals also constituted 41,7% of the sample. Therefore, this lack of association indicates that spirituality or religiosity seem not to influence the regulation effect of acceptance in this study. However, possible associations could become more evident with a larger sample. Finally, and similar to our first study, there were no associations between acceptance and resilience, possibly again due to the healthy sample (see 2.3.4).

3.4.4. Conclusions and outlook

With the second study of the dissertation project, we introduced the regulation strategy distraction to our within-subjects design and compared it with acceptance and a neutral control condition. In addition to the heat pain, we introduced another pain modality to the design, namely electrical pain stimuli.

For the heat pain ratings, we only found a significant reduction of pain unpleasantness during the distraction condition compared to the control condition. This finding supports the assumption that distraction prevents the encoding of affective information (Sheppes & Meiran, 2007). The findings for acceptance are opposed to the findings from the first study. An explanation might be a considerable reduction of the number of trials and, therefore, in statistical power. Another consideration might be the rather complex study design, where participants were subjected to three conditions and two pain modalities. This multitude of different tasks might have been cognitively too demanding and therefore could have impeded the strategy use. Therefore, future studies should select a less demanding design to investigate more than three strategy conditions, for example, a mixed design.

For the electrical pain ratings, both acceptance and distraction decreased the pain intensity and unpleasantness compared to the control condition in the middle of the experiment only. The lack of differences between the two strategies suggests that acceptance might be initiated as early as distraction in the emotion-generative process (Gross, 1998b). However, this assumption regarding the temporal dynamics should be examined further by using different pain durations.

Interestingly, participants indicated, descriptively, better regulation with distraction than acceptance during the heat pain trials, consistent with the pain ratings. Nevertheless, they also indicated that they regulated worse with distraction over time during the electrical pain trials, contrary to the pain rating results. This timing effect could indicate an increased effort for distraction over time. Distraction and acceptance equally modulated the pain experience so that there is no indication of differences in mechanisms regarding the pain modality. However, it cannot be unraveled clearly whether the difference can be traced back to the distinct pain modalities, durations, or even number of trials. Future studies should further investigate this question by controlling the number of trials and varying pain durations and modalities.

Furthermore, we did not find any differences between conditions for the HR. Similar to the first study, we found an anticipatory HR decrease (De Pascalis et al., 1995) from the cue phase to the pain phase for both heat and electrical pain stimuli. Furthermore, SCRs of the electrical pain trials did also not differ between conditions. More interestingly, there were significant decreases in SCL during heat pain trials in the later trial phases for acceptance and distraction only, possibly reflecting less pain due to regulatory efforts of both strategies. In the last phase of the trial, the recovery phase, acceptance tended to reduce the SCL compared to the control condition, maybe pointing towards later effects of acceptance reflected by SC. These effects could probably be detected with a more prolonged pain stimulation.

Correlation analysis yielded interesting associations for the trait factor optimism. More specifically, higher optimists downregulated their self-reported pain intensity and unpleasantness more successfully with acceptance but not distraction. The effects were more pronounced for the electrical pain trials, indicating that optimists could have engaged more in the heat pain stimuli, corresponding to accepting concepts. There were further close to significant associations for psychological flexibility and conscious interaction with the regulatory success of acceptance but again not distraction. These findings suggest that optimism is a crucial trait factor supporting the use of acceptance as a pain regulation strategy. Being psychologically flexible and interacting consciously with the surrounding also seem to affect the effectiveness of acceptance. Future studies investigating acceptance should include the assessment of these factors to provide further evidence.

4. Study 3: Regulating brief and tonic heat pain: Acceptance vs. distraction vs. reappraisal

4.1. Introduction

In the first two studies of this dissertation project (see chapters 2 and 3), we compared the regulation strategy acceptance with a neutral control condition by inducing brief, short heat pain stimuli in a within-subjects design. We showed that acceptance led to reduced pain intensity and unpleasantness compared to the control condition. In the second study, we expanded the design of study 1 by adding the regulation strategy distraction and another pain modality, namely phasic electrical pain stimulation. During heat pain trials, only distraction decreased the pain unpleasantness compared to the control condition. During the electrical pain trials, acceptance and distraction equally lowered the pain intensity and unpleasantness in the middle of the experiment. We further found a decreased SCL during the heat pain trials for both strategies at the end of the trial.

One of the goals of this dissertation project (see 1.4) was to contrast acceptance with distraction and reappraisal, two already established regulation strategies that represent different time points (Sheppes & Gross, 2011) in the process model of ER (1998b) (see 1.2.1). We already introduced active, neutral distraction in study 2 and expanded the design by adding the strategy reappraisal to this project's third and last study. Reappraisal has been shown to effectively alter the pain experience, especially for temporally limited experimental pain (Adamczyk et al., 2020; Fardo et al., 2015; Lapate et al., 2012; Woo et al., 2015) compared to longer-lasting experimental pain (Denson et al., 2014; Hovasapian & Levine, 2016). In ER studies, reappraisal proved effective when the strategy was initiated early or enough time was provided for the regulation process (Sheppes & Meiran, 2007). When reappraisal was initiated late, and there was not enough time to engage in the strategy, its implementation consumed more cognitive resources and, therefore, lost effectiveness (Sheppes & Meiran, 2008; Thiruchselvam et al., 2011). However, with enough training and automation, reappraisal became less cognitively effortful and more effective in regulating pain (Denson et al., 2014; Fardo et al., 2015) and emotions (Denny & Ochsner, 2014) in the long-term. Controllability of pain was also found to be an essential factor in the regulatory success of reappraisal (Wiech et al., 2008). For this study, participants in the reappraisal group were instructed to reinterpret the perceived heat as something positive instead of painful, similarly to the instructions used by Lapate et al. (2012).

We suggested that the previous study design could have included too many conditions as within-factors, which might have been cognitively demanding and hampered strategy use. In this study, we therefore opted for a mixed design to not overwhelm the participants with too many tasks and pain stimuli. More precisely, one regulation strategy was contrasted with the control condition as a within-subjects factor. We split the participants into three groups by strategy: the acceptance group, the distraction group, and the reappraisal group, constituting the between-factor. Similar to studies 1 and 2, we assessed the pain intensity and unpleasantness ratings and regulation ratings and recorded HR and SC continuously throughout the entire experiment.

Moreover, we aimed to compare pain stimulation durations rather than pain modalities to investigate the temporal dynamics of the strategies further. More specifically, we aimed to determine whether acceptance and distraction would differ with prolonged pain stimulation. For phasic, electrical pain, the strategies did not differ in our second study. For short heat pain, the strategies did not differ from each other and the control condition. However, the SC reflected the tendency that regulation effects of acceptance might become more evident in longer pain durations. The second study contained two different pain durations and modalities, so possible differences between strategies could not be clearly attributed to the cause. Therefore, we used heat pain as the only modality in this current study and solely varied the pain duration. Thus, we adopted the short heat pain stimulus used in the previous two studies and juxtaposed a tonic, long heat pain stimulation (Lautenbacher et al., 1995) of 3 minutes as within-subjects factor.

We hypothesized that all three strategies, acceptance, distraction, and reappraisal, would decrease the self-reported pain intensity and unpleasantness compared to the control condition for short and long heat pain trials. Additionally, we expected that all strategies would modulate the pain unpleasantness more strongly than the pain intensity.

Acceptance has effectively reduced the short heat pain perception in our first study and the electrical pain unpleasantness in the second study. Distraction also effectively decreased the heat pain unpleasantness and phasic electrical pain perception in the second study. Reappraisal should also be effective given the temporally limited and controllable pain stimulus. Moreover, our study design includes early strategy initiation due to a cue announcing the strategy before the pain stimulus. However, according to the process model (Gross, 1998b), reappraisal is initiated later in the emotion-generative process than distraction and possibly also acceptance. Reappraisal should thus be cognitively more demanding and need more training and repetitions. Therefore, we expected distraction to be more effective than reappraisal in regulating short heat pain, but acceptance would not differ from the other two strategies. Furthermore, we assumed that reappraisal would lead to training effects and a decrease in self-reported pain over the time course of the experiment. In contrast, no training effects for acceptance or distraction would occur, similar to the previous two studies. Accordingly, we expected the regulation ratings for acceptance and distraction not to differ and rise for reappraisal.

Furthermore, we hypothesized that distraction might fail for a prolonged pain duration due to its relatively short-term properties (Sheppes et al., 2009), whereas reappraisal would gain effectivity due to the long-term regulatory goals. Therefore, we expected reappraisal and acceptance to be more effective than distraction in downregulating the pain unpleasantness of long heat pain. This increased effectiveness should become evident over the time course of the 3-minute trial by increasing pain unpleasantness ratings for distraction compared to acceptance and reappraisal.

Additionally, we compared the regulatory success of each strategy for short and long heat pain trials with each other. We expected that acceptance and reappraisal would regulate long heat pain more effectively than short heat pain.

Regarding the autonomic measures, we expected an anticipatory or regulatory HR deceleration (De Pascalis et al., 1995; Mohammed et al., 2021) during all conditions, similar to study 1. We further hypothesized an ongoing decelerating HR during acceptance throughout the entire short heat pain trial, becoming more evident in the long heat pain trials. Moreover, we hypothesized that the effects of pain regulation with acceptance would be visible in later phases in the SCL, similar to study 2. Again, these decreases in SCL by acceptance should become even more pronounced during the long heat pain trials compared to the control condition.
Distraction did not affect SCL or HR in our previous study, so we did not expect to find differences in autonomic measures for distraction during short heat pain compared to the control condition. For long heat pain, on the other hand, we hypothesized distraction to become cognitively more demanding over time and therefore lead to an increase in SCL and HR.
Corresponding to the hypotheses for the pain ratings, we assumed that reappraisal would lead to greater decreases in HR and SCL for short and long heat pain compared to the control condition. Moreover, we expected reappraisal to attenuate the autonomic measures more profoundly than distraction, whereas no differences should occur with acceptance.

We further expected that the trait factor optimism would facilitate regulatory success for all three strategies. We also assumed that individuals with high psychological flexibility as well as an accepting ER style would regulate better with acceptance. Distraction was not affected by the construct of psychological flexibility in the previous study, so we did not expect any associations. Participants with a reappraising ER style were expected to regulate better with their matching strategy reappraisal. Moreover, despite no associations with resilience in the first two studies, possibly due to a healthy sample, we assumed that highly resilient participants would regulate their pain more effectively with either of the three strategies. Finally, we assumed that regulation with acceptance and reappraisal would be more successful for religious or spiritual participants.

4.2. Methods

Carolin Böhm, Julia Böhne und Kevin Leonard Dätz, students from the University of Würzburg, supervised by Haspert, assisted in data collection and processing and used part of this data in their bachelor and master theses.

4.2.1. Participants

One hundred thirty participants were recruited via the local online platforms Sona Systems (Sona Systems Ltd., Tallinn, Estonia) or Wuewowas (www.wuewowas.de). Exclusion/inclusion criteria were an age between 18 and 35 years, fluent in the German language, no intake of central nervous or pain medication, or no chronic and pain-related conditions. Course credit or 15 € were granted for participation.

Optimal sample size was calculated for a fixed effects ANOVA via G*Power (Faul et al., 2009) following the study by Kohl et al. (2013) (effect size (f) = .3, 3 groups, 2 degrees of freedom, power = .8, alpha = .05). The calculation indicated an optimal total sample size of 111 participants. Thus, we aimed at recruiting 40 participants per group by taking possible drop-out into account. Participants who rated less than NRS = 1 on the pain intensity scale (NRS 0-10) on average in the control condition would have been excluded from further analyses, but no participant met this criterion. Two participants could not complete the experiment due to technical issues. Another six participants were excluded from data analysis because they used other than the assigned strategies (MCS: NRS = 9, see below) during the strategy or the control condition. One participant took pain medication 24 hours before the experiment and was therefore excluded from the analysis. No outliers (pain ratings, *SD* > 3) were identified. The final sample consisted of 121 participants (64 females). Participants were between 18 and 34 years old (*M* = 23.27, *SD* = 3.65), most of them were unmarried (97.5%), students (87.6%), right-handed (89.3%) and non-smokers (84.3%). An overview of the sociodemographic information separated per group is shown in Table 4.1. The institutional review board of the medical faculty of the University of Würzburg approved the experimental procedure.

Table 4.1. Study 3: Sociodemographic information.

	Group Acceptance n = 41 (20 female)	Group Distraction n = 38 (21 female)	Group Reappraisal n = 42 (23 female)	*p*
Age	23.76 (4.01)	23.18 (3.95)	22.88 (2.95)	.545
School degree				
Abitur	39	36	36	.681
Fachabitur	0	0	1	
Realschule	2	2	4	
First language				
German	38	36	38	.909
Other	3	2	4	
Handedness				
right	40	32	37	.103
left	1	6	5	
Smoked in the last 24 hrs	2	6	8	.125
Caffeine in the last 24 hrs	24	23	23	.871
Current pain intensity (NRS 0-9)	0.3 (0.18)	0.39 (1.28)	0.47 (1.63)	.320
Pain coping (NRS 0-9)	6.38 (1.49)	6.22 (1.32)	5.68 (1.85)	.110

Note. Frequencies of response with p-values from fisher's exact tests (for nominal data) and means with standard deviations in parentheses with p-values from one-way ANOVAs (for interval data) with the factor group.

Participants were informed about the specifics of the experiment, signed a written informed consent and filled out a questionnaire on sociodemographic information (see Appendix A and Appendix D2.2.1). Participants further completed several questionnaires on pain-related variables and constructs influencing pain processing and pain experience: the State-Trait Anxiety Inventory (STAI) (Laux et al., 1981; Spielberger et al., 1983), the Resilience Scale 11 (RS-11) (Schumacher et al., 2005; Wagnild & Young, 1993), the Life-Orientation-Test Revised (LOT-R) (Glaesmer et al., 2008; Scheier et al., 1994), the Pain Sensitivity Questionnaire (PSQ) (Ruscheweyh et al., 2009), the Pain Catastrophizing Scale (PCS) (Meyer et al., 2008; Sullivan et al., 1995), the Fear of Pain Questionnaire-III (FPQ-III) (Baum et al., 2013; McNeil & Rainwater, 1998) and the Aspects of Spirituality (ASP) (Büssing et al., 2007). They also completed a number of questionnaires on ER: the Emotion Regulation Questionnaire (ERQ) (Abler & Kessler, 2009; Gross & John, 2003), the Affective Style Questionnaire (ASQ) (Graser et al., 2012; Hofmann & Kashdan, 2010), and the Acceptance and Action Questionnaire-II (AAQ-II) (Bond et al., 2011; Hoyer & Gloster, 2013). Mean questionnaire scores and standard deviations are shown in Table 4.2.

Table 4.2. Study 3: Mean questionnaire scores of the groups.

Questionnaires	Group Acceptance *M (SD)*	Group Distraction *M (SD)*	Group Reappraisal *M (SD)*	*p*
AAQ-II				
Total	18.57 (7.24)	17.21 (6.45)	17.69 (6.55)	.661
ASP				
Conscious interactions	74.02 (14.41)	74.73 (8.85)	72.73 (13.62)	.772
Religious orientation	33.60 (26.23)	30.99 (24.84)	25.99 (20.81)	.344
Search for Insight / Wisdom	61.59 (23.32)	**71.30**[a] (18.77)	**58.42**[a] (22.38)	**.026***
Transcendence conviction	43.14 (24.00)	43.20 (24.82)	37.05 (24.32)	.424
ASQ				
Suppression/concealing	3.13 (0.72)	3.15 (0.65)	3.09 (0.70)	.944
Adjusting/reappraisal	3.28 (0.80)	3.24 (0.62)	3.25 (0.89)	.971
Tolerating/accepting	3.83 (0.50)	3.86 (0.66)	3.67 (0.57)	.267
ERQ				
Cognitive reappraisal	4.65 (0.80)	4.75 (0.94)	4.72 (0.87)	.864
Expressive suppression	3.56 (1.28)	3.84 (1.22)	3.63 (1.16)	.568
FPQ-III				
Total	70.83 (14.39)	76.24 (12.34)	69.29 (13.72)	.057[#]
LOT-R				
Pessimism	4.68 (2.68)	4.18 (1.93)	4.69 (2.44)	.561
Optimism	8.66 (2.76)	9.00 (2.09)	8.17 (2.52)	.322
PCS				
Total	19.73 (9.00)	20.26 (5.47)	19.74 (7.88)	.940
PSQ				
Total	3.52 (1.36)	3.45 (1.51)	3.23 (1.37)	.611
RS-11				
Total	60.51 (7.20)	59.61 (5.77)	57.93 (8.24)	.255
STAI				
State	37.85 (6.07)	37.55 (7.21)	38.17 (6.66)	.918
Trait	37.32 (8.82)	35.66 (8.31)	37.55 (9.37)	.590

Note. AAQ-II = Acceptance and Action Questionnaire II, ASQ = Affective Style Questionnaire, ERQ = Emotion Regulation Questionnaire, FPQ-III = Fear of Pain Questionnaire-III, PCS = Pain Catastrophizing Scale, PSQ = Pain Sensitivity Questionnaire, RS-11 = Resilience Scale 11, STAI = State-Trait Anxiety Inventory, LOT-R = Life-Orientation-Test Revised. Mean questionnaire scores (*M*) and standard deviations (*SD*) per group. P-values from one-way ANOVAs with the factor group. Significant differences are marked in bold, group differences are marked by superscript letters, $p^{\#} < .10$, $^{*}p < .05$.

After the experiment, participants filled out a manipulation check survey (MCS), similar to studies 1 and 2. In order to check for the comprehensibility of the instructions and perceived successful implementation of the strategies, they had to indicate how clear and comprehensible the strategy and control instructions were (NRS 1-9; 1 = unclear, 9 = clear) and how well they succeeded in applying these instructions (NRS 1-9; 1 = not at all, 9 = very well). Furthermore, participants indicated whether they used anything other than the assigned strategies. For that, they had to indicate whether they tried to distract themselves from the pain stimuli (not in the distraction group), accept the pain stimuli (not in the acceptance group), tried to change the evaluation of the pain stimuli (not in the reappraisal group) or tried to suppress the pain (NRS 1-9; 1 = never, 9 = very often). They were also asked whether they used another strategy than the one they were supposed to (NRS 1-9; 1 = never, 9 = very often). There was also the opportunity to comment on the ratings or indicate further details for all these questions. Subsequently, participants answered questions via checkboxes on previous experiences with relaxation methods or training (no, yoga, meditation, mindfulness, other) and how frequent these relaxation methods were practiced in the last 8 months (never, 1-2 times a month, 3-4 times a month, 2-3 times a week, more than 3 times a week). In addition, religious and spiritual beliefs were assessed equally to studies 1 and 2. Finally, the participants could give feedback via open-ended questions on the pain stimuli or instructions, the experiment in general, and the supposed purpose. See the complete MCS in Appendix G. An overview of the MCS information separated per group is shown in Table 4.3.

Table 4.3. Study 3: MCS.

Manipulation check item	Group Acceptance	Group Distraction	Group Reappraisal	*p*
Comprehensibility of instruction (strategy) (NRS 1-9)	**7.70**[a] (1.62)	**8.55**[a,e] (0.56)	**8.24**[f] (1.14)	**.008****
Comprehensibility of instruction (control) (NRS 1-9)	**7.93**[c,d] (1.47)	**8.84**[c,e] (0.44)	**8.64**[d,f] (0.76)	**<.001*****
Success of implementation (strategy) (NRS 1-9)	**6.24**[g] (1.74)	**6.50**[h] (1.64)	**6.55**[i] (1.34)	.647
Success of implementation (control) (NRS 1-9)	**7.68**[g] (1.57)	**7.97**[h] (1.03)	**8.12**[i] (0.89)	.248
Applied distraction (NRS 1-9)	4.17 (2.60)	-	3.86 (2.67)	.620
Applied acceptance (NRS 1-9)	-	6.51 (2.40)	6.62 (1.83)	.828
Applied reappraisal (NRS 1-9)	**5.05** (2.71)	**3.49** (2.39)	-	**.010***
Applied suppression (NRS 1-9)	4.41 (2.45)	3.89 (2.53)	3.31 (2.11)	.108
Applied another strategy (NRS 1-9)	2.66 (1.94)	2.86 (2.41)	2.05 (1.58)	.176
Relaxation methods				
No	10	8	16	.214
Yoga	23	22	17	.238
Meditation	19	18	13	.234
Mindfulness	14	9	10	.491
Other	5	4	7	.736
Religious denomination				
Catholic	15	14	20	.800
Protestant	11	11	9	
Other	4	2	1	
None	11	11	12	
Believe in a higher entity				
Yes	17	12	15	.837
No	9	12	13	
Not sure	15	14	14	
Belief system				
Spiritual	7	7	4	.917
Religious	8	6	7	
Atheist	6	5	8	
Agnostic	13	13	18	
Undefined	5	6	5	
Other	2	1	0	
Importance of spirituality / religiousness in personal life (1 = not at all, 5 = very)	2.49 (1.17)	2.45 (1.27)	2.10 (1.12)	.257

Note. Means with standard deviations in parenthesis and frequencies of the manipulation check survey responses per group and p-values for group differences. Mixed model ANOVAs were calculated separately for comprehensibility and success of implementation. One-way ANOVAs with the factor group were performed for interval data and fisher's exact tests for nominal data. Exploratory post-hoc independent and pairwise t-tests were performed to identify differences. Significant differences (ps < .05) between groups and conditions are marked in bold and specified by superscript letters, *$p < .05$, **$p < .01$, ***$p < .001$.
The control condition instructions were clearer ($p = .002$) and better applicable ($p < .001$) than the strategy instructions, independent of group. Distraction instructions were clearer and more comprehensible than acceptance instructions ($p = .003$). Distraction ($p = .003$) and reappraisal ($p = .01$) were perceived as better applicable than acceptance. Participants perceived the control conditions as more applicable in the distraction ($p < .001$) and reappraisal ($p = .007$) groups compared to the acceptance group. Participants in the acceptance group applied wrongfully more reappraisal than in the distraction group.

4.2.2. Thermal Stimulation

Unlike in studies 1 and 2, where we used the 25 x 50 mm thermode, in this study, we switched to the Somedic MSA thermal stimulator with an active thermode area of 30 x 30 mm (Somedic SenseLab AB, Somedic, Sösdala, Sweden) due to availability reasons. It is therefore essential to note that the pain thresholds used in this study are not directly comparable with the ones from study 1 and 2. All pain stimuli were initiated with the software Presentation® (Version 17.2, Neurobehavioral Systems Inc., Albany, CA, USA) and controlled and presented via the Software SenseLab (Version 5.2., Somedic SenseLab AB, Sösdala, Sweden).

As in both previous studies (see 2.1.2), the method of adjustment (Horn-Hofmann & Lautenbacher, 2015) was used for pain threshold assessment. For this purpose, the thermode was attached to the left volar forearm near the wrist (position 1, see Figure 4.1) and fixed with a Velcro strap. The average threshold temperature of the three repetitions of this procedure was used as the individual pain threshold (M = 45.51°C, SD = 2.10). If the heat pain stimuli were experienced as not painful during the practice trials, the pain threshold procedure was repeated, and the practice trials restarted afterward. The pain threshold was used to adjust both short and long heat pain trials.

Two different heat pain stimuli durations were presented for all participants in all groups: short and long pain stimuli. The heat was calibrated as 1°C above the individual pain threshold for both pain durations. The short heat pain stimulation lasted for 10 s continuously, and the trial was constructed as in the two studies before (see 2.2.2 and 3.2.2.1). The long heat pain stimulation lasted for 3 minutes and consisted of pulsating contact heat. We adapted the protocol from the stimulation procedures described in Lautenbacher et al. (1995). The long heat pain stimulation was constructed as follows: First, the thermode started heating up from 10°C below the pain threshold (baseline temperature) to 1°C above the pain threshold (target temperature). Afterward, 90 heat pain pluses (30 pulses per minute, 0.5 Hz) were presented. One pulse contains a decrease, and an increase of the temperature (from 0.5°C below to 1°C above the individual pain threshold), which gives the stimulation a saw tooth shape (Lautenbacher et al., 1995) (see 4.2.4). After 90 pulses, the thermode cooled down to the baseline temperature. The maximum heating/cooling rate was 5°C/sec.

In case the heat pain stimuli were experienced as too painful during the practice trials, the instructor offered to lower the target temperature by 0.5°C for the particular pain duration. That was the case for 13 participants and only for the long heat pain trials (M = 46.45°C, SD = 2.07). One of these participants asked to lower the temperature twice so that the long heat pain trials were 1°C lower than the short heat pain trials, whereas the difference for the other 12 participants amounted to 0.5°C. The experimenter started the practice trials from the beginning after every new calibration to ensure that the pain intensity of all heat pain stimuli was painful but bearable. Mean target temperatures and standard deviations per group are shown in Table 4.4.

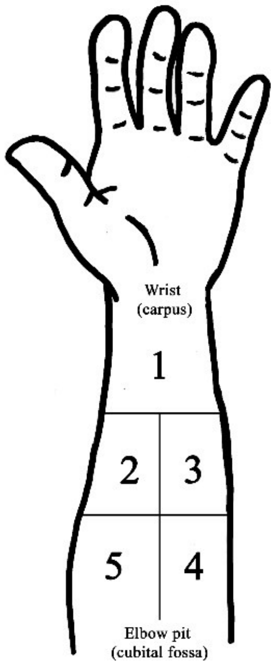
Table 4.4. Study 3: Mean target temperatures per group and pain duration.

	Group Acceptance *M (SD)*	Group Distraction *M (SD)*	Group Reappraisal *M (SD)*	*p*
Target temperature short	46.49 (2.06)	46.39 (1.96)	46.63 (2.31)	.883
Target temperature long	46.45 (2.03)	46.33 (1.91)	46.56 (2.28)	.888

Note. Mean (*M*) target temperatures with standard deviations (*SD*) and p-values per group and pain duration. P-values from one-way ANOVAs with the factor group.

The position of the thermode was changed throughout the whole experiment to avoid habituation or sensitization to the heat pain (Hollins et al., 2011; Jepma et al., 2014) and to avoid damages to the skin. After the pain threshold procedure and the first block of practice trials (position 1, left arm), the thermode was relocated to the right arm, position 1, where the practice continued with the second block. After the practice trials and during the experiment, the thermode position was changed after every 8 blocks, following the sequence (positions 2-5) illustrated in Figure 4.1. For the first block of the experiment, the thermode was attached to the forearm at position 2 and then rotated after each block clockwise so that the order of the position sequence was 2, 3, 4, and 5. Afterward, the same sequence was repeated on the other arm until the end of the experiment. The sequences started on the left or right arm, counterbalanced between participants. With this rotation procedure, a long heat pain stimulus was only once applied on a particular patch of skin. Also, the same amount of short and long heat pain stimulation was applied on both arms.

Figure 4.1. Study 3: Schematic illustration of the thermode positions.



4.2.3. Measures

4.2.3.1. Ratings

Instructions about the ratings as well as the ratings themselves were presented on a screen (resolution 1280 x 1024 pixels, background-color: RGB 132, 132, 132, font type = Arial bold, font size = 16, font color: RGB 255, 255, 255) and programmed with the software Presentation® (Version 17.2, Neurobehavioral Systems Inc., Albany, CA, USA). As in the studies before, participants learned about evaluating and distinguishing between pain intensity and pain unpleasantness using the radio metaphor by Price et al. (1983). In order to not disrupt the participants' engagement in the strategy application and to not function as a visual distraction during the long heat pain trials, we decided to use an 11-level numeric rating scale (NRS) (Braams et al., 2012; Kohl et al., 2013; Lapate et al., 2012; Masedo & Esteve, 2007) instead of the visual rating scale (VAS) we used in the first two studies. To avoid confusion with different rating scales, we used the NRS for the evaluation of both short and long heat pain trials in this study.

Participants gave ratings after each heat pain trial using the NRS for *pain intensity* and *unpleasantness* (pain ratings) during the experiment. For pain intensity, an NRS with the caption "How painful was the heat stimulus?" was presented, ranging from 0 = "not painful at all" to 10 = "extremely painful". For pain unpleasantness, an NRS with the caption "How unpleasant was the heat stimulus?" was presented, ranging from 0 = "not unpleasant at all" to 10 = "extremely unpleasant". Participants also had to rate how well they could regulate with the respective strategy after trials in the strategy condition. Furthermore, participants were asked to give *regulation ratings* after each trial. For regulation ratings, an NRS with the caption "How well did you succeed in regulating the pain with the strategy?" was presented, ranging from 0 = "not succeeded at all" to 10 = "succeeded extremely well". The captions were presented in font size 22 and the scale in font size 24 in the middle of the screen, with white letters in Arial font and a grey background. See Appendix J for an example of an NRS.

Participants were instructed to inform the experimenter about their rating when they saw the NRS on the screen. After the short heat pain trials, pain intensity, pain unpleasantness, and regulation ratings were presented successively. During long heat pain trials, the NRS for unpleasantness appeared every 30 s for 3 s on the screen right under the instruction cue, so that 6 unpleasantness ratings were gathered per each long heat pain trial. Afterward, only in the strategy condition, a regulation rating was presented. We forewent the pain intensity assessment for the long pain trials to prevent any further disruption to the participant's strategy use. We chose to assess the affective pain component over the sensory as this dimension was more affected by our manipulations in our previous studies. Moreover, we decided to use the tonic heat pain model for our long pain trials, which predominantly alters the affective component of pain (Lautenbacher et al., 1995).

The experimenter wrote down the respective rating given orally by the participant and continued with the following rating or trial, respectively. We decided to assess the temporal dynamics of the long heat pain trials with only one pain dimension as we assumed that more ratings might jeopardize the engagement in the strategy use. To this end, we opted for pain unpleasantness as we expected pain regulation via emotion regulation strategies to be reflected more in the affective than the sensory component of subjective pain. Trials were excluded from analyses in case the thermode did not heat up.

4.2.3.2. Psychophysiology

Electrodes for the measurement of both the electrocardiography (ECG) and the skin conductance (SC) were attached, recorded continuously with the Brain Vision Recorder, V-Amp Edition 1.10 (Brain Products Inc, Munich, Germany) and processed with the Brain Vision Analyzer software (BrainProducts, Munich, Germany) precisely the same way as in the studies before (see 2.2.3.2 and 3.2.3.2). Short heat pain trials were averaged into three content-related phases to analyze temporal dynamics: cue (seconds 0-7), pain (seconds 7-17), and recovery of pain (seconds 17-25). Broad time intervals were analyzed to capture potentially delayed psychophysiological reactions to the heat pain stimulation (Loggia et al., 2011). To analyze the temporal dynamics of the long heat pain trials, averaged values of 30-s time windows were exported (starting at second 7.5 after cue onset), so that six time points could be analyzed over the 3-minute time course of the trial. Trials were excluded from analyses if the thermode did not heat up. One participant was excluded from HR analyses due to a corrupted ECG signal and one outlier ($SD > 3$) for each short and long heat pain analysis, respectively ($N_{HR} = 119$). Three participants were excluded from skin conductance analysis of short heat pain trials due to corrupted skin conductance signals, and another five participants were defined as outliers ($SD > 3$) ($N_{SCL\_short} = 113$). Three participants were excluded from SCL analyses of long heat pain trials due to corrupted SC signals and one outlier ($SD > 3$) ($N_{SCL\_long} = 117$).

4.2.4. Instructions

Participants received all instructions on a computer screen with a resolution of 1280 x 1024 pixels, presented on a grey background (background-color: RGB 132, 132, 132) with white letters (font type = Arial bold, font size = 16, font color: RGB 255, 255, 255). The instructions for the control condition were the same for all 3 groups and the same as in studies 1 and 2 (see 2.2.4 and 3.2.4). The strategy instructions varied between groups. Participants received the same instructions for acceptance in the acceptance group as in studies 1 and 2 (see 2.2.4 and 3.2.4), and participants in the distraction group received the same instructions for distraction as in study 2 (see 3.2.4). In the reappraisal group, participants were asked to apply the assigned strategy reappraisal as follows:

> "When the word REAPPRAISE appears on the screen, you should try to reappraise any feelings, sensations, and behavioral reactions to the pain. To do this, you should imagine the pain being good for you and having a positive effect. In doing so, you select an imagination with which you can identify the best and in which you can put yourself the best. Here are some examples:

Select a reappraisal strategy you can easily imagine and maintain the image throughout the whole experiment:

a. I have a soothing hot-water bottle lying on my arm.
b. I am warming myself with a cherry pit pillow.
c. I am warming myself with a hot beverage.
d. I am sitting in a bathtub with hot water.
e. I am working out and getting very warm.
f. Own suggestion

Can you imagine that the heat could have a positive outcome? Please let the experimenter know now which reappraisal strategy you have chosen."

Independent of the assigned group, participants then received a summary of instructions on the screen (the word in square brackets depended on the group):

"SUMMARY:
In summary, this means:
The [ACCEPT/IMAGINE/REAPPRAISE] instruction is the previously described strategy you should apply when the word appears on the screen. You should not use a strategy when the PERCEIVE instruction appears."

See Table 4.5 for the frequencies of the imaginations selected for distraction and reappraisal. Own suggestions were, e.g., "walking home from here", "walking to the bank", or "walking my daughter to school". The experimenter reassured that the participants had no further questions. If there were any difficulties in comprehension, participants could read the instructions once again.

Table 4.5. Study 3: Frequencies of selected imaginations for acceptance and distraction.

Imagination	Frequency
Distraction (*n* = 38)	
Work / university	19
Supermarket / bakery	12
Market place	0
Town hall	1
Central station	2
Own suggestion	4
Reappraisal (*n* = 42)	
Hot-water bottle	16
Cherry pit pillow	5
Hot beverage	8
Bathtub with hot water	5
Workout	4
Own suggestion	4

The visual instruction cues were image files created with Microsoft PowerPoint (Microsoft Corporation, Redmond, USA) with the same properties as study 1 (see 2.2.4). The cue word describing the respective condition (ACCEPT, IMAGINE, REAPPRAISE or PERCEIVE) was centered and in capital, bold letters (font color black, font type Calibri, and font size 96).

The NRS appeared for 3 s every 30 s for the long heat pain stimuli while the instruction cue remained on the screen. The NRS was technically implemented by replacing the instruction cue with the same image file except containing the NRS for unpleasantness ratings. With this method, participants had the impression that the instruction cue did not change, but only the NRS faded in and out on the screen. The NRS was added below the cue word (font color black, font type Calibri, font sizes 22-24). The position of the NRS caption was 6.45 cm horizontal and 13.73 cm vertical, the position of the scale was 3.5 cm horizontal and 15.96 cm vertical, and the positions of the two anchors were 17.53 cm vertical and 0 cm (left) or 18.14 cm (right) horizontal.

4.2.5. Procedure

Participants sat down in front of the monitor and signed the written informed consent. Afterward, they filled out the questionnaire on sociodemographic information and the RS-11. Then, the experimenter briefly explained the following procedures and began with the pain threshold procedure with standardized instructions presented on the screen. The pain threshold procedure, the practice trials, and the experimental procedure were controlled using the software Presentation® (Version 17.2, Neurobehavioral Systems Inc., Albany, CA, USA). After assessing the individual pain threshold, the experimenter turned off the monitor, took down the thermode, and asked the participants to wash their hands without soap. As soon as the participants returned, the experimenter attached the ECG and SC electrodes and placed the thermode on the left arm near the wrist. Participants should read the instructions on the screen carefully and continue with the space bar. Standardized instructions included the radio metaphor, examples of the NRS, and instructions regarding the two conditions followed on the screen. Next, participants selected one specific strategy (imagination, see Table 4.5) from a list in the distraction and reappraisal group and informed the experimenter. If there were no further questions, the practice trials followed. Practice trials consisted of one long heat pain stimulus in the strategy condition, one block of four short heat pain trials, two strategies, and two control trials. Order of practice trials (long/short, control/strategy) was counterbalanced across participants. After the practice trials, the experimenter ensured that participants had no further questions regarding the experimental procedure. Then, the experimenter turned off the monitor, removed the thermode, and participants filled out the STAI State questionnaire. After that, the experimenter placed the thermode back on the respective thermode position, turned on the monitor, and started the psychophysiology recordings. Participants were instructed to address the experimenter if there were any questions about the NRS or the instructions about the conditions. It was also pointed out that they could terminate the experiment at any time. Participants could then start the experiment by pressing the space bar.

Every trial started with the presentation of the instruction cue (*cue onset, second 0*) on the screen corresponding to the assigned condition. The instruction cue remained on the screen until after the heat pain stimulation (*cue offset: second 20 / 190 for short / long, respectively*). Five s after cue onset, the thermode started heating up from the baseline temperature and reached the target temperature after 2.2 s (*pain onset, second 7.2*). Then, either the short (10 s) or long (180 s) heat pain stimulation was delivered, and the thermode started cooling down (*pain offset, second 17.2 / 187.2 for short / long, respectively*) to the baseline temperature in 2.2 s. After the cue offset, a fixation cross was presented in the middle of the screen for 5 s. Subsequently, the respective NRS for pain intensity, unpleasantness, and regulation ratings appeared on the screen where appropriate (see 4.2.3.1). See Figure 4.2 and Figure 4.2 for schematic illustrations of both heat pain trials. The interstimulus interval (ITI) was randomly set between 10 to 12 s to avoid anticipation effects and ensure enough time to recover from pain.

Figure 4.2. Study 3: Schematic illustration of a short heat pain trial (10 s).

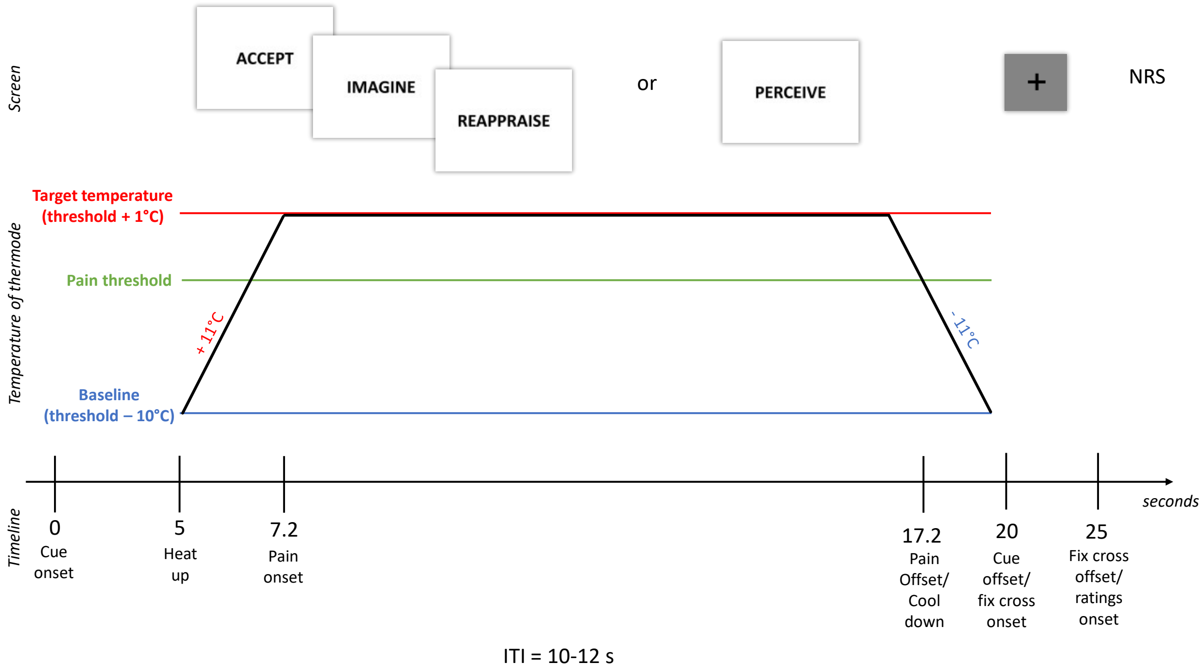
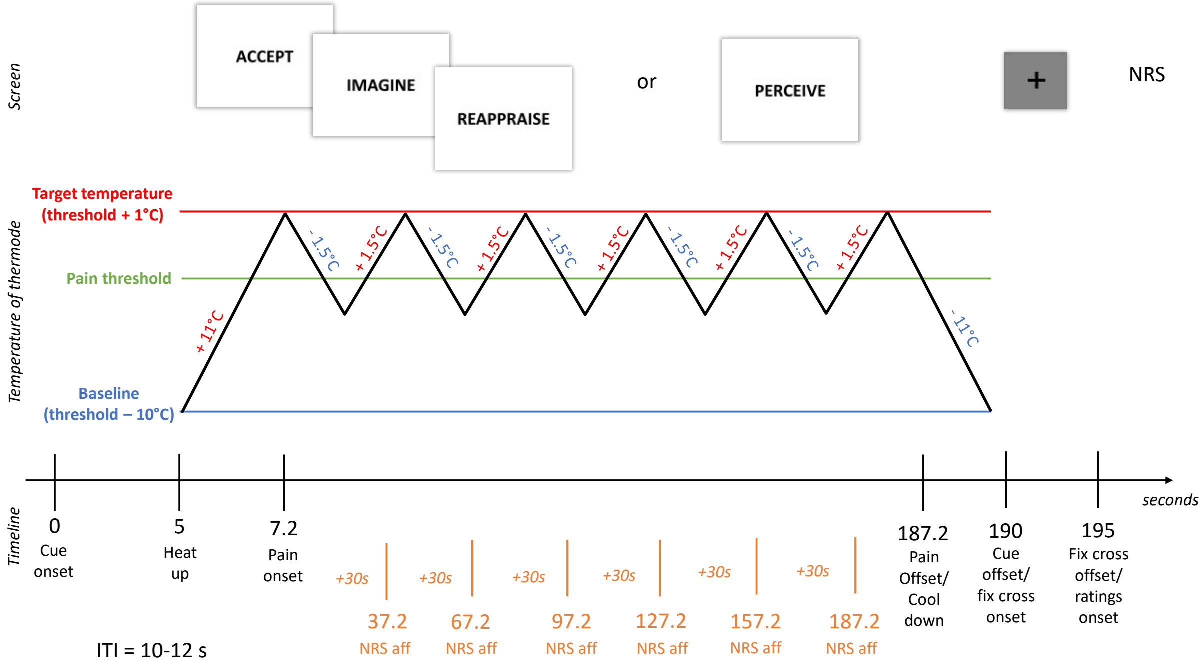


Figure 4.3. Study 3: Schematic illustration of a long heat pain trial (3 min).



The experiment consisted of several blocks of short and long heat pain trials. One block comprised six short heat pain stimuli or one long heat pain stimulus. Whether the experiment started with a short or long block or a strategy or control condition was counterbalanced across participants. No condition was presented twice or more in a row. A short block always followed a long block and the other way around. The whole experiment consisted of four short and four long blocks – thus 24 short trials and four long trials in total –and took about 30 minutes to complete. After the experiment, participants filled out the remaining questionnaires (STAI Trait, LOT-R, PSQ, FPQ-III, ASP, ERQ, ASQ, AAQ-II) and the MCS.

4.2.6. Statistical Analysis

IBM SPSS Statistics Version 25 (IBM Corp. Released 2017. IBM SPSS Statistics for Windows, Version 25.0. Armonk, NY: IBM Corp.) was used for all statistical analyses. The significance level was defined as $p < .05$.

Analyses of short heat pain trials were performed as follows: Pain ratings (intensity and unpleasantness) were analyzed separately with a mixed model ANOVA with the within-factor *strategy* (2 levels: control condition vs. strategy condition), the within-factor *trials* (4 levels: trials 1-3, trials 4-6, trials 7-9, trials 10-12) by averaging three consecutive trials per condition, and the between-factor *group* (3 levels: acceptance, distraction, reappraisal).

Analysis of regulation ratings was conducted with a mixed model ANOVA with the within-factor *trials* (4 levels: trials 1-3, trials 4-6, trials 7-9 and trials 10-12) and the between-factor *group* (3 levels: acceptance, distraction, reappraisal). Heart rate (HR) and skin conductance level (SCL) were analyzed separately with mixed model ANOVAs with the within-factor *strategy* (2 levels: control condition vs. strategy condition), the between-factor *group* (3 levels: acceptance, distraction, reappraisal), and the

within-factor *phase* (3 levels: cue, seconds 0-7; pain, seconds 7-17, recovery, seconds 17-25).
Analyses of long heat pain trials were conducted as follows: Pain unpleasantness ratings, heart rate (HR), and skin conductance level (SCL) were analyzed with a mixed model ANOVA with the within-factor *strategy* (2 levels: control condition vs. strategy condition), the within-factor *time* (6 levels: unpleasantness ratings at second 30, 60, 90, 120, 150,180; time windows 0-30, 30-60, 60-90, 90-120, 120-150, 150-180 for psychophysiology), and the between-factor *group* (3 levels: acceptance, distraction, reappraisal). Analysis of regulation ratings was carried out with a mixed model ANOVA with the within-factor *trials* (2 levels: regulation rating 1 and 2) and the between-factor *group* (3 levels: acceptance, distraction, reappraisal).
Pain intensity and unpleasantness ratings were z-standardized across each participant, separately for each pain rating dimension and pain duration. Difference scores were calculated from these z-standardized values by deducting the strategy condition from the control condition. Pairwise t-tests were conducted with these z-standardized difference scores, comparing intensity vs. unpleasantness ratings for the three groups. This analysis was conducted for short heat pain only. Pairwise t-tests were also conducted with these z-standardized difference scores (pain unpleasantness only), comparing short vs. long heat pain for the three groups.
Post-hoc one-way ANOVAs, t-tests, or repeated contrasts were used to compare different factor levels. Difference scores were used to follow up on significant interactions when necessary. Partial eta-squared η_p^2 for ANOVAs and Cohen's *d* (Cohen, 1988; Lakens, 2013) for t-tests were used as measures of effect size. For repeated-measures ANOVAs, the Greenhouse-Geisser correction was applied when the assumption of sphericity (Mauchly's test) was violated. P-value was Bonferroni-adjusted for multiple testing.
Pearson correlations were performed separately for each group to explore the association between difference scores (control and strategy condition) and ER questionnaire scores (ERQ, ASQ, AAQ-II) and RS-11, ASP, and LOT-R scores as potential indicators of resilience.

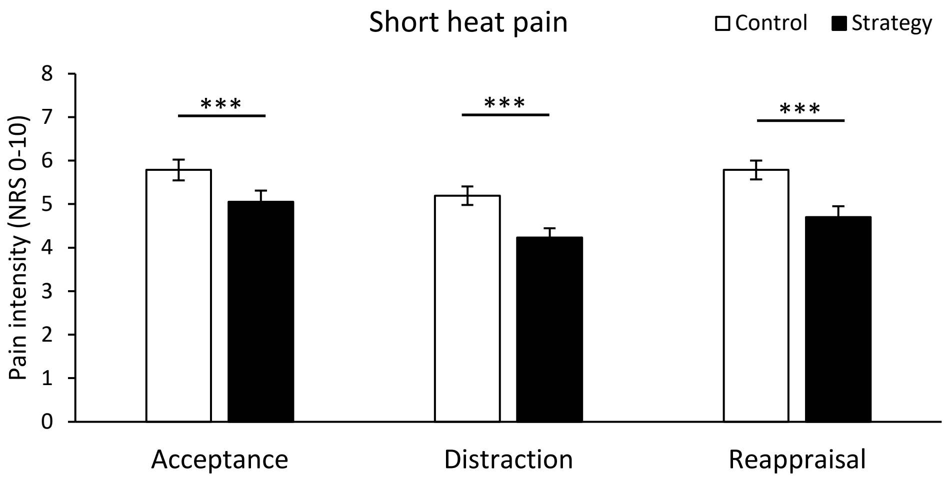
4.3. Results

4.3.1. Short heat pain trials

4.3.1.1. Pain intensity

Analysis of pain intensity ratings of the short heat pain trials revealed a significant main effect of the within-factor *strategy*, $F(1, 118) = 238.21$, $p < .001$, $\eta_p^2 = .669$, indicating higher pain intensity ratings during control trials ($M = 5.04$, $SD = 1.44$) compared to strategy trials ($M = 4.68$, $SD = 1.56$) (see Figure 4.4). There was no significant main effect of the between-factor *group*, $F(2, 118) = 2.58$, $p = .080$, $\eta_p^2 = .042$.

Figure 4.4. Study 3: Pain intensity of short heat pain.

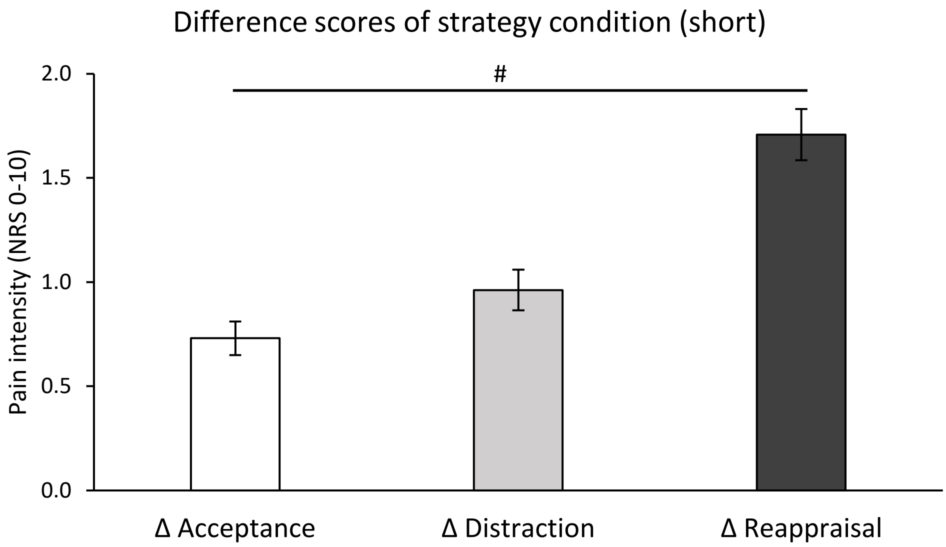


Note. Mean pain intensity ratings and SEMs of short heat pain trials per group and strategy condition, ***$p < .001$. There was no significant interaction of strategy x group.

Furthermore, there was a significant main effect of *trials*, $F(3, 354) = 7.97$, $p < .001$, $\eta_p^2 = .063$. Repeated contrasts with Bonferroni-corrected p-values (3 tests) revealed a significant difference between trials 4-6 ($M = 5.04$, $SD = 1.59$) and trials 7-9 ($M = 5.38$, $SD = 1.61$), $F(1, 118) = 12.79$, $p = .002$, $\eta_p^2 = .098$, while no differences between trials 1-3 ($M = 4.91$, $SD = 1.56$) and trials 4-6 nor trials 7-9 and 10-12 ($M = 5.23$, $SD = 1.74$) could be found, all *p*s > .42. Results indicate an increase of pain intensity over trials throughout of the experiment.

The analyses further showed a close to significant interaction of the within-factor *strategy* and the between-factor *group*, $F(2, 118) = 3.01$, $p = .053$, $\eta_p^2 = .049$. To follow up on this marginally significant interaction, the mean difference scores between the control and strategy conditions were calculated for each group. Exploratory post-hoc independent t-tests with Bonferroni-adjusted p-values (3 tests) showed a marginally significant difference between acceptance ($M = 0.73$, $SD = 0.51$) and reappraisal ($M = 1.08$, $SD = 0.80$), $t(81) = -2.36$, $p = .063$, $d = 0.22$, whereas the other analyses were not significant, all *ps* > .21. Figure 4.5 shows that the difference between the reappraisal and control condition was bigger than the difference between the acceptance and control condition.

Figure 4.5. Study 3: Pain intensity difference scores of short heat pain.

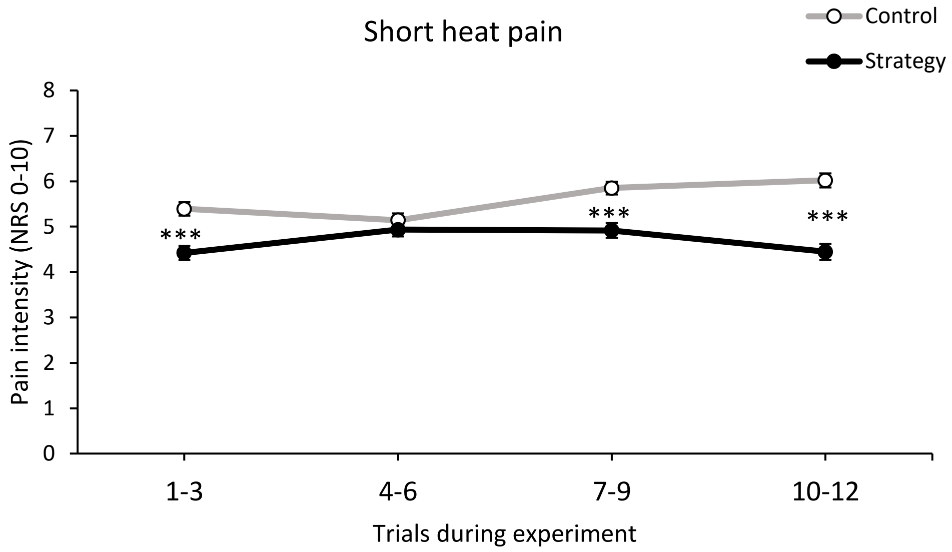


Note. Mean difference scores of the strategy condition (control – strategy) of pain intensity ratings and SEMs of short heat pain trials per group, #*p* < .07.

Additionally, there was a significant interaction between the within-factors *strategy* and *trials*, $F(2.55, 300.61) = 3.01$, $p < .001$, $\eta_p^2 = .247$. Post-hoc pairwise t-tests using Bonferroni-corrected p-values (4 tests) showed significant differences between the control and strategy condition during trials 1-3 (control: $M = 5.39$, $SD = 1.62$, strategy: $M = 4.42$, $SD = 1.72$), $t(120) = 8.94$, $p < .001$, $d = 0.81$, trials 7-9 (control: $M = 5.85$, $SD = 1.56$, strategy: $M = 4.92$, $SD = 1.80$), $t(120) = 10.50$, $p < .001$, $d = 0.96$, and trials 10-12 (control: $M = 6.02$, $SD = 1.69$, strategy: $M = 4.45$, $SD = 1.95$), $t(120) = 15.41$, $p < .001$, $d = 1.40$, but not during trials 4-6 ($p > .13$). Figure 4.6 shows an approximation of the control and strategy condition in the first half of the experiment (trials 4-6), while the gap between control and strategy condition increases in the second half of the experiment. To further clarify this strategy and trials interaction, difference scores between the control and strategy condition were calculated for each level of the factor trials. Pairwise t-tests with Bonferroni-adjusted p-values (6 tests) yielded significant differences between all trials, all *p*s < .001, except trials 1-3 ($M = 0.97$, $SD = 1.19$) and trials 7-9 ($M = 0.93$, $SD = 0.98$), $t(120) = 0.28$, $p > 1$, $d = 0.03$.

The remaining interactions (*trials* x *group*, *strategy* x *trials* x *group*) did not reach significance, all *p*s > .30.

Figure 4.6. Study 3: Pain intensity of short heat pain over time.

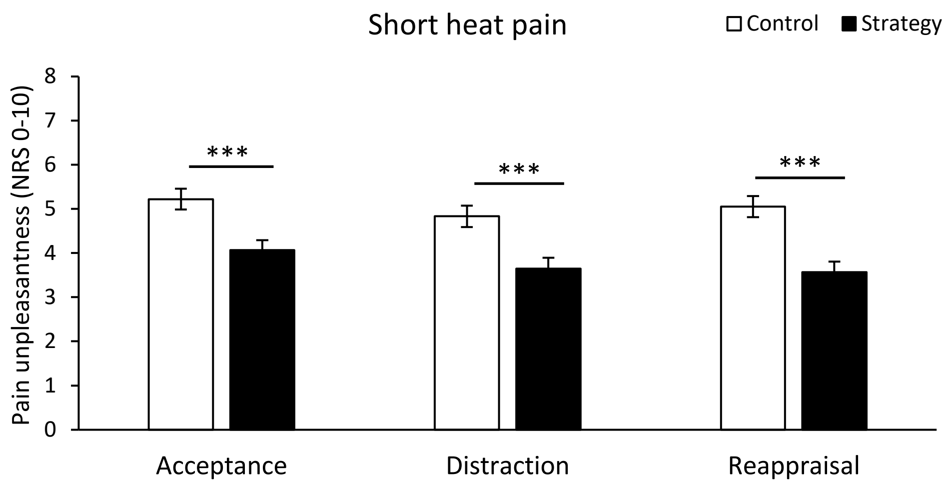


Note. Mean pain intensity ratings and SEMs of short heat pain trials per strategy condition over the time course of the experiment, ***p < .001.

4.3.1.2. Pain unpleasantness

Analysis of pain unpleasantness ratings of the short heat pain trials revealed a significant main effect of the within-factor *strategy*, $F(1, 118) = 290.30$, $p < .001$, $\eta_p^2 = .711$, indicating lower pain unpleasantness during control trials ($M = 5.04$, $SD = 1.52$) compared to strategy trials ($M = 3.76$, $SD = 1.49$) (see Figure 4.7), similar to the pain intensity analyses.

Figure 4.7. Study 3: Pain unpleasantness of short heat pain.



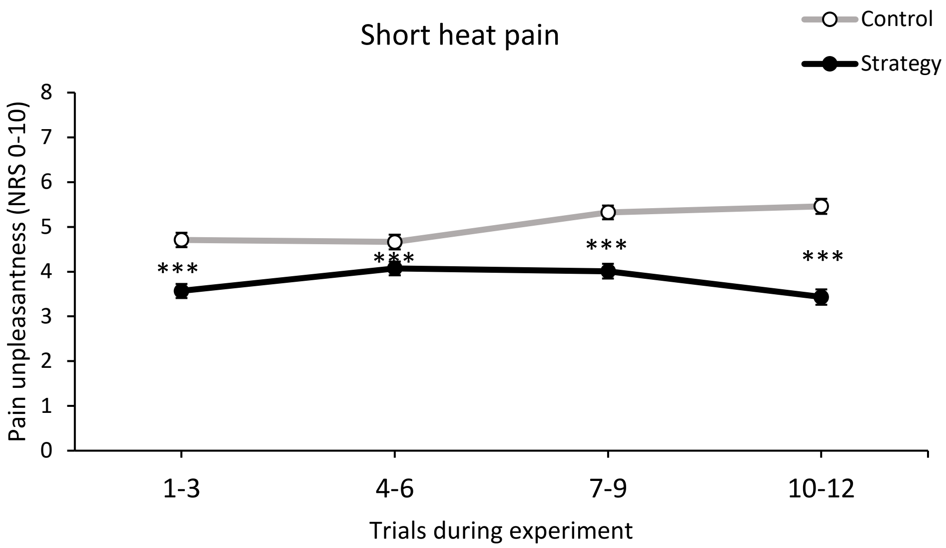
Note. Mean pain unpleasantness ratings and SEMs of short heat pain trials per strategy condition and group, ***p < .001. There was no significant interaction of strategy x group.

Furthermore, there was a significant main effect of *trials*, $F(3, 354) = 6.92$, $p < .001$, $\eta_p^2 = .055$. Repeated contrasts with Bonferroni-corrected p-values (3 tests) showed a significant difference between trials 4-6 ($M = 4.37$, $SD = 1.64$) and trials 7-9 ($M = 4.67$, $SD = 1.64$), $F(1, 118) = 9.23$, $p = .009$, $\eta_p^2 = .073$, indicating an increase of pain unpleasantness over trials in the middle of the experiment. The remaining comparisons did not reach significance, all *p*s > .14. There was no significant main effect of the between-factor *group*, $F(2, 118) = 0.86$, $p = .423$, $\eta_p^2 = .014$, and no significant interaction between the within-factor *strategy* and the between-factor *group*, $F(2, 118) = 2.25$, $p = .110$, $\eta_p^2 = .037$.

There was a significant interaction between the within-factors *strategy* and *trials*, $F(2.35, 277.45) = 30.52$, $p < .001$, $\eta_p^2 = .205$. Post-hoc pairwise t-tests with Bonferroni-adjusted p-values (4 tests) showed significant differences between the control and strategy condition during the whole experiment: trials 1-3 (control: $M = 4.71$, $SD = 1.77$, strategy: $M = 3.57$, $SD = 1.75$), $t(120) = 8.48$, $p < .001$, $d = 0.77$, trials 4-6 (control: $M = 4.66$, $SD = 1.83$, strategy: $M = 4.07$, $SD = 1.71$), $t(120) = 4.84$, $p < .001$, $d = 0.44$, trials 7-9 (control: $M = 5.33$, $SD = 1.69$, strategy: $M = 4.01$, $SD = 1.73$), $t(120) = 12.65$, $p < .001$, $d = 1.15$, and trials 10-12 (control: $M = 5.46$, $SD = 1.83$, strategy: $M = 3.43$, $SD = 1.87$), $t(120) = 17.13$, $p < .001$, $d = 1.56$. Similar to the pain intensity ratings, Figure 4.8 points towards an approximation of the control and strategy condition in the first half of the experiment (trials 4-6), while the gap between control and strategy condition increases in the second half of the experiment. To unravel the strategy and trials interaction further, difference scores between the control and strategy condition were calculated for each level of the factor trials. Pairwise t-tests with Bonferroni-adjusted p-values (6 tests) showed significant differences between all trials, all *p*s < .04, except trials 1-3 ($M = 0.97$, $SD = 1.19$) and trials 7-9 ($M = 0.93$, $SD = 0.98$), $t(120) = -1.20$, $p > 1$, $d = 0.11$.

The remaining interactions (*trials* x *group*, *strategy* x *trials* x *group*) did not reach significance, all *ps* > .11.

Figure 4.8. Study 3: Pain unpleasantness of short heat pain over time.



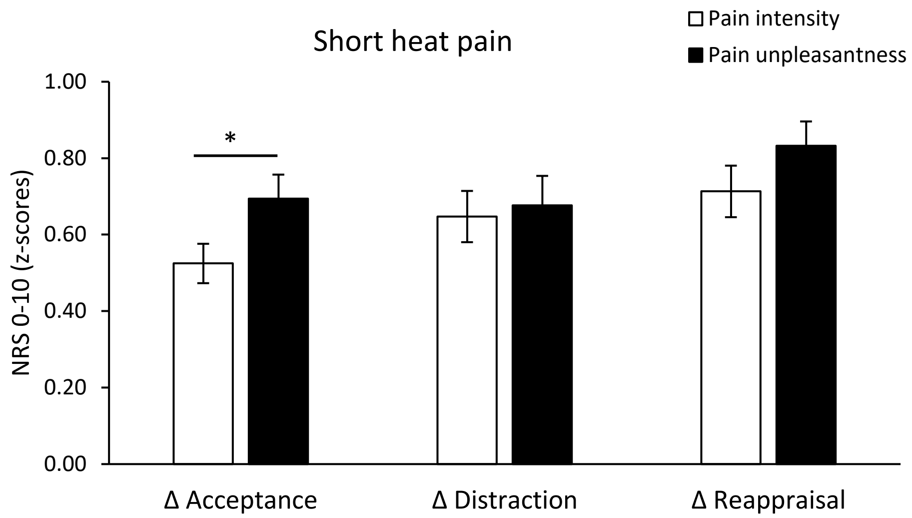
Note. Mean pain unpleasantness ratings and SEMs of short heat pain trials per strategy condition over the time course of the experiment, $^{***}p < .001$.

4.3.1.3. Pain intensity vs. pain unpleasantness

Analysis of the z-standardized difference scores (control – strategy) for each group (3 tests) revealed one significant difference between pain intensity ($M = 0.52$, $SD = 0.33$) and pain unpleasantness

(*M* = 0.69, *SD* = 0.40) for acceptance difference scores, *t*(40) = -3.11, *p* = .010, *d* = .49, while the other two comparisons did not reach significance, all *ps* > .134. Figure 4.9 shows the higher difference scores of pain unpleasantness ratings compared to pain intensity for acceptance.

Figure 4.9. Study 3: Comparison of pain intensity and unpleasantness for short heat pain.



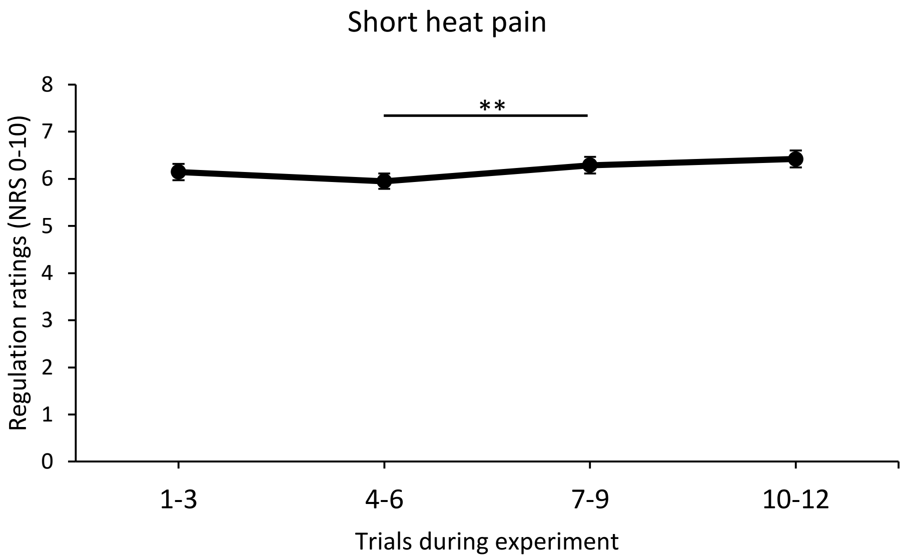
Note. Mean z-standardized difference scores of the strategy condition (control – strategy) and SEMs of short heat pain trials per pain rating dimension and group, **p* < .05.

4.3.1.4. Regulation ratings

Analysis of regulation ratings of the short heat pain trials revealed a significant main effect of the within-factor *trials*, $F(2.80, 330.27) = 6.10$, $p = .001$, $\eta_p^2 = .049$. Repeated contrasts with Bonferroni-adjusted p-values (3 tests) yielded a significant difference between trials 4-6 (*M* = 5.95, *SD* = 1.82) and trials 7-9 (*M* = 6.29, *SD* = 1.96), $F(1, 118) = 11.50$, $p = .003$, $\eta_p^2 = .089$, indicating an increase in how participants perceived their regulatory performance in the middle of the experiment (see Figure 4.10). The remaining comparisons did not reach significance, all *ps* > .38.

There was no significant main effect of the between-factor *group* nor a significant interaction between *trials* and *group*, all *ps* > .19.

Figure 4.10. Study 3: Pain regulation of short heat pain over time.



Note. Mean pain regulation ratings and SEMs of short heat pain trials over the time course of the experiment, $^{**}p < .01$

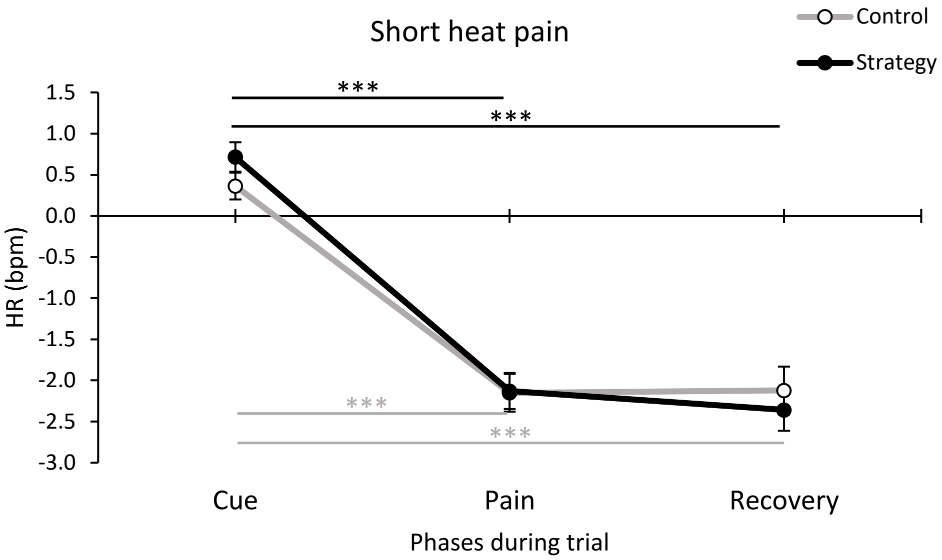
4.3.1.5. Heart rate (HR)

Analysis of HR during the short heat pain trials did not yield a significant main effect of the within-factor *strategy,* $F(1, 116) = 0.06$, $p = .802$, $\eta_p^2 = .001$. However, there was a significant main effect of the within-factor *phase*, $F(1.57, 181.76) = 133.87$, $p < .001$, $\eta_p^2 = .536$. Repeated contrasts with Bonferroni-corrected p-values (2 tests) showed a lower heart HR during the pain phase ($M = -2.14$, $SD = 2.01$) compared to the cue phase ($M = 0.54$, $SD = 1.57$), $F(1, 116) = 229.15$, $p < .001$, $\eta_p^2 = .664$, while pain phase and recovery phase ($M = -2.24$, $SD = 2.61$) did not differ, $p = 1$.

Moreover, there was a marginally significant main effect of the between-factor *group,* $F(2, 116) = 2.94$, $p = .057$, $\eta_p^2 = .048$. Exploratory independent t-tests with Bonferroni-adjusted p-values (3 tests) indicated a lower HR in the distraction group ($M = -1.95$, $SD = 1.97$) compared to the acceptance group ($M = -1.02$, $SD = 1.53$), $t(76) = 2.33$, $p = .067$, $d = 0.54$, whereas the comparison of reappraisal ($M = -1.35$, $SD = 1.70$) with the two other groups did not reach significance, all $ps > .46$, $\eta_p^2 = .006$. There was no significant interaction between the within-factor *strategy* and the between-factor *group*, $F(2, 116) = 0.36$, $p = .699$.

More interestingly, there was a significant interaction between the within-factors *strategy* and *phase*, $F(1.65, 190.80) = 3.89$, $p = .030$, $\eta_p^2 = .032$. Post-hoc pairwise t-tests with Bonferroni-corrected p-values (9 tests) showed no significant differences between the strategy and the control condition at all three time points of the factor phase, all ps > .528. However, there were significant HR decelerations from the cue phase to the pain phase for the strategy condition, $t(118) = 13.05$, $p < .001$, $d = 1.20$, and for the control condition, $t(118) = 13.10$, $p < .001$, $d = 1.20$. Furthermore, we found significant HR decelerations from the cue phase to the recovery phase in the strategy condition, $t(118) = 11.54$, $p < .001$, $d = 1.06$, and in the control condition, $t(118) = 9.29$, $p < .001$, $d = 0.85$. See the HR deceleration for both conditions in Figure 4.11.

Figure 4.11. Study 3: HR over the course of the short heat pain trial.

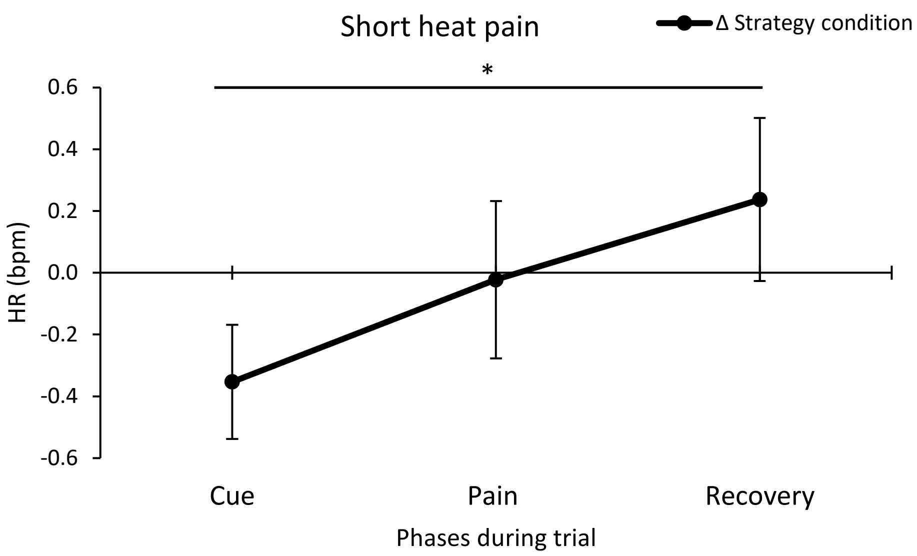


Note. Mean baseline-corrected (seconds -1 – 0) heart rate (HR) and SEMs of short heat pain trials over the time course of the trial (phases), ****p* < .001.

To test this interaction further, difference scores between the control and strategy conditions for each level of the factor phase were calculated and analyzed. Pairwise t-tests with Bonferroni-corrected p-values (3 tests) yielded one significant difference between the recovery phase ($M = 0.24$, $SD = 2.88$) and the cue phase ($M = -0.35$, $SD = 2.02$), $t(118) = -2.43$, $p = .049$, $d = 0.22$. Figure 4.12 shows an approximation of the HR difference scores during the pain phase and a change of sign from negative to positive from the cue to the recovery phase, meaning that the HR was higher in the strategy condition compared to the control condition in the cue phase and lower in the recovery phase.

There were no further significant interactions, all *ps* > .20 for *phase* x *group* and *strategy* x *phase* x *group*.

Figure 4.12. Study 3: HR difference scores over the course of the short heat pain trial.

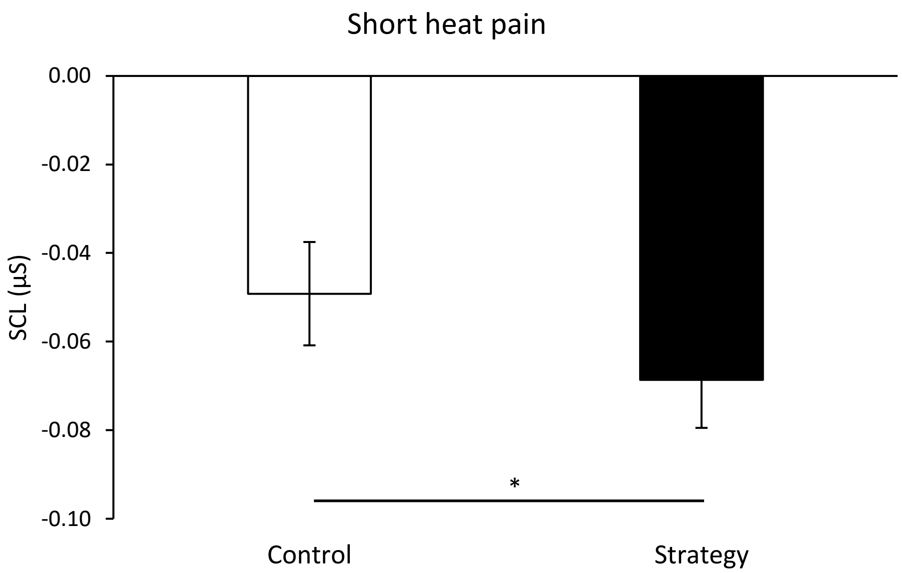


Note. Mean difference scores of the strategy condition (control – strategy) of the baseline-corrected (seconds -1 – 0) heart rate (HR) and SEMs of short heat pain trials over the time course of the trial (phases), **p* < .05.

4.3.1.6. Skin conductance level (SCL)

Analysis of SCL during the short heat pain trials showed a significant main effect of the within-factor *strategy*, $F(1, 110) = 4.28$, $p = .041$, $\eta_p^2 = .037$, indicating a lower SCL during the strategy condition ($M = -0.07$, $SD = 0.12$) compared to the control condition ($M = -0.05$, $SD = 0.12$) (see Figure 4.13).

Figure 4.13. Study 3: SCL of short heat pain.



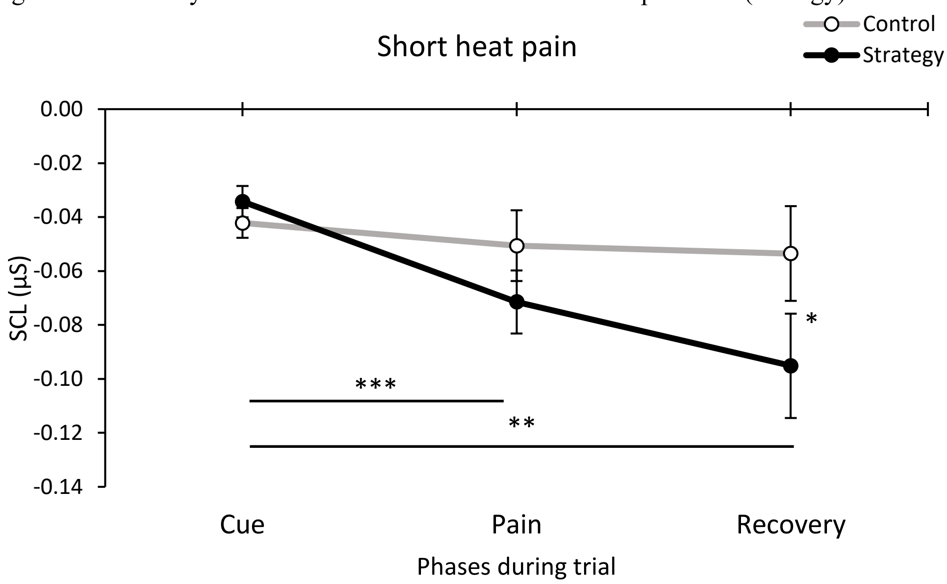
Note. Mean baseline-corrected (seconds -1 – 0) skin conductance level (SCL; seconds 0-25) and SEMs of short heat pain trials per strategy condition, **p* < .05.

Furthermore, there was a significant main effect of the within-factor *phase*, $F(1.34, 147.88) = 5.19$, $p = .015$, $\eta_p^2 = .045$. Repeated contrasts with Bonferroni-adjusted p-values (2 tests) revealed a significant decrease in SCL from the cue phase (M = -0.04, SD = 0.05) to the pain phase (M = -0.06, SD = 0.12), $F(1, 110) = 8.04$, $p = .011$, $\eta_p^2 = .069$. There was no significant difference in SCL between the pain phase and the recovery phase (M = -0.07, SD = 0.18), $p = .39$.

Moreover, there was a marginally significant main effect of the between-factor *group*, $F(2, 110) = 2.78$, $p = .067$, $\eta_p^2 = .048$. Exploratory independent t-tests with Bonferroni-corrected p-values (3 tests) indicated a lower SCL in the distraction than the acceptance group, $t(70) = 2.40$, $p = .057$, $d = 0.57$, whereas the remaining comparisons showed no significance, all $ps > 0.65$. There was no significant interaction between the within-factor *strategy* and the between-factor *group*, $F(2, 110) = 0.80$, $p = .454$, $\eta_p^2 = .014$.

However, analysis revealed a significant interaction between the within-factors *strategy* and *phase*, $F(1.53, 168.01) = 13.76$, $p < .001$, $\eta_p^2 = .111$. Post-hoc pairwise t-tests with Bonferroni-adjusted p-values (9 tests) showed significant differences between the control and the strategy condition during the recovery phase only (control: M = -0.05, SD = 0.21; strategy: M = -0.10, SD = 0.19), $t(112) = 3.07$, $p = .024$, $d = 0.30$. There were no significant differences between the control and strategy condition during the cue and pain phases, all $ps > 0.53$. Moreover, there were significant decreases in SCL from the cue phase (M = -0.03, SD = 0.06) to the pain phase (M = -0.07, SD = 0.12), $t(112) = 4.41$, $p < .001$, $d = 0.42$, and the cue phase to the recovery phase, $t(112) = 3.88$, $p = .002$, $d = 0.37$, only in the strategy condition, whereas no significant differences during the time course of the trial for the control condition could be found, all ps = 1. Figure 4.14 shows a deceleration of the SCL only for the strategy condition, whereas the SCL for the control condition remains unchanged over the time course of the trial.

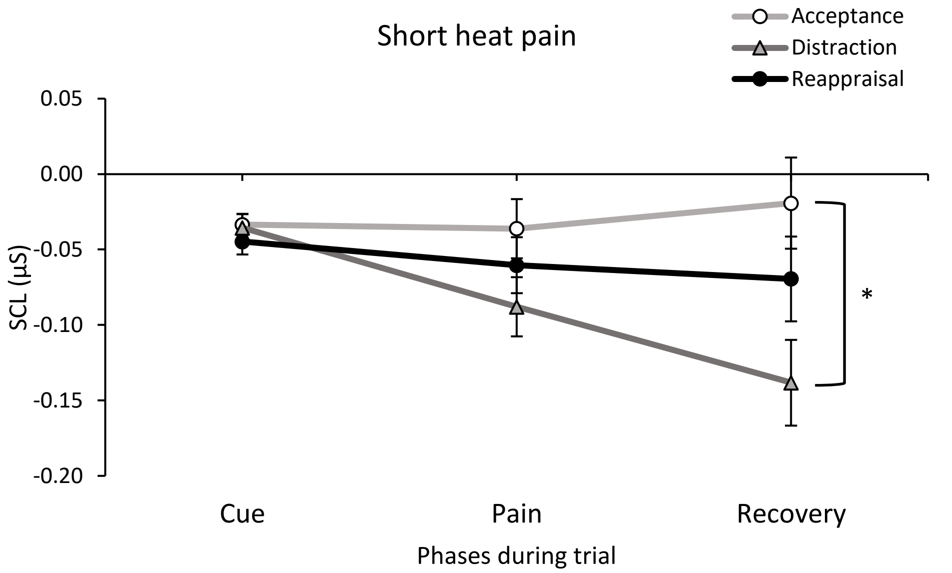
Figure 4.14. Study 3: SCL over the course of the short heat pain trial (strategy).



Note. Mean baseline-corrected (seconds -1 – 0) skin conductance level (SCL) and SEMs of short heat pain trials over the time course of the trial (phases) per strategy condition, *$p < .05$, **$p < .01$, ***$p < .001$.

Furthermore, there was a significant interaction between the within-factor *phase* and the between-factor *group*, $F(4, 220) = 4.06$, $p = .003$, $\eta_p^2 = .069$. A post-hoc one-way ANOVA revealed significant differences between groups only for the recovery phase, $F(2,110) = 4.06$, $p = .020$, $\eta_p^2 = .069$, whereas no significant group differences were shown for the cue and pain phases, all *ps* > .18. Bonferroni-corrected (3 tests) independent t-tests showed a significantly lower SCL during recovery for the group distraction ($M = -0.14$, $SD = 0.17$) compared to the group acceptance ($M = -0.02$, $SD = 0.18$), $t(70) = 2.86$, $p = .018$, $d = 0.68$ (see Figure 4.15). The other two comparisons did not reach significance, all *ps* > .27. The interaction *strategy* x *group* x *phase* did not reach significance, $p = .77$.

Figure 4.15. Study 3: SCL over the course of the short heat pain trial (group).



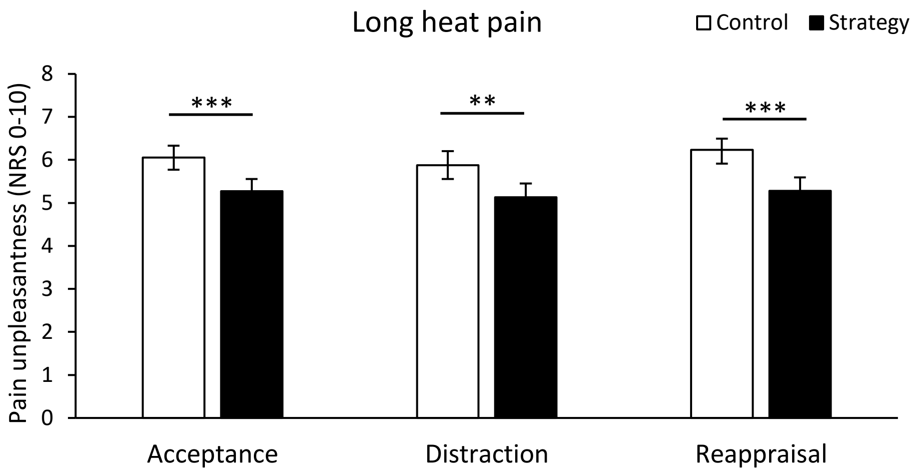
Note. Mean baseline-corrected (seconds -1 – 0) skin conductance level (SCL) and SEMs of short heat pain trials over the time course of the trial (time periods) per group, $*p < .05$.

4.3.2. Long heat pain trials

4.3.2.1. Pain unpleasantness

Analysis of pain unpleasantness ratings of the long heat pain trials yielded a significant main effect of the within-factor *strategy*, $F(1, 118) = 54.93$, $p < .001$, $\eta_p^2 = .318$, indicating higher pain unpleasantness during control trials ($M = 6.06$, $SD = 1.81$) compared to strategy trials ($M = 5.23$, $SD = 1.93$) (see Figure 4.16). There was no significant main effect for the between-factor group, F(2, 118) = 0.20, p = .820, $\eta_p^2 = .003$, and no significant interaction with the within-factor strategy, $F(2, 118) = 0.34$, $p = .714$, $\eta_p^2 = .006$.

Figure 4.16. Study 3: Pain unpleasantness of long heat pain.

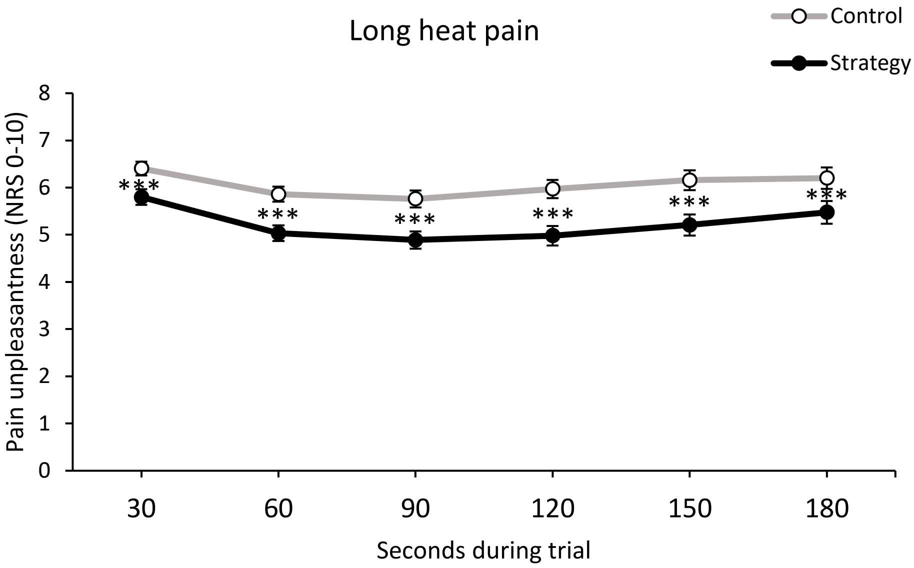


Note. Mean pain unpleasantness ratings and SEMs of long heat pain trials per strategy condition and group¸**$p < .01$, ***$p < .001$. There was no significant interaction of strategy x group.

However, analysis also showed a main effect of the within-factor *time*, $F(1.45, 171.52) = 9.17, p < .001$, $\eta_p^2 = .072$. Repeated contrasts with Bonferroni-adjusted p-values (5 tests) revealed a significant decrease in pain unpleasantness from seconds 30 ($M = 6.10$, $SD = 1.59$) to second 60 ($M = 5.45$, $SD = 1.70$), $F(1, 118) = 42.77$, $p < .001$, $\eta_p^2 = .266$, and significant increases from second 120 ($M = 5.48$, $SD = 2.10$) to second 150 ($M = 5.68$, $SD = 2.26$), $F(1, 118) = 12.69$, $p = .003$, $\eta_p^2 = .097$, and second 150 to second 180 ($M = 5.84$, $SD = 2.45$), $F(1, 118) = 8.81$, $p = .018$, $\eta_p^2 = .070$. The other two comparisons did not reach significance, all *p*s > .065. This time course shows a decrease of unpleasantness ratings during the first minute of the trial and an increase during the third and last minute of the trial.

Furthermore, there was a significant interaction between the within-factors *time* and *strategy*, $F(3.66, 431.27) = 3.74$, $p = .007$, $\eta_p^2 = .031$. Pairwise post-hoc t-tests with Bonferroni-corrected p-values (6 tests) revealed significant differences for all levels of the factor time between the control and the strategy condition, all *p*s < .001 (see Figure 4.17).

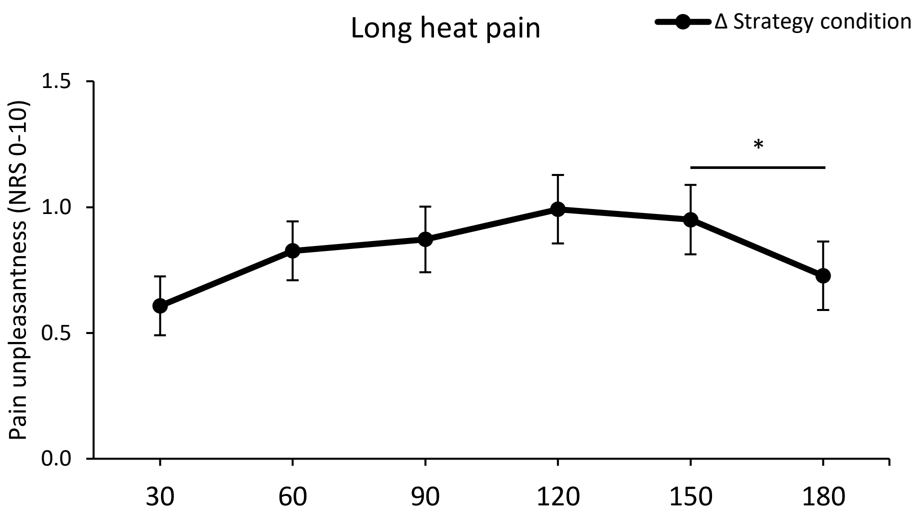
Figure 4.17. Study 3: Pain unpleasantness over the course of the long heat pain trial.



Note. Mean pain unpleasantness ratings (every 30 seconds) and SEMs of long heat pain trials per strategy condition over the time course of the trial¸ ***$p < .001$.

To further test this *time* and *strategy* interaction, difference scores between the control and strategy conditions were calculated for each level of the factor time and analyzed with repeated contrasts. Analysis with Bonferroni-adjusted p-values (5 tests) yielded one significant decrease in difference scores from second 150 ($M = 0.95$, $SD = 1.52$) to second 180 ($M = 0.72$, $SD = 1.50$), $F(1, 120) = 8.13$, $p = .026$, $\eta_p^2 = .063$, whereas the remaining comparisons were not significant, all *ps* > .11. Figure 4.18 shows the decrease of difference scores in the last 30 s, pointing towards a closer approximation between the control and strategy conditions at the end of the trial. The other interactions (*time* x *group*, *strategy* x *time* x *group*) did not reach significance, all *ps* > .60.

Figure 4.18. Study 3: Pain unpleasantness over the course of the long heat pain trial.

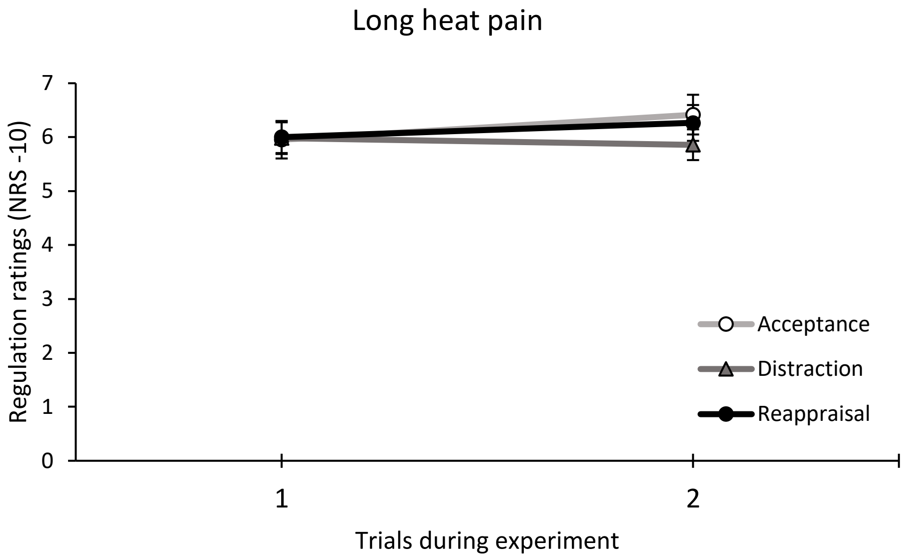


Note. Mean difference scores of the strategy condition (control – strategy) of the pain unpleasantness ratings (every 30 seconds) and SEMs of long heat pain trials over the time course of the trial¸ *$p < .05$.

4.3.2.2. Regulation ratings

Analysis of the regulation ratings of the long heat pain trials showed no significant main effects of *group*, $F(2, 118) = 0.24$, $p = .789$, $\eta_p^2 = .004$, or *trials*, $F(2, 118) = 1.24$, $p = .190$, $\eta_p^2 = .015$, and no significant interaction (*trials* x *group*). Figure 4.19 shows the two regulation ratings after long heat pain trials separated per group, indicating no differences throughout the experiment and between groups.

Figure 4.19. Study 3: Pain regulation of long heat pain over time.



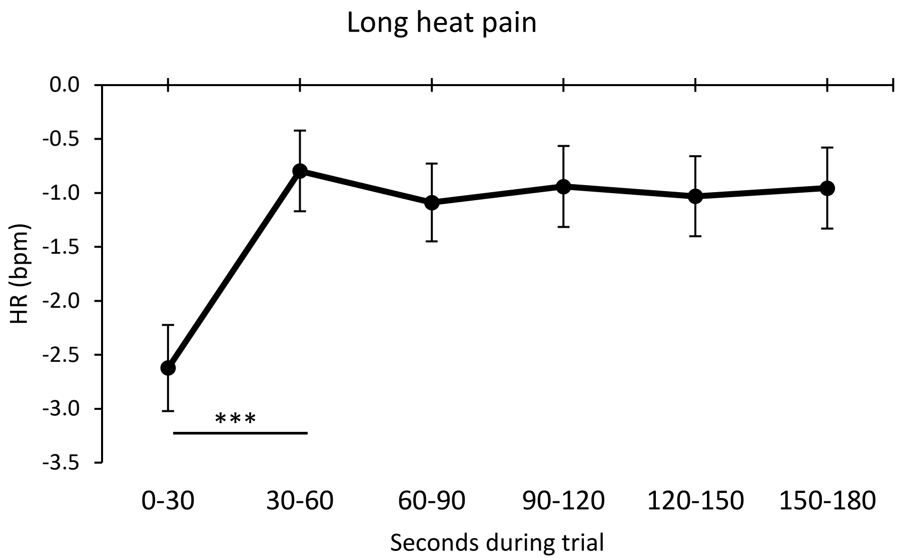
Note. Mean pain regulation ratings and SEMs of long heat pain trials over the time course of the experiment per group. There were no significant mean effects or interactions.

4.3.2.3. Heart rate (HR)

Analysis of HR during long heat pain trials showed no significant main effect of the within-factor *strategy,* $F(1, 116) = 0.79$, $p = .377$, $\eta_p^2 = .007$, and no significant main effect of the between-factor *group*, $F(2, 116) = 0.20$, $p = .821$, $\eta_p^2 = .003$. There was also no significant interaction between the within-factor *strategy* and the between-factor *group*, $F(2, 116) = 0.09$, $p = .913$, $\eta_p^2 = .002$.

However, there was a significant main effect of the within-factor *time*, $F(3.67, 425.93) = 25.96$, $p < .001$, $\eta_p^2 = .183$. Repeated contrasts with Bonferroni-adjusted p-values (5 tests) revealed a significant increase in HR from the time window 0-30 s ($M = -2.62$, $SD = 4.35$) to 30-60 s ($M = -0.80$, $SD = 4.09$), $F(1, 116) = 90.84$, $p < .001$, $\eta_p^2 = .439$, while the remaining comparisons did not reach significance, all *p*s > .47. Figure 4.20 shows a strong increase in HR during the first minute of the long heat pain trial but HR remains unchanged for the rest of the trial. Analysis yielded no significant interactions, all *p*s > .26 (*strategy* x *time, group* x *time, strategy* x *group* x *time*).

Figure 4.20. Study 3: HR over the course of the long heat pain trial.



Note. Mean baseline-corrected (seconds -1 – 0) heart rate (HR) and SEMs of long heat pain trials over the time course of the trial, ***$p < .001$.

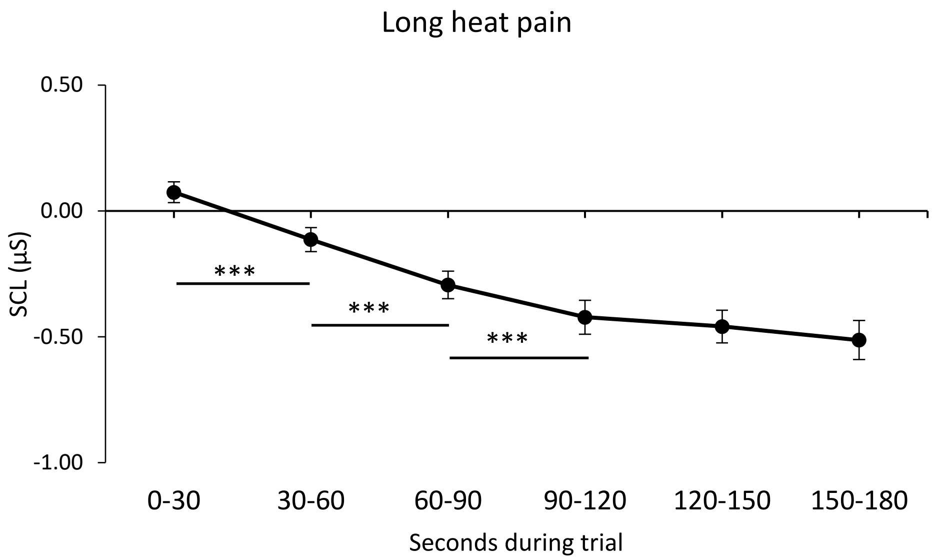
4.3.2.4. Skin conductance level (SCL)

Analysis of the SCL yielded no significant main effects of the within-factor *strategy*, $F(1, 114) = 0.20$, $p = .659$, $\eta_p^2 = .002$, or the between-factor *group*, $F(2, 114) = 0.79$, $p = .377$, $\eta_p^2 = .007$. There was also no significant interaction between the within-factor *strategy* and the between-factor *group*, $F(2, 114) = 0.58$, $p = .563$, $\eta_p^2 = .010$.

Nevertheless, there was a significant main effect of the within-factor *time*, $F(2.10, 239.37) = 58.01$, $p < .001$, $\eta_p^2 = .337$. To analyze the time course, repeated contrasts with Bonferroni-corrected p-values (5 tests) were calculated. Analysis revealed a significant difference between the time windows 0-30 s ($M = 0.07$, $SD = 0.45$) and 30-60 s ($M = -0.11$, $SD = 0.52$), 30-60 s and 60-90 s ($M = -0.29$, $SD = 0.59$), and 60-90 s and 90-120 s ($M = -0.42$, $SD = 0.73$), all *p*s < .001. The remaining time windows 90-120 s, 120-150 s ($M = -0.46$, $SD = 0.70$), and 150-180 s ($M = -0.51$, $SD = 0.84$) did not differ from each other, all *p*s = 1. Figure 4.21 shows the continuous decrease of SCL throughout the long heat pain trial.

There were no significant interactions (*time* x *group*, *strategy* x *time*, *strategy* x *time* x *group*) detected by the analysis ($p > .55$).

Figure 4.21. Study 3: SCL over the course of the long heat pain trial.

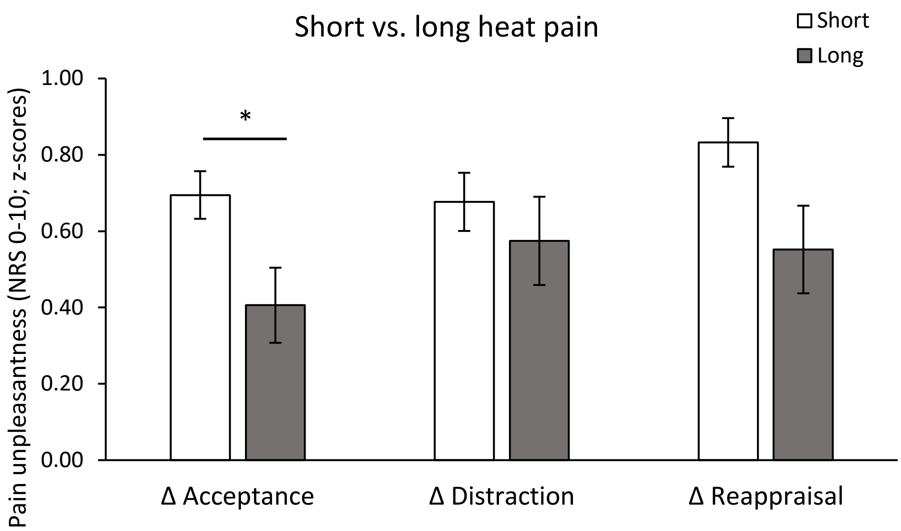


Note. Mean baseline-corrected (seconds -1 – 0) skin conductance level (SCL) and SEMs of long heat pain trials over the time course of the trial, ****p* < .001.

4.3.3. Short vs. long heat pain trials

Analysis of pain durations (short vs. long) for each group (3 tests) with z-standardized difference scores of the pain ratings (control – strategy) yielded one significant difference between short ($M = 0.69$, $SD = 0.40$) and long ($M = 0.41$, $SD = 0.63$) heat pain trials for acceptance difference scores, $t(40) = 2.70$, $p = .031$, $d = .421$, while the other two comparisons did not reach significance, all *ps* > .158. Moreover, analysis between groups for every z-standardized pain duration (6 tests) with difference scores showed no significant difference between groups for short or long pain trials, all *ps* > .721. Figure 4.22 shows the higher difference scores of short compared to long heat pain trials for acceptance.

Figure 4.22. Study 3: Comparison of short and long heat pain unpleasantness.



Note. Mean z-standardized difference scores of the strategy condition (control – strategy) and SEMs per heat pain duration (short vs. long) and group, **p* < .05.

4.3.4. Correlation analyses

4.3.4.1. Short heat pain trials

Correlation analyses of *pain intensity* difference scores (control condition – strategy condition) revealed significant relationships with the ASP questionnaire subscales religious orientation (group reappraisal) and conscious interaction (group acceptance), and the LOT-R pessimism subscale (group distraction). These correlations indicate a better regulatory outcome for acceptance for higher self-administered conscious interaction (e.g., "conscious interactions with others and self"), better regulation with distraction for lower trait pessimism, and better regulation with reappraisal for higher religious orientation (e.g., "praying, reading spiritual/religious books"). Moreover, there were positive close to significant associations of distraction difference scores with the ASP search for insight/wisdom subscale and the ASP transcendence conviction subscale, and a close to significant negative correlation with the LOT-R pessimism subscale. These tendencies suggest that less trait pessimism, more self-assessed search for insight (e.g., "insight and truth, broad awareness"), and conviction in transcendence (e.g., "existence of higher beings") results in a better regulatory outcome for distraction. Table 4.6 shows the Pearson's coefficients with p-values and number of subjects from the pain intensity analyses per group.

Table 4.6. Study 3: Correlation analyses of pain intensity and questionnaires (short).

	Group Acceptance			Group Distraction			Group Reappraisal		
Questionnaires	*r*	*p*	*n*	*r*	*p*	*n*	*r*	*p*	*n*
Pain intensity (short) difference score									
AAQ-II									
Total	-.055	.733	41	.010	.950	38	-.063	.690	42
ASP									
Conscious interactions	**.522**	**<.001*****	41	.127	.446	38	.027	.863	42
Religious orientation	.115	.476	41	.144	.387	38	**.465**	**.002****	42
Search for Insight / Wisdom	-.226	.156	41	.102	.544	38	.269	.085#	42
Transcendence conviction	-.018	.910	41	.189	.256	38	.302	.052#	42
ASQ									
Suppression / concealing	.100	.533	41	.034	.841	38	.016	.921	41
Adjusting / reappraisal	-.013	.937	41	-.201	.225	38	-.015	.924	41
Tolerating / accepting	.009	.954	41	-.203	.221	38	.180	.261	41
ERQ									
Cognitive reappraisal	-.187	.242	41	.186	.265	38	.230	.144	42
Expressive suppression	.070	.664	41	.167	.317	38	-.084	.598	42
LOT-R									
Pessimism	-.183	.251	41	**-.326**	**.046***	38	-.279	.074#	42
Optimism	.17	.287	41	-.023	.890	38	.197	.211	42
RS-11									
Total	.103	.523	41	-.129	.439	38	.220	.161	42

Note. Pearson's r (*r*) with p-values (*p*) and number of subjects (*n*) per group from two-tailed Pearson correlation analyses of pain intensity difference scores (control – strategy) of short heat pain trials with ER and resilience questionnaire scores. Significant correlations are marked in bold, #*p* < .10, **p* < .05, ***p* < .01, ****p* < .001.

Correlation analyses of the *pain unpleasantness* difference scores (control - strategy condition) showed significant positive associations with the ASQ subscale adjusting / reappraisal, the ASP conscious interaction subscale, the LOT-R optimism subscale, and the RS-11 total score (group acceptance). Significant negative correlations were found for the accepting / tolerating ASQ subscale in the group distraction and the LOT-R pessimism subscale for the group acceptance. These relationships imply a better regulatory outcome for acceptance with more habitual use of reappraisal, more trait optimism, resilience, and conscious interaction, while less trait pessimism. A lower accepting ER style led to a better regulatory outcome for distraction. Furthermore, there were close to significant negative correlations with the AAQ-II total score for acceptance and the RS-11 total score for distraction. There was also a positive correlation with the ERQ reappraisal subscale for reappraisal. These tendencies suggest that more psychological flexibility led to better regulation with acceptance, less habitual accepting led to better regulation with distraction, and more habitual use of reappraisal led to better regulation with reappraisal. Table 4.7 shows the Pearson's coefficients with p-values and number of subjects from the pain unpleasantness analyses per group.

Table 4.7. Study 3: Correlation analyses of pain unpleasantness and questionnaires (short).

	Group Acceptance			Group Distraction			Group Reappraisal		
Questionnaires	*r*	*p*	*n*	*r*	*p*	*n*	*r*	*p*	*n*
Pain unpleasantness (short) difference score									
AAQ-II									
Total	-.277	.080$^{\#}$	41	.063	.706	38	.019	.904	42
ASP									
Conscious interactions	**.354**	**.023***	41	.061	.714	38	.113	.477	42
Religious orientation	.176	.271	41	-.210	.207	38	.105	.508	42
Search for Insight / Wisdom	-.201	.208	41	-.134	.421	38	-.057	.720	42
Transcendence conviction	.063	.696	41	-.155	.352	38	.026	.872	42
ASQ									
Suppression / concealing	.072	.656	41	.114	.496	38	.169	.292	41
Adjusting / reappraisal	**.314**	**.045***	41	.067	.688	38	.155	.333	41
Tolerating / accepting	.243	.126	41	**-.419**	**.009****	38	.226	.155	41
ERQ									
Cognitive reappraisal	.049	.762	41	-.034	.840	38	.283	.069$^{\#}$	42
Expressive suppression	-.034	.834	41	.053	.751	38	-.091	.568	42
LOT-R									
Pessimism	**-.396**	**.010***	41	-.054	.747	38	-.189	.232	42
Optimism	**.489**	**.001*****	41	-.063	.709	38	.148	.350	42
RS-11									
Total	**.361**	**.020***	41	-.300	.068$^{\#}$	38	.016	.921	42

Note. Pearson's r (*r*) with p-values (*p*) and number of subjects (*n*) per group from two-tailed Pearson correlation analyses of pain unpleasantness difference scores (control – strategy) of short heat pain trials with ER and resilience questionnaire scores. Significant correlations are marked in bold, $^{\#}$ < .10, **p* < .05, ***p* < .01, ****p* < .001.

4.3.4.2. Long heat pain trials

Correlation analyses of the mean *pain unpleasantness* difference scores (control condition – strategy condition) of long heat pain trials revealed significant positive associations with the ASQ accepting / tolerating subscale and with the ERQ cognitive reappraisal subscale for the group reappraisal and a negative association with the ASP search for insight/wisdom subscale for the group acceptance. These relationships indicate better regulatory performance for acceptance with less search for insight (e.g., "insight and truth, broad awareness") and better regulation with reappraisal with more habitual tendencies for accepting and reappraisal. Furthermore, there were positive close to significant correlations for the group distraction with the ASP subscales search for insight/wisdom and transcendence conviction and the LOT-R optimism subscale. More search for insight, conviction in transcendence (e.g., "the existence of higher beings"), and trait optimism possibly led to a better regulatory output for distraction. Table 4.8 shows the Pearson's coefficients with p-values and number of subjects from the pain unpleasantness analyses of long heat pain trials per group.

Table 4.8. Study 3: Correlation analyses of pain unpleasantness and questionnaires (long).

	Group Acceptance			Group Distraction			Group Reappraisal		
Questionnaires	*r*	*p*	*n*	*r*	*p*	*n*	*r*	*p*	*n*
Pain unpleasantness (long) ***difference score***									
AAQ-II									
Total	-.002	.989	41	.066	.692	38	.069	.664	42
ASP									
Conscious interactions	-.002	.990	41	-.139	.405	38	.138	.384	42
Religious orientation	-.092	.569	41	-.111	.508	38	.156	.324	42
Search for Insight / Wisdom	**-.335**	**.032***	41	-.098	.560	38	.275	.078#	42
Transcendence conviction	-.094	.558	41	-.213	.198	38	.258	.098#	42
ASQ									
Suppression / concealing	-.103	.522	41	-.163	.327	38	-.071	.659	41
Adjusting / reappraisal	-.058	.720	41	-.262	.112	38	.172	.283	41
Tolerating / accepting	-.036	.821	41	-.128	.445	38	**.316**	**.044***	41
ERQ									
Cognitive reappraisal	-.100	.532	41	-.070	.677	38	**.361**	**.019***	42
Expressive suppression	-.260	.101	41	-.008	.961	38	-.086	.589	42
LOT-R									
Pessimism	-.057	.722	41	.045	.789	38	-.219	.163	42
Optimism	.149	.352	41	-.066	.692	38	.280	.073#	42
RS-11									
Total	-.111	.488	41	-.190	.252	38	.064	.686	42

Note. Pearson's r (*r*) with p-values (*p*) and number of subjects (*n*) per group from two-tailed Pearson correlation analyses of pain unpleasantness difference scores (control – strategy) of long heat pain trials with ER and resilience questionnaire scores. Significant correlations are marked in bold, # < .10, *$p < .05$, **$p < .01$, ***$p < .001$.

4.4. Discussion

In the third and last study of this dissertation project, we compared three pain regulation strategies with each other and a control condition in a mixed design. We introduced the pain regulation strategy reappraisal to the previously investigated strategies acceptance and distraction. Furthermore, participants were divided into groups per strategy. Within each group, a control condition to every strategy was introduced. Moreover, we induced short heat pain as in the two previous studies and additionally introduced a long heat pain stimulus of 3 minutes. As before, we gathered pain intensity and unpleasantness ratings and regulation ratings after the short heat pain trials. During the long heat pain trials, pain unpleasantness was assessed, and regulation ratings were gathered in the strategy condition. HR and SC were continuously recorded. In addition, the participants' ER styles, optimism and pessimism, psychological resilience, and religious and spiritual coping were collected via questionnaires.

4.4.1. Adaptive strategies reduce the heat pain perception

We hypothesized that all three strategies, acceptance, distraction, and reappraisal, would decrease the self-reported pain intensity and unpleasantness compared to the control condition for short and long heat pain trials. Our results confirmed this hypothesis. All three strategies decreased the pain intensity and unpleasantness ratings compared to the control condition for short heat pain. Similarly, all three strategies attenuated the pain unpleasantness for long heat pain.

We further assumed that distraction would be more effective in downregulating self-reported pain than reappraisal for short heat pain while there would be no differences with acceptance. In contrast to our expectations, we did not find any differences between the three strategies. However, we found a close to significant tendency, showing that reappraisal decreased the pain intensity but not unpleasantness slightly stronger than acceptance. This tendency could indicate a later initiation of acceptance in the emotion-generative process than reappraisal, meaning it could even be response-focused instead of antecedent-focused. Another explanation could be that reappraisal was easier to implement than acceptance, maybe due to more familiarity with reappraisal in every-day life. In fact, participants rated the instructions for distraction the most and the instructions for acceptance the least comprehensible in the MCS, while reappraisal was located in between (see Table 4.3 in chapter 4.2.1). This pattern is similar to the pain intensity ratings. Nevertheless, there were no differences between the ratings regarding the strategy implementation success in the MCS. Again, the most feasible explanation would be the theoretical concept of acceptance, indicating that acceptance does not target the sensory experience (Hayes et al., 1999a; Kohl et al., 2012; Masedo & Esteve, 2007). The finding that acceptance is less effective than reappraisal in pain regulation is in line with previous research (Hampton et al., 2015; Kohl et al., 2013). Moreover, it supports the suggestion that acceptance is less effective than distraction and reappraisal in reducing temporally limited pain compared to pain tolerance tasks (Kohl et al., 2012). However, this needs to be clarified in future research by, e.g., contrasting different pain durations with pain tolerance tasks while investigating acceptance and other pain regulation strategies. Interestingly, reappraisal appeared to have been even more successful than distraction, however entirely descriptively. These findings could question the underlying mechanisms regarding the process model (Gross, 1998b), where distraction intervenes earlier in the emotion-generative process than reappraisal and should therefore be more effective in pain regulation in the short term.

Notably, the distraction group in this study showed a close to significantly higher fear of pain measured by the FPQ-III (see 4.2.1) than the other two groups. In previous research, perceiving pain as a threat did not affect the effectivity of distraction (Van Damme et al., 2008) or even increased its effectivity (Rischer et al., 2020). Assuming that participants with a higher fear of pain would more likely perceive pain as a threat, these results could conceivably be translated to ours. However, according to Johnson (2005), fear of pain leads to the perception of pain as more threatening, which increases the hypervigilance for pain and should make it more difficult to distract oneself from the pain. Thus, the higher fear of pain measures in the distraction group might have mitigated the effects of distraction in the current study. However, distraction still proved to be effective in reducing the heat pain perception. The influence of the fear of pain on pain regulation should be investigated more in future studies.

Overall, optimal conditions were established for the implementation of reappraisal, namely controllability (Wiech et al., 2008), an anticipation phase (McRae et al., 2010; Moodie et al., 2020; Sheppes & Meiran, 2007, 2008; Thiruchselvam et al., 2011; Van Bockstaele et al., 2019), and a temporally limited and moderate pain stimulation (Adamczyk et al., 2020; Fardo et al., 2015; Lapate et al., 2012; Woo et al., 2015). These factors could have contributed to and reinforced the effectiveness of reappraisal in this study. Future studies could systematically vary such factors by, e.g., intensifying painful stimuli gradually or varying the controllability by altering the predictability of the pain stimulus or the strategy onset. These could foster insights into different dynamics of reappraisal.

Interestingly, our assumption that all strategies would modulate the pain unpleasantness more strongly than the pain intensity could only be confirmed for acceptance. This finding is in line with our first but contrary to our second study. As noted in the previous studies, this result is again in line with the theoretical approach that proposes that acceptance mainly targets affective instead of sensory components of pain (Hayes et al., 1999a; Kohl et al., 2013; Masedo & Esteve, 2007), which we confirmed with our first and the current study. In the second study, the effects might not have been evident due to the small number of trials of the experiment. We further assumed that the affective information of distraction would not be encoded, leading to more substantial reductions in pain unpleasantness ratings. However, similar to the second study of this dissertation project, this assumption could not be confirmed. Both distraction and reappraisal appear to target both pain dimensions equally.

Contrary to our hypothesis, reappraisal and acceptance were not more effective than distraction in downregulating the pain experience of the long heat pain stimuli. One explanation could be that a pain stimulus of 3 minutes is still a relatively brief and temporally limited pain stimulus and cannot be considered long-term pain. Thus, we could not detect possible underlying temporal dynamics regarding the three strategies. Moreover, all three strategies effectively downregulated the 3 minutes of experimental pain. In line with the multiple resource theory (Birnie et al., 2017; Van Ryckeghem et al., 2017), distraction tends to become more challenging when cognitive resources are limited, e.g., when prolonged or chronic pain is competing with it. It appears that in our study, the long heat pain stimulus did not compete with the resources used by distraction, so that no impairments were found. Therefore, it would be worthwhile inducing longer pain durations or assessing the pain tolerance with, e.g., a CPT in future studies to investigate the dynamics of distraction further. Studies have already indicated a loss in effectiveness for distraction with prolonged experimental pain for chronic pain patients (Goubert et al., 2004; Nouwen et al., 2006) and overall difficulties in implementing distraction for chronic pain. Therefore, future investigations should focus on distraction mechanisms with a healthy sample and chronic pain patients as there seems to be a lack of methodologically clear clinical studies (Van Ryckeghem et al., 2017). Remarkably, we found a significant interaction between the strategy condition and the time course of the long heat pain trial. More specifically, the regulatory success of all strategies decreased at the end of the 3-minute trial. Simultaneously, the long pain stimulus became more unpleasant at the end of the trials, which might have led to these difficulties in implementing all strategies.

Finally, it should be noted that we integrated only four long heat pain trials due to ethical reasons, thus two trials per each strategy and control condition, which could have limited the validity. However, there seems to have been enough statistical power to yield some significant findings with robust effect sizes. Nevertheless, further studies should investigate the three strategies with prolonged pain stimuli and a greater number of trials.

Our hypotheses regarding different training effects for the strategies could not be confirmed. More specifically, we expected that reappraisal would decrease pain intensity and unpleasantness over time, while the pain ratings for acceptance and distraction would not change. There were no differences between the strategies over the time course of the experiment for short heat pain. However, we found interactions between strategy and time for all groups. More precisely, the regulatory success of all three strategies, reflected by difference scores of the pain ratings, decreased in the first half but increased for both pain dimensions in the second half of the experiment. This finding indicates initial difficulties with strategy application but possible training effects with experimental progress for all strategies equally. Thus, we found training effects over time not only for reappraisal, as expected but also for acceptance and distraction, contrary to our expectations and the results regarding heat pain stimulation in our previous two studies. The regulation ratings of all three strategies also increased in the middle of the experiment, supporting the pain rating results. The training effects of reappraisal are in accordance with the emotion regulation literature (Denny & Ochsner, 2014) and also with the process-specific hypothesis, showing that regulatory success increased for reappraisal when more time was provided for strategy implementation (Sheppes et al., 2009; Sheppes & Meiran, 2007, 2008). Even though we did not find any training effects for acceptance in our first two studies, we found a clear indication in this third study. There already have been assumptions of possible training effects for acceptance in emotion (Evans et al., 2014; Moore et al., 2015) and pain regulation research (Germain & Kangas, 2015; Helbig-Lang et al., 2015), stating that acceptance strategies usually are less familiar and therefore might require more training. However, these studies did not investigate training effects directly. With this study, we could finally show that regulatory success with acceptance can increase over time, suggesting that repetition and training can help with a better implementation. Interestingly, we also found increased regulatory success for distraction, even though this strategy develops early in childhood (Cole et al., 2018), and therefore should have been familiar. Future studies should systematically investigate training effects with more extensive training and conduct longitudinal studies with training over several days.

We further predicted that acceptance and reappraisal would regulate long heat pain more effectively than short heat pain. However, comparing z-standardized difference scores of the pain unpleasantness ratings between the two heat pain durations yielded only one significant result. Interestingly and opposed to our assumption, the regulatory success for acceptance was lower during the long heat pain than the short heat pain. Participants downregulated equally successful their pain unpleasantness during both pain durations with distraction and reappraisal. These findings suggest that participants had difficulties regulating with acceptance but not distraction and reappraisal during the prolonged pain compared to the short pain. However descriptively, a similar pattern could be observed for distraction and reappraisal as for acceptance. An explanation for these results could be the higher pain unpleasantness during the long heat pain and, therefore, higher cognitive costs resulting in less pain regulation effectiveness. The significant reduction for acceptance is surprising considering acceptance being effective for chronic pain patients (Kohl et al., 2014; Kratz et al., 2017; Vowles et al., 2017) and in pain tolerance tasks (Kohl et al., 2012) that can be considered as tonic pain as well. Moreover, acceptance seems to be especially effective in downregulating the affective pain component as demonstrated repeatedly by previous research (Hayes et al., 1999a; Kohl et al., 2013; Masedo & Esteve, 2007) and our current research. However, it could be argued that acceptance might actually target neither the sensory nor the affective pain component. Instead, acceptance could target pain endurance in experimental tolerance tasks and focus on the values-based engagement in daily life activities in chronic pain interventions. Conceptually, acceptance is supposed to contradict experiential avoidance (Hayes et al., 2006), so tolerating pain longer instead of aborting the task would fit into that concept. Similar dynamics could be responsible for decreasing the experience of temporally limited pain. As the task in our study was to accept the pain as it is without judging it, participants might have engaged even more into the long compared to the short heat pain because they had more time to do so. Naturally, they would have perceived the pain stronger. Therefore, the engagement into the short heat pain was curtailed, leading to more reduced pain ratings. Overall, the reduction of pain intensity and unpleasantness by acceptance might be a side effect of the mindfulness component. Even though the regulatory success measured by pain ratings was lower for the long pain trials than for the short pain trials, participants in the acceptance condition could have still been willing to experience the long heat pain for a more extended period or more frequently than in the distraction or reappraisal condition. The assessment of other self-reported variables, including other pain-related experiences such as pain endurance, pain-specific resilience (Slepian et al., 2016), or loading capacity as a measure of cognitive resource consumption, could be more appropriate for investigating acceptance and delivering further insights into its mechanisms. Tonic pain models should be further implemented for acceptance research.

4.4.2. Autonomic measures capture regulatory efforts only for brief heat pain

To analyze the autonomic measures for this study, we divided the short heat pain trials according to the first two studies into three phases: cue, pain, and recovery. The long heat pain trials were averaged into six time- bins, each comprising 30 s of the 180 minutes.

We expected an anticipatory or regulatory HR deceleration (De Pascalis et al., 1995; Mohammed et al., 2021) in all conditions and a constant deceleration during acceptance and reappraisal throughout the short heat pain trials, indicating regulatory effort. As expected, we found an anticipatory or regulatory HR for both the strategy and control conditions, similar to study 1. However, we did not find any differences between the three strategies in the HR. Moreover, regulatory success calculated via difference scores increased from the cue phase to the recovery phase. Descriptively, there was a change in sign from the cue to the recovery phase, meaning that the HR was higher in the strategy condition than in the control condition during the cue phase, which changed to the contrary during the recovery phase. This observation could suggest a slight hint towards a regulatory effort reflected by the HR in this study.

We further expected that acceptance and reappraisal would lead to a HR deceleration, and distraction would lead to a HR acceleration during the long heat pain trials, which could not be confirmed. During the long heat pain, HR increased significantly in the first minute but remained at the same level for the rest of the trial. There were no differences between the strategies compared to the control condition and each other. This finding is surprising considering the regulation effects in HR found for the short heat pain. Considering the self-reported pain was downregulated successfully by all strategies compared to the control condition, this lack of findings only affected the HR measure. Either no strategy was able to modulate the HR during the long pain, or the HR was not able to reflect regulation for the prolonged heat pain. A possible explanation could be that the participants perceived the long heat pain (NRS 0-10: $M = 5.64$, $SD = 1.78$) as more unpleasant than the short heat pain (NRS 0-10: $M = 4.40$, $SD = 1.44$), which could have led to a more pronounced HR acceleration, not allowing any reflection of regulatory effects or effort. Thus, the HR might only be a suitable measurement of pain regulation when the pain is not too unpleasant or too painful. Future studies should systematically investigate possible ceiling or floor effects to determine the exact circumstances under which HR can measure pain regulation. For example, they could systematically vary the pain intensities and duration during the application of established strategies while measuring the HR continuously.

We further assumed that the SCL would decrease during acceptance in the later phases of the short and long heat pain trials, similar to study 2. Reappraisal was also predicted to decrease the SCL for both pain durations, while distraction should have no effect on the SCL of short heat pain and increase the SCL of long heat pain. These hypotheses could only be confirmed partially and only for the short pain duration. Compared to the control condition, all three strategies decreased the SCL during the late recovery phase of the short heat pain trials. Moreover, the strategies led to a continuous decrease of SCL over the time course of the trial, while the SCL during the control condition remained unaffected. These results show that SCL is a valid measure of pain regulation. However, we could not unravel different mechanisms underlying the strategies as no differences appeared, consistent with the finding for the pain ratings.

We only found a decrease in SCL over the time course of the long heat pain trial, but we found no differences between the strategies with each other and the control condition. This finding indicates habituation of the SC to the long heat pain, whereas there was no general habituation to the pain reflected by the pain ratings and HR. Rhudy et al. (2010) found diverging pain perception and SC reactions in a within-subjects design with repeated pain stimulation, which might be explained by the loss of stimulus novelty over time also reflected by SC response (Bradley et al., 1993; Bromm & Scharein, 1982). In our current study, the SC did not habituate over the time course of the experiment as we varied the thermode's location on the skin. However, during the long heat pain trials, the thermode had to remain at the same position on the participants' arms for 3 minutes so that habituation could not be avoided. Nevertheless, SC is the only measure showing habituation. Therefore, SC seems to have reflected the stimulus novelty more strongly than the pain perception during the long heat pain trials. Thus, SC might not be a suitable pain correlate for tonic heat pain. One frequently used method in pain assessment is the number of fluctuations in SC (Sugimine et al., 2020; Treister et al., 2012), which might be worthwhile using in future studies with tonic heat pain. However, the normalized SC has been shown to differentiate more reliably between heat pain levels than the number of fluctuations while also reflecting the self-reported pain intensity and unpleasantness (Sugimine et al., 2020). Nevertheless, Sugimine et al. (2020) used heat pain stimulation of a maximum of 60 s with a temperature of at least 46°C, which is not directly comparable with the individually adjusted, long heat pain stimulation used in this study. Future studies should further examine SC habituation effects in tonic pain as well as the processing and analyzing approaches suitable specifically for tonic pain models. Moreover, there was a difference in SCL between the distraction and the reappraisal group in the recovery phase of the short heat pain trial. However, the groups also included the control condition, so no conclusion regarding strategy effectiveness can be drawn from this result. It seems like the SCL decreased in the distraction group in both conditions while it remained unaffected in the other two groups. This decrease in the distraction group could indicate that participants could have used distraction or other regulation strategies in the control condition as well. Nevertheless, we excluded participants that indicated in the MCS using other strategies frequently.

Overall, the autonomic measures HR and SC seemed to have reflected pain regulation, especially in later phases, particularly after the pain stimulus. The late reflection is not surprising due to the latency of these measures (Braams et al., 2012; Dawson et al., 2007). However, we cannot draw a clear conclusion regarding underlying mechanisms due to no differences between the strategies. None of the three strategies showed indications of cognitive costs or reductions in regulation, measured by autonomic indices. Moreover, there were no hints towards a different temporal dynamic consistent with the process model (Gross, 1998b). Nevertheless, including tonic but moderate experimental pain in future studies could lead to further conclusions.

4.4.3. Optimism enhances general pain regulation

We hypothesized that the trait factor optimism would facilitate regulatory success for all three strategies. Accordingly, optimistic participants downregulated their self-reported pain unpleasantness more successfully with acceptance in the short heat pain condition. For pain intensity, we found a close to significant association between optimism and regulatory success with acceptance. These findings expand the results of our previous study, where we identified these associations for electrical pain trials and tendencies for heat pain stimuli. We suggested in study 2 that the connection either became weaker with longer pain duration or that the small number of trials weakened the effect. We can assume the latter with the current finding and showed a strong association between optimism and acceptance. These results align with Scheier et al. (1986), who found a relationship between the acceptance of stressful events and optimism. As explained in more detail in the discussion of study 2 (see 3.4), high optimists might engage more in the pain stimulus (Hinkle & Quiton, 2019), which is also part of the acceptance concept. Thus, optimism might support the implementation of acceptance.

Interestingly, this association modulated mainly the pain unpleasantness of the short heat pain but disappeared for the long heat pain. As mentioned numerously, regulation with acceptance conceptually targets pain unpleasantness, so optimism seems to have facilitated pain regulation with acceptance. However, similar considerations as previously can be applied regarding the long heat pain. Participants perceived the long heat pain as more unpleasant than the short heat pain, which might have weakened the association between optimism and acceptance. Furthermore, there were only four long heat pain trials and, therefore, less statistical power. Thus, possible associations might not have been evident. Future studies should further investigate this association with varying pain intensities, duration, and enough trial repetitions.

There were no significant relationships between optimism and regulatory success with reappraisal or distraction regarding both pain dimensions and durations. However, we found a negative association between pessimism and regulatory success with distraction of short heat pain trials for pain intensity ratings. This finding means that less pessimistic participants downregulated better their experienced pain intensity with distraction, indicating an indirect relationship with optimism. These findings support the assumption by Basten-Günther et al. (2019), who reviewed in their meta-analysis that optimists shift their attention away from the negative attributes of pain. For reappraisal, there was a close to significant negative association with pessimism for short heat pain intensity and a close to significant positive association with optimism for long heat pain unpleasantness. These findings suggest that optimism could facilitate pain regulation generally, at least with adaptive strategies. Basten-Günther et al. (2019) also reviewed that optimistic individuals flexibly adapt their coping styles to their circumstances (Geers et al., 2008), which might explain the associations in this study. Moreover, optimism has been positively associated with problem-focused ER (Scheier et al., 1986). Optimistic participants might have been able to implement either of the three strategies flexibly as they were all adequate for the circumstance. However, it appears that acceptance was the strategy of choice for optimistic individuals, reflected by better pain regulation with acceptance. The trait factor optimism should be incorporated in future studies on pain regulation strategies to validate the assumption of optimism supporting pain regulation success.

We assumed an association between regulatory success with acceptance and psychological flexibility and, equivalently, an accepting ER style. We further expected reappraising participants to regulate better with reappraisal. Similar to the second study, we only found psychological flexibility leading to a slightly better pain regulation with acceptance but impacting only the affective pain experience. Interestingly, participants with an accepting ER style regulated better with reappraisal during the long heat pain trials. Moreover, participants with a reappraising ER style regulated better in the acceptance condition but not in the reappraisal condition of short heat pain trials. On the one hand, these results might lead to the question of whether the ASQ can differentiate between ER styles. On the other hand, these findings could support the assumption that acceptance involves reappraisal as an underlying mechanism. As Gross (1998b) categorized reappraisal as cognitive change and an antecedent-focused ER strategy in his process model, acceptance might also be considered antecedent-focused, supporting previous suppositions (Hofmann et al., 2009). Webb et al. (2012) even classified acceptance as a reappraisal strategy and defined it as reappraising the emotional response by accepting it and not judging it. Thus, having a reappraising ER style could have facilitated the implementation of acceptance. Reappraising individuals could find it easier to modulate their pain evaluation by not judging the pain. On the other hand, accepting individuals could have been more proficient in reappraising the long heat pain stimulus due to similar reasons. Nevertheless, individuals with a reappraising ER style measured by the ERQ downregulated their self-reported pain unpleasantness better during the reappraisal of the long heat pain and slightly better during the short heat pain. It might be possible that the ERQ assessed the reappraising ER style more accurately than the ASQ. Moreover, a reappraising ER style only facilitated the pain regulation with reappraisal for the affective but not sensory component. This result could indicate that pain regulation with reappraisal targets the cognitive change of the emotional reaction to the pain rather than the sensory pain experience.

Surprisingly, participants with an accepting ER style had difficulties downregulating the pain unpleasantness with distraction during the short heat pain trials. An explanation could be that accepting individuals focused more on the pain and engaged more in it, so using distraction might have been counterintuitive for them. To further clarify whether matching ER styles facilitate strategy use, researchers should employ highly valid instruments and systematically investigate ER style and strategy, e.g., by screening the ER style prior to the experiment and assigning participants to the matching or mismatching strategy instructions. This research should also be conducted with chronic pain patients to facilitate the translation to a clinical context, where matching ER styles with the taught strategies in pain therapy could save valuable time and accelerate pain treatment.

We assumed that highly resilient participants would generally be better at pain regulation. We could confirm this hypothesis partially. Resilient participants regulated better with acceptance during the short heat pain trials. However, this connection for resilience and pain regulation was only evident for the pain unpleasantness ratings. Moreover, there was a trend for a negative relationship between distraction and resilience. Thus, resilience seems to improve pain regulation with acceptance but impair regulation with distraction. Nevertheless, these association might not be very strong as they were not evident in our previous studies. Moreover, the RS-11 might not be a very sensitive questionnaire to assess the whole concept of resilience. Future studies should include a broader selection of questionnaires assessing various constructs and facets of resilience in their studies.

Finally, we hypothesized that regulation with acceptance would be more successful for religious or spiritual participants. Similar to our first study, individuals that interacted consciously regulated better with acceptance during the short heat pain trials. This connection was evident for both pain dimensions. Interestingly, this conscious interaction did not benefit the regulation of long heat pain. Unexpectedly, the ASP scale "search for insight/wisdom" correlated negatively with acceptance during the long heat pain trials. This subscale refers to philosophical and existential views (Büssing et al., 2014). Büssing et al. (2014) showed that – especially in a German compared to a Polish student sample – the subscale "search for insight/wisdom" was only tendentially associated with "conscious interactions", and had less religious connotations. Our sample also consisted mainly of German students, so we can assume that this subscale did not necessarily reflect religiousness in this study. Overall, spirituality appeared to help with pain regulation with acceptance. As assumed, religious orientation facilitated the regulation of short heat pain intensity with reappraisal. Furthermore, there were tendencies concerning associations between reappraisal and search for insight and transcendence conviction for short heat pain intensity and long heat pain unpleasantness. Conclusively, reappraisal might also be affected by religiousness or spirituality, which aligns with Vishkin et al. (2019) and should be considered in future research.

4.4.4. Conclusion and outlook

With this dissertation project's third and last study, we expanded our within-subjects design to a mixed design. We introduced the pain regulation strategy reappraisal and compared it with the strategies acceptance and distraction as a between-factor. Furthermore, we added a tonic, long heat pain stimulation of 3 minutes to the within-factor, including brief, short heat pain stimuli of 10 s as in the studies before.

As predicted, all three strategies decreased the self-reported pain intensity and unpleasantness compared to the control condition for short heat pain. For long heat pain, again, all three strategies reduced the pain unpleasantness compared to the control condition. Contrary to our expectations, we did not find any significant differences between the strategies for both pain durations. However, reappraisal decreased the self-reported pain intensity of short heat pain slightly stronger than acceptance but only

close to significant, while no differences were found for pain unpleasantness. Accordingly, only acceptance modulated the pain unpleasantness more strongly than the pain intensity. These observations strongly support the concept of acceptance not targeting sensory experiences (Hayes et al., 1999a). Distraction and reappraisal seemed to have affected both pain dimensions equally. Furthermore, we found possible training effects for all strategies, starting from the middle of the experimental time course for the short heat pain trials. For the long heat pain, strategy effectiveness decreased at the end of the trials while pain unpleasantness increased, indicating difficulties in strategy implementation, possibly because of higher pain unpleasantness. Interestingly, regulatory success with acceptance was reduced during the long heat pain compared to the short heat pain despite evidence suggesting that acceptance would be effective for chronic pain (Kohl et al., 2014; Kratz et al., 2017; Vowles et al., 2017) and in pain tolerance tasks (Kohl et al., 2012). It could be possible that acceptance does not target any pain experiences but other pain-related variables such as pain endurance or resilience.
The autonomic measures HR and SC captured the regulatory efforts for all strategies during the short heat pain trials, mainly reflected in the later trial phase. However, they could not differentiate between the three strategies, consistent with the self-reported pain experience. Interestingly and contrary to the pain ratings, the autonomic measures failed to discriminate between strategies and conditions during the long heat pain trials, possibly due to the little number of trials or the higher pain unpleasantness. Therefore, we suggested that HR and SC might not be suitable for assessing pain regulation in tonic pain models.

As hypothesized, correlation analyses supported the results of study 2 and revealed a strong association between optimism and acceptance, especially for the short heat pain unpleasantness. However, optimism did not facilitate regulation of the long heat pain with acceptance, consistent with the lesser regulatory success measured by the pain unpleasantness ratings. We further showed weak, indirect associations between optimism with regulatory success with distraction and reappraisal, suggesting that optimism could generally facilitate pain regulation, at least with adaptive strategies. Similarly, psychological flexibility facilitated the affective pain regulation slightly with acceptance. However, accepting or reappraising ER styles seemed to have partially facilitated pain regulation with the respective other strategy, indicating either conceptual overlaps between the two strategies or failure to measure the correct concept by the questionnaire ASQ. Furthermore, an accepting ER style seemed to have interfered with the regulatory success with distraction, demonstrating a possible contrast in conceptualization. Moreover, religiousness and spirituality appeared to have facilitated pain regulation with acceptance and reappraisal. Finally, resilient participants regulated better with acceptance but worse with distraction.

Future research should further investigate the three strategies' mechanisms by varying pain duration, pain intensity, and pain tasks. More specifically, a longer pain duration than the one used in this study might lead to a more precise differentiation and bring further insights. For example, distraction could become less effective with more prolonged pain, while acceptance and reappraisal could gain effectiveness. The pain task used in experimental settings appears to play a role in the pain regulation effectiveness, especially with acceptance (Kohl et al., 2012), at least when pain intensity or unpleasantness ratings are included as pain measures. Therefore, a greater variety of pain tasks should be incorporated into the pain regulation research. The use of pain tolerance tasks dominates the pain regulation research with acceptance (Evans et al., 2014; Feldner et al., 2006; Forsyth & Hayes, 2014; Hayes et al., 1999a; Jackson et al., 2012; Kehoe et al., 2014; Keogh et al., 2005; Kohl et al., 2013; Masedo & Esteve, 2007; McMullen et al., 2008; Moore et al., 2015; Paez-Blarrina et al., 2008a; Paez-Blarrina et al., 2008b; Roche et al., 2007), while the use of temporally limited experimental pain is scarce (Braams et al., 2012; Hampton et al., 2015; Prins et al., 2014; Reiner et al., 2016). Thus, there is a need for a wider variety in experimental pain induction, such as heat, electrical, or mechanical pain with different pain durations, to further detect underlying mechanisms. Moreover, self-reported variables assessing the pain perception should be expanded to other dimensions than sensory and affective pain and include, e.g., pain endurance, pain controllability, or resilience. For tonic pain, additional neurological, physiological, or behavioral measures such as fMRI, HR variability, or pain recovery should accompany autonomic measures to quantify their benefit or replacement further. Trait variables such as optimism and resilience and ER styles should be further considered in pain regulation research and investigated systematically.

5. General discussion

The current dissertation project aimed to investigate the effectiveness of the adaptive strategies acceptance, distraction, and reappraisal in pain regulation. The main goal was to explore these strategies' underlying mechanisms and temporal dynamics by varying the pain modalities and durations in an experimental setting with acute pain. Recent research suggested that acceptance is a valid emotion regulation (ER) strategy (Aldao et al., 2010; Dunn et al., 2009; Hofmann et al., 2009; Kohl et al., 2012; Liverant et al., 2008; Szasz et al., 2011) but it is still under debate where acceptance should be located in the process model of ER by Gross (1998b). More specifically, it has been discussed whether acceptance is antecedent-, response-focused, or both (Hofmann & Asmundson, 2008; Hofmann et al., 2009; Liverant et al., 2008; Wolgast et al., 2011). On the other hand, distraction and reappraisal are clearly classified into antecedent- and response-focused ER strategies, respectively, according to the process model (Gross, 1998b), see. 1.2.1 Therefore, we contrasted acceptance with the two already established ER strategies distraction and reappraisal (Sheppes & Gross, 2011) in three consecutive studies. Moreover, we chose a within-subjects design to decrease sampling error, increase effect sizes (Webb et al., 2012), and take intraindividual differences in regulatory abilities and autonomic measures (Loggia et al., 2011) into account. We further introduced a neutral control condition to increase internal validity and accurately capture each strategy's effectiveness (Webb et al., 2012). Finally, we assessed self-reported pain and regulation as well as autonomic measures as pain correlates during the experiments and included psychometric measures of habitual ER styles and trait factors to the studies. The following sections will give an overview over the three studies, discuss their results and limitations, conclude their implications and provide an outlook for future research.

5.1. Results and conclusions

In the first study of this dissertation project, we introduced the ER strategy acceptance and compared it with a neutral control condition in a within-subjects design. Healthy participants received individually adjusted, short heat pain stimuli with a duration of 10 s. In our second study, we further expanded that within-subjects design and introduced the ER strategy distraction. Moreover, we added brief electrical pain with a duration of 20 ms as another pain modality. Thus, the second study contained acceptance, distraction, and the control condition as one within-factor and heat and electrical pain as another within-factor. In the third study, we further introduced the ER strategy reappraisal, leaving out the electrical pain but adding long heat pain stimuli with a duration of 3 minutes. Due to the increasing number of strategies, we altered the study design into a mixed design. Thus, each strategy was contrasted with the control condition, and the two heat pain durations were includedas within-factors. Moreover, we compared the three strategies with each other between groups. We assessed self-reported pain intensity, pain unpleasantness and regulation ratings, the autonomic pain correlates HR and SC, and pain-related traits as well as the ER style in all three studies similarly.

5.1.1. Acceptance effectively reduces the self-reported pain perception

As hypothesized, acceptance reduced the pain intensity and unpleasantness of the short heat pain stimulations significantly compared to the control condition in studies 1 and 3. These results are in line with the studies by Masedo and Esteve (2007) and Paez-Blarrina et al. (2008a), who also found reduced pain intensity ratings for acceptance, and with Braams et al. (2012), who found reduced pain unpleasantness ratings for acceptance compared to control conditions containing spontaneous coping. Furthermore, acceptance reduced the pain unpleasantness more profoundly than the pain intensity, as indicated by studies 1 and 3. These findings strongly support and provide further evidence for the theoretical approach of acceptance. The concept indicates that acceptance primarily targets the affective experience by disconnecting feelings and behavior while overlooking the sensory components of an experience (Hayes et al., 1999a; Kohl et al., 2013; Masedo & Esteve, 2007). However, the two pain dimensions are intertwined and are, therefore, not independent of each other (Price et al., 1987). Thus, it is only logical that the pain intensity decreases at least somewhat automatically with the pain unpleasantness.

Nevertheless, other studies did not show any decrease in pain intensity for acceptance compared to control conditions (Kehoe et al., 2014; Reiner et al., 2016). Interestingly, most studies investigating the acceptance of pain used tonic pain instead and contained several methodological and conceptual deviations that make a direct comparison difficult. For instance, pain tasks varied from a cold pressor task (Masedo & Esteve, 2007) to single (Braams et al., 2012) or multiple (Paez-Blarrina et al., 2008a) electrical stimuli to radiant (Kehoe et al., 2014) or tonic (Reiner et al., 2016) heat pain tasks. Tonic pain, can lead to more pain unpleasantness than brief pain stimulation (Rainville et al., 1992), and it is therefore hard to compare the two types of pain stimuli. As acceptance conceptually targets mainly the affective pain component, it might become less effective with explicitly unpleasant pain modalities, which could have been the case in the studies by Kehoe et al. (2014) and Reiner et al. (2016). However, study 3 of this dissertation revealed that acceptance also effectively decreased the self-reported pain unpleasantness of the long heat pain stimulation compared to the control condition, even though less effectively than the pain unpleasantness of the short heat pain stimulation. Acceptance appeared to have indeed lost effectiveness when pain unpleasantness increased, which is surprising considering the proven effectiveness for chronic pain (Kohl et al., 2014; Kratz et al., 2017; Vowles et al., 2017), and in pain tolerance tasks (Kohl et al., 2012). The concept of acceptance itself can provide an explanation. Acceptance targets the behavior and function of an aversive event, such as pain endurance, rather than any other pain experience (Hayes et al., 1999a; Kohl et al., 2013; Masedo & Esteve, 2007). Therefore, the assessment of the two pain dimensions, intensity and unpleasantness, might not be very practical for acceptance. Instead, future studies should additionally include other pain indicators and pain-related experiences such as pain endurance, pain-specific resilience, or cognitive resource consumption with tonic pain models. An outlook for possible pain-related measures will be discussed in more detail in chapter 5.2.

Unexpectedly, acceptance did not affect the perceived pain intensity and unpleasantness of the short heat pain in study 2. However, methodological differences could have led to a decreased validity in study 2. Due to an elaborate experimental design, we only included six heat pain trials per condition, which might have decreased the statistical power and led to a lack of sensitivity. Further, as expected, and similar to the study by Braams et al. (2012), acceptance decreased the pain unpleasantness of the electrical pain trials in study 2. However, we found a significant interaction with time for both pain rating dimensions, indicating that acceptance significantly decreased the perceived electrical pain only in the middle of the experiment (trials 6-10 out of 15). These results were somewhat surprising, possibly suggesting training effects at the beginning but habituation to the electrical stimulus at the end of the experiment. Electrical stimulation might not be the method of choice for inducing pain in a laboratory setting except for neurophysiological measures due to its phasic properties. Moreover, our results suggested that electrical stimuli might be prone to habituation effects.

Due to the different approaches, methods, and dependent variables mentioned above, the concrete circumstances that contribute to the effectiveness of acceptance are still inconclusive. However, we showed with all three studies that acceptance clearly reduced the perceived pain intensity and unpleasantness of short and the pain unpleasantness of the long heat pain stimulation.

In contrast to our assumptions, acceptance did not affect the autonomic measures in any of the three studies, even though there were indications of regulatory efforts in studies 1 and 3. Descriptively, acceptance led to a continuous HR deceleration in study 1, while the HR increased during the control condition trials. In study 3, there was an increase in the difference between the strategy and control conditions throughout the short heat pain trial. These descriptive findings might point towards a regulatory effort and maybe a rather late onset of acceptance reflected by HR. We assumed that these findings might become more evident with a more tonic pain stimulation. However, there was no evidence of any regulatory efforts reflected by the HR during the long heat pain trials. On the one hand, this result could mean that the HR could not capture any efforts of pain regulation and is, therefore, not a suitable measure in pain regulation research. However, Braams et al. (2012) found a pronounced HR deceleration during acceptance compared to a control condition involving spontaneous coping even after phasic electrical stimuli. On the other hand, HR might have failed to detect regulatory efforts because the pain was too unpleasant or painful during the tonic pain stimulation in our last study. Nickel et al. (2017) showed that HR was not related to pain or stimulus intensity using tonic pain but pointed out that the duration of the pain stimulus might play a role.

There were no effects of acceptance on the SC during the electrical stimulation, probably due to the brevity of the pain trials. Similarly, Breimhorst et al. (2011) showed that the SCR failed to discriminate between pain intensities for painful electrical stimulation. Thus, electrodermal activity appears not to be the measure of choice for electrical pain. Future studies should consider measuring somatosensory evoked potentials via EEG instead when using electrical pain (Staahl & Drewes, 2004).
Interestingly, we found heterogeneous results for the SC during the short heat pain trials over all three studies. In study 1, there was no difference between acceptance and the control condition in SCL. However, in study 2, the SCL decreased significantly during acceptance at the end of the trials, while no decline was found for the control condition. Moreover, there was a close to significant difference between the two conditions at the end of the trial. Finally, in study 3, acceptance led to a significant reduction in SCL compared to the control condition at the end of the short heat pain trial. These findings convincingly point towards an effective SCL reduction by acceptance at later time points, namely the recovery period (last 8 s of the trial, right after pain stimulation) in our study. However, it is unclear why the effect was absent in the first study, even though similar effect sizes were produced in the third study. We first assumed that the SC would not be affected strongly because it measures mainly the sensory component (Loggia et al., 2011), and acceptance targets primarily the affective component (Hayes et al., 1999a). However, studies 2 and 3 proved this argument to be obsolete. Secondly, we proposed that the SCL reduction would become even more evident in tonic pain because the SCL reduction became more pronounced in the later phases of the short heat pain trials in study 2. Unexpectedly, we could not find any effects of acceptance on the SCL during the long heat pain trials, either due to the small trial number or the higher pain unpleasantness. Therefore, the question remains inconclusive why acceptance did not affect the SCL in study 1.

Future pain regulation research should further clarify if autonomic measures are suitable for measuring differences in pain regulation. Our studies have already suggested that they are unsuitable for tonic and electrical pain models. However, they might be helpful in different pain tasks or other research questions. Furthermore, we concluded earlier that acceptance does not aim to reduce the pain experience itself. Thus, there is a need for other psychophysiological parameters, such as, e.g., cortisol levels reflecting the connection between pain and stress. See chapter 5.2 for more details.

Conclusively, we showed with this dissertation project that acceptance effectively decreased the self-reported pain intensity and unpleasantness of brief and tonic heat pain as well as phasic, electrical pain compared to a neutral control condition. Autonomic measures partially reflected the regulatory efforts of acceptance during short heat pain, especially SC. However, both HR and SC provided mixed results so that more robust measures might assess pain regulation with acceptance more reliably. The subsequent chapter will examine acceptance in comparison with distraction and reappraisal.

5.1.2. Similar effectiveness for acceptance, distraction, and reappraisal

This dissertation project has demonstrated the effectiveness of acceptance as a regulation strategy for experimentally induced heat and electrical pain. However, the question which still needs to be addressed concerns the circumstances under which acceptance is more or less effective than the strategies distraction and reappraisal.

In study 2, ***distraction*** reduced the self-reported pain unpleasantness of the short heat pain trials compared to the control condition, while acceptance did not show significant differences between distraction and the control condition. Acceptance and distraction did not affect the perceived heat pain intensity in this study. As we mentioned earlier, the statistical power of the heat pain trials might have been decreased due to the limited number of trials so that potential effects may not have been detected. However, results indicate that distraction could have been slightly more effective than acceptance in downregulating the affective component of the heat pain perception. Nevertheless, both strategies effectively reduced the electrical pain intensity and unpleasantness compared to the control condition in the middle of the experiment. Descriptively, the effects were more substantial using distraction on the sensory dimension and using acceptance on the affective pain dimension. However, no significant differences resulted from a comparison of the two strategies when considering the two pain dimensions. In study 3, acceptance and distraction significantly reduced the pain intensity and unpleasantness of the short and long heat pain trials. Again, there were no differences between the two strategies.

The autonomic measures HR and SC did not capture any differences between acceptance and distraction in studies 2 and 3. Like acceptance, distraction decreased the SCL in the later phase of the short heat pain trials in study 3, indicating a regulatory effort.

The lack of significant differences between acceptance and distraction makes it difficult to make conclusions about the underlying mechanisms. Both strategies proved effective for phasic, brief, and tonic pain. Therefore, the absence of any significant differences could indicate similar initiation time points of both strategies in the emotion-generative process according to the process-specific hypothesis by Sheppes and Gross (2011) (see 1.2.4). On the other hand, the limited number of trials and lower statistical power in study 2 might have concealed possible effects. Hypothetically and shown descriptively, there might have been stronger decreases in pain unpleasantness for distraction than for acceptance with a greater number of trials during the short heat pain trials in study 2. This result would have supported the assumption by the process model of ER (Gross, 1998b) that distraction is initiated earlier in the emotion-generative process than acceptance. In fact, the regulation ratings in study 2 substantiate this assumption with the tendentially significant result that participants regulated better with distraction than acceptance during the short heat pain stimulation. However, further research with within-subjects designs and a greater number of trials is needed to identify possible differences. Interestingly, participants stated in the manipulation check survey that they regulated more poorly throughout the experiment with distraction but not acceptance during the electrical pain trials. This finding might hint towards a greater effort and consumption of cognitive resources over time for distraction. In line with the multiple resource theory (Birnie et al., 2017; Van Ryckeghem et al., 2017) and the ironic process theory (Wegner, 1994), the distractor might not have been able to compete with the pain because the pain became more salient over time. Johnson (2005) argued that imagery distraction could be less effective than other distraction tasks because no response is involved. However, no indices of an increasing consumption of resources were evident for the long heat pain in study 3, possibly due to a small number of trials or the pain being not prolonged enough to be considered long-term. Future studies should further vary pain modalities and durations while paying attention to providing enough statistical power.

The comparisons of acceptance with ***reappraisal*** revealed similar results as with distraction. Reappraisal did not differ from acceptance nor distraction regarding self-reported pain unpleasantness and autonomic measures for both pain durations in study 3. Interestingly, there was a marginally significant interaction, which traces back to reappraisal reducing the self-reported pain intensity, but not unpleasantness, of the short heat pain more effectively than acceptance. Previous research (Hampton et al., 2015; Kohl et al., 2013) suggested that reappraisal is more effective than acceptance in reducing the pain experience. However, Kohl et al. (2013) assessed only the self-reported pain intensity. The choice of the pain-related measures used in a study appears to play a crucial role in whether acceptance is considered more or less effective than other strategies. In our third study, acceptance and reappraisal reduced the pain unpleasantness equally, while only the sensory pain component was decreased more profoundly by reappraisal, which is again in line with the theoretical approach of acceptance (Hayes et al., 1999a; Kohl et al., 2013; Masedo & Esteve, 2007).

In summary, we showed with this dissertation project that all three strategies, acceptance, distraction, and reappraisal effectively reduced the self-reported pain intensity and unpleasantness of phasic electrical, brief and tonic heat pain compared to a neutral control condition. Moreover, regulatory efforts were visible for all three strategies in the later trial phase of the brief heat pain trials of study 3, reflected by a decreased SCL compared to the control condition. However, no significant differences between the strategies were evident, so a final evaluation regarding possible differences in their underlying mechanisms remains inconclusive. Nevertheless, future studies should replicate these findings and expand them with refined designs, considering our limitations and suggestions (see 5.2). Moreover, the lack of a statistical significance does not equal a lack of statistical equivalence. Even small effects can be meaningful, which should be further tested via equivalence tests (Lakens et al., 2018). Implications for the process model of emotion regulation will be discussed in the next section.

5.1.3. Theoretical implications for the process model of emotion regulation

The process model of ER (Gross, 1998b) initially did not entail pain perception but focused on regulating emotions. However, as outlined in detail in the introduction (see 1.1.4.), emotions, cognitions, and the perception of pain cannot be separated and affect each other (Bradley et al., 2001; Lang et al., 1990; Wiech & Tracey, 2009). Pain itself contains sensory and affective components (see 1.1) and can be managed by regulating emotional and cognitive aspects (Wiech et al., 2008). Emotion dysregulation can even result in the development and maintenance of chronic pain (Koechlin et al., 2018; Konietzny et al., 2016). Emotion regulation success has been shown to predict pain regulation success, indicating that emotion regulation abilities can also be applied to pain regulation (Lapate et al., 2012). Therefore, a broad range of research regarding pain regulation emerged over the last decades (see 1.3.3). More and more researchers investigating pain regulation employ the process model of ER (Gross, 1998b) as their theoretical foundation and make use of the existing emotion regulation literature (Adamczyk et al., 2020; Aldao et al., 2010; Braams et al., 2012; Burns et al., 2008; Denson et al., 2014; Hampton et al., 2015; Haspert et al., 2020; Lapate et al., 2012).

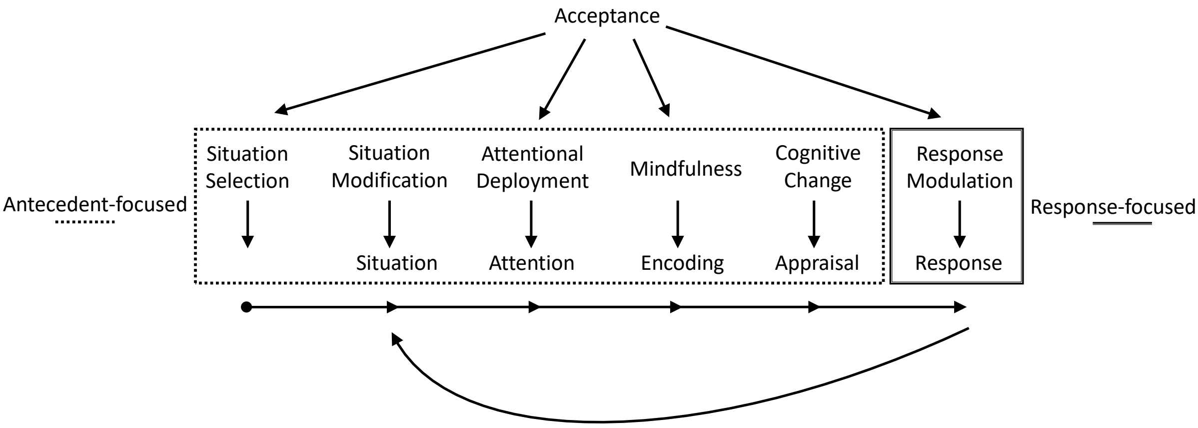
Regarding the process model of ER by Gross (1998b) and the debate concerning acceptance in the ER literature (see 1.2.1.), classification and allocation of acceptance within the model still remains challenging and inconclusive. It has been debated whether acceptance can be categorized within the process model as antecedent- or response-focused (Hofmann & Asmundson, 2008; Hofmann et al., 2009; Liverant et al., 2008; Wolgast et al., 2011) (see 1.2.2.3)

In ER research, temporal dynamics of reappraisal have been captured by HR recordings in the first 3 s after stimulus onset (Mocaiber et al., 2011; Pavlov et al., 2014). Moreover, few studies (Hofmann et al., 2009; Wolgast et al., 2011) found general reductions in HR and SC during acceptance conditions. They suggested that acceptance had a more robust effect on these measures than self-reported experiences. Because of these findings, we expected acceptance to be more effective in decreasing autonomic measures than distraction and reappraisal. However, we could not confirm this assumption as we did not detect any effects of pain regulation in the HR throughout our studies. Similarly, Dan-Glauser and Gross (2015) did not find any effects of acceptance on the HR. Only for the SCL, we found an evident decline for all three strategies compared to the control condition at the end of the short heat pain trials of studies 2 and 3 but not study 1. In pain regulation research, studies including HR or SC are very scarce. Similar to our third study, Denson et al. (2014) did not find any effects of reappraisal during a CPT reflected by the HR compared to a control condition. On the contrary, Braams et al. (2012) showed a decelerated HR during acceptance of electrical stimuli compared to a control condition. To our knowledge, Hampton et al. (2015) have conducted the only study to date assessing SCR during short heat pain but did not find any effects of acceptance or reappraisal. In conclusion, the matter of temporal dynamics cannot be answered clearly by our results or past research. Pain regulation by all three strategies was evident in the SCL of later phases of the short heat pain trials, which might suggest later onsets in the emotion-generative processes, contrary to the process model of ER and our hypotheses.

The self-reported pain experiences can give a little more insight into the underlying mechanisms of the strategies. According to the process model (Gross, 1998b), reappraisal is initiated later in the emotion-generative processes than distraction. Thus, we expected distraction to be more effective than reappraisal for the short heat pain, while acceptance should not differ. Moreover, we hypothesized that reappraisal and acceptance would be more effective in downregulating the long heat pain than distraction. Surprisingly, none of the strategies differed from each other. Thus, it could be argued that acceptance might even be initiated as early as distraction during emotion generation, depending on the emotion-eliciting event or, in this case, pain modality or duration. We suggested in chapter 1.4 that potential underlying mechanisms of acceptance would be the non-evaluation of pain and counteracting avoidance. Mechanisms of detachment and mindfulness would be logically initiated in the process model before the cognitive change occurs. In order to change an evaluation of an event, the evaluation has to be already generated. However, acceptance prevents an individual from even forming that evaluation. Therefore, logically, it can be placed at the same level as or closely after the "attentional deployment" point in the process model. This conclusion would explain why acceptance and distraction were similarly effective in our studies. One of the suggested underlying mechanisms of distraction was not attending to and not encoding the affective components (McRae et al., 2010). Accepting an event or pain would mean attending to it, encoding the affective component but not evaluating it. Therefore, we suggest extending the process model by adding "encoding" to the emotion-generative process. When a situation has been attended to, the information must be encoded before it can be appraised. Thus, we suggest that mindfulness – the non-evaluating mechanism of acceptance – would be placed at the new ER point "encoding" in the emotion-generative process. The mechanism counteracting avoidance would be included in the emotion regulation process "situation selection" before the event occurs and the emotion generation is initiated. Attentional processes might also be involved in acceptance since a situation is sought out and attended to actively, allocating acceptance to "attentional deployment" but reversing the direction. Furthermore, as argued in previous research (Liverant et al., 2008; Wolgast et al., 2011), acceptance can also target the already generated emotional reaction or "response modulation".

See Figure 5.1 for our adaption of the process model of ER by Gross (1998b), including the sequence "encoding", and the mechanisms mindfulness and acceptance.

Figure 5.1. Adaptation of the process model of ER by Gross (1998b), extended by acceptance.



Note. Six points of emotion regulation during the emotion-generative process, divided into antecedent- and response-focused emotion regulation. The original process model (Gross, 1998b) was extended by the additional sequence "encoding", the emotion regulation point "mindfulness, and the emotion regulation strategy "acceptance", with the possibility of targeting four points in the emotion regulation process. Adapted from "Emotion regulation: Conceptual and empirical foundations" by J. J. Gross., 2014, in J. J. Gross (Ed.), Handbook of Emotion Regulation, second edition, pp. 3-20. Copyright 2014 by The Guilford Press.

Following this line of argumentation, acceptance might even have the ability to flexibly adapt to the circumstances and position itself in the emotion-generative process where needed. This concept would be consistent to the psychological flexibility that is fostered by acceptance (Hayes et al., 2006) (see 1.2.2.1.). This assumption might implicate that acceptance could be a universally adaptable strategy. In our studies, even a brief acceptance training substantially affected pain perception. However, if and how acceptance can be acquired under all circumstances needs to be further investigated.

As stated before, the effectiveness of acceptance seems to depend strongly on the pain measure and pain task used in a study. Inducing more tonic or intense pain might assist with further clarification and classification of acceptance within the process model. Future pain regulation research should also focus on the strategies' consumption of the cognitive resources to make propositions regarding long-term effectiveness and practicability for pain management interventions. More importantly, research should further integrate various adaptive pain regulation strategies and investigate their conditions, such as regulatory goals, controllability, or trait factors.

Finally, it should be noted that the translation from the process model of ER to pain regulation and vice versa could be limited. As mentioned at the beginning of this section, the process model originally refers to the regulation of emotions but has been widely employed in pain regulation research. However, future studies should further investigate and verify our proposed extension of the process model not only with other pain paradigms but especially with ER paradigms. Only then can the original debate regarding the allocation of acceptance within the process model be answered conclusively.

5.1.4. Pain regulation more effective with higher levels of optimism and resilience but unaffected by ER style

Effective and adaptive emotion regulation depends on many factors (see 1.2.3), such as regulatory flexibility, context sensitivity, the repertoire of ER strategies (Bonanno & Burton, 2013; Troy et al., 2013), or certain trait dispositions (see 1.3.3.5). The ER style – the habitual, individual tendencies to use a particular ER strategy in everyday life – has been proposed to increase the effectiveness of pain regulation when it matches the ER strategy used (Forys & Dahlquist, 2007; Moore et al., 2015). Therefore, we assumed that participants in our studies would be more successful in pain regulation when the strategies matched their ER styles. The regulatory success was calculated via the difference scores of the pain ratings between the control and the strategy condition. In addition, we assessed part of the participants' psychological flexibility comprising of acceptance via the Acceptance and Action Questionnaire-II (AAQ-II) (Bond et al., 2011; Hoyer & Gloster, 2013). Furthermore, we assessed the suppressing, reappraising, and accepting ER styles via the Affective Style Questionnaire (ASQ) (Graser et al., 2012; Hofmann & Kashdan, 2010) and the reappraising and suppressing ER styles via the Emotion Regulation Questionnaire (ERQ) (Abler & Kessler, 2009; Gross & John, 2003).

Contrary to our expectations, higher psychological flexibility led to less regulatory success with acceptance for both pain rating dimensions in our first study. Furthermore, an accepting ER style did not affect the regulatory success with acceptance. However, the subsequent studies showed effects in the expected direction. In studies 2 and 3, psychologically flexible participants downregulated the short heat and electrical pain unpleasantness tendentially better with acceptance. A reason for the reversed effect of study 1 could be the somewhat higher psychological inflexibility in the sample (AAQ-II, NRS 1-7, maximum sum score = 49: M = 20.34, SD = 6.22), compared to studies 2 (M = 17.00, SD = 8.27) and 3 (M = 18.57, SD = 7.24). Presumably, the sample did not consist of enough highly psychologically flexible participants in our first study to yield an association. Furthermore, the small sample size of study 1 might have diminished possible effects or even skewed the results (Button et al., 2013; Hung et al., 2017; Malbec et al., 2022). However, effect sizes and statistical power should have been sufficient to detect true effects. Overall, the effects in studies 2 and 3 were not large enough to discover a significant association. Unexpectedly, none of our studies revealed positive associations between an accepting ER style, measured by the ASQ, and regulatory success with acceptance. Moreover, there were no other associations between any other ER styles and regulatory success of matching strategies. This lack of associations is in line with the findings by Hampton et al. (2015) specific to reappraising and suppressing ER styles. They concluded that habitual ER styles might only have a minimal effect on regulatory success because regulation strategies can be trained and acquired rather easily. Our results also indicate that ER styles could act less as fixed trait dispositions but as habits that can be relearned. In this dissertation project, participants regulated their pain successfully irrespective of their matching ER styles. Interestingly, there were significant associations between accepting and reappraising ER styles and regulatory success with the other respective strategy. As discussed in the previous section, acceptance and reappraisal are positioned very closely to each other in the emotion-generative process of the process model by Gross (1998b) and share conceptual similarities. Therefore, participants could have found adapting the other respective strategy to be easier, leading to increased regulatory success. Adamczyk et al. (2020) argued that reappraisal involves various mental processes that are cognitively demanding and therefore lead to attenuated emotional responses. They refer to these processes as "understanding" and "elaborating", which take place before the actual cognitive change is executed. Considering our extended process model (see Figure 5.1), these processes could be placed at the position "encoding" in the emotion-generative process – similar to mindfulness. Accordingly, Webb et al. (2012) classified acceptance- and mindfulness-based approaches as reappraisal strategies in their meta-analysis. Thus, reappraisal and acceptance appear to share similar underlying mechanisms, such as elaborating/encoding an emotion-eliciting event. Remarkably, participants with an accepting ER style seemed to have difficulties implementing distraction in study 3. This result underlines the opposing constructs of acceptance and distraction.

One trait factor linked to better pain processing (Boselie et al., 2014; Geers et al., 2008; Hanssen et al., 2013) and emotion regulation (Scheier et al., 1986) is optimism. Thus, we expected optimistic participants to regulate more successfully with all three strategies than less optimistic participants. We assessed optimism and pessimism with the Life-Orientation-Test Revised (LOT-R) (Scheier et al., 1994) and could confirm this hypothesis partially. Study 1 did not yield any connections between optimism and regulatory success, possibly due to the small sample. However, studies 2 and 3 revealed strong associations between optimism and regulatory success with acceptance. More precisely, the more optimistic the participants were, the better they regulated with acceptance and the less unpleasant they perceived the short heat pain and the electrical pain. This finding is in line with Scheier et al. (1986), who found a relationship between acceptance, optimism, and stressful events. Conclusively, optimism facilitates regulatory success with acceptance that mainly impacts the affective pain dimension. Moreover, there were negative associations for distraction and reappraisal with pessimism. These findings suggest that optimism might enhance pain regulation in general but especially with acceptance. Nevertheless, future research should integrate optimism to validate possible connections further when investigating pain regulation. According to Basten-Günther et al. (2019), whether optimists perceive the pain as controllable or threatening impacts their attention, targeting it either away from negative aspects or focusing more on the pain. Moreover, optimists appear to adapt their pain regulation flexibly to the context (Geers et al., 2008). Therefore, the connection between optimism and pain regulation should be investigated with different pain regulation strategies while varying pain durations and modalities.

Another trait factor – resilience – has been considered a protective factor of developing chronic pain (Goubert & Trompetter, 2017; Hemington et al., 2017). Thus, we assumed that resilience could also facilitate pain regulation. We expected that resilient participants would regulate better with any of the three strategies. We captured psychological resilience with the Resilience Scale 11 (RS-11)

(Schumacher et al., 2005; Wagnild & Young, 1993). Surprisingly, the first two studies of this dissertation project did not reveal any associations between resilience and pain regulation. However, study 3 showed that highly resilient participants downregulated the short heat pain unpleasantness significantly better with acceptance and tendentially worse with distraction. The connection between resilience and acceptance is in line with Ramirez-Maestre et al. (2014), who also found a strong correlation between resilience and an accepting ER style in chronic pain patients. This relationship is not surprising considering the similarities between resilience and psychological flexibility concepts. More specifically, resilience describes the ability to flexibly adapt to complex or challenging life experiences (VandenBos & APA, 2015) and therefore appears to include psychological flexibility that can be obtained by, e.g., acceptance (see 1.2.2.). However, the negative correlation between distraction and resilience is less conclusive. Highly resilient participants seemed to have difficulties implementing distraction in our third study. One explanation could be that the resilient participants in our study would have implemented another strategy than distraction to regulate their pain but had no choice due to the group assignment. In contrast, acceptance appeared more natural to the resilient participants. The impact of resilience on pain regulation effectiveness should be further investigated in future studies.

Finally, religiousness and spirituality have been linked to effective ER, especially with acceptance and reappraisal (Prati & Pietrantoni, 2009; Vishkin et al., 2019). Therefore, we assumed that having a religious or spiritual orientation would increase the regulatory success with acceptance and reappraisal but not distraction. Thus we assessed the self-reported aspects of spirituality with the Second Version of the Aspects of Spirituality Questionnaire (ASP 2.1) (Büssing et al., 2014). In studies 1 and 3 of this dissertation project, participants that interacted consciously with their surroundings regulated better with acceptance and tendentially reappraisal. However, study 2 only revealed a tendency between conscious interaction and distraction but not acceptance. Overall, only study 3 revealed significant associations, indicating that spirituality facilitated pain regulation with acceptance and religious orientation facilitated pain regulation with reappraisal. The link between spirituality, measured via the subscale conscious interaction, and acceptance appears logical considering that interacting consciously and mindfully are very similar concepts. Even though the findings remain relatively inconclusive, they suggest that being spiritually or religiously oriented might help with effective pain regulation. These associations, however, need to be investigated thoroughly in future research.

Ultimately, correlational analyses revealed a series of interesting insights. First of all, our results indicate that ER styles seem to play a minor role in the effectiveness of pain regulation strategies, which appear to be easily learned regardless of the ER style. Moreover, our results suggested similar underlying mechanisms of reappraisal and acceptance, possibly located at our newly introduced “encoding” point in the emotion-generative process (see 5.1.3). Second, results implied that higher trait optimism could improve general pain regulation, especially with acceptance. Third, higher trait resilience led to better pain regulation with acceptance but worse with distraction, suggesting that resilient participants could adapt their regulation strategy flexibly. Finally, spirituality appears to enhance effectivity with acceptance and religiosity with reappraisal; however, still more research is needed.

5.2. General limitations and outlook

Several limitations of the conducted studies need to be addressed. One limitation regarding our design might be similarities between the acceptance and the control condition instructions. We instructed the participants to "try to sense the pain and react to it as it is" in the control condition to trigger a usual pain reaction. We further included in both conditions the phrases "Do not distract yourself. Do not change or control your sensations in any way." to prevent the usage of any form of distraction or reappraisal. Moreover, we tried to match the two instructions in length and content as much as possible to minimize variance. However, one could argue that mindfully accepting the pain (acceptance condition) and trying to sense the pain and react to it as it is (control condition) could also have content-related similarities. Nevertheless, the acceptance instruction additionally included the concepts of mindfulness and defusion. To clarify the purpose and comprehension of acceptance and exemplify the instructions, we added the "clouds in the sky" metaphor, used by Kohl et al. (2013), as an example of defusion. Participants indicated in the MCS that the control condition instructions were significantly more comprehensible than the acceptance instructions in studies 1 and 2, and their implementation was significantly more successful than acceptance in studies 1 and 3. Moreover, they implemented acceptance still rather successfully, indicated by ratings over 6 (NRS 1-9) in all studies. Thus, it appears that the participants differentiated between the two conditions while being able to implement both of them. This distinction is also reflected in our results through the self-reported as well as autonomic pain measures. Future research should work on a more distinct neutral control condition without fostering other regulation strategies or spontaneous coping and, e.g., omitting possible confounding instructions such as "try just to sense the pain".

Another concern regarding the within-subjects design could be possible carry-over effects between conditions. Participants could have started using the recently learned strategies in the control condition, which could have been prevented with a between-subjects design. However, this would have been at the cost of controlling for intraindividual differences in, e.g., regulatory abilities, pain processing, and autonomic responding. Moreover, the previously mentioned distinction reflected in our results and the MCS suggests that no or minimal carry-over effects occurred in our studies. As it is inevitable that participants might use strategies other than the one instructed regardless of within- or between-subjects designs (Cioffi & Holloway, 1993), it is crucial to assess all possibilities carefully in a manipulation check and exclude participants that did not follow the instructions. The manipulation check we used could be refined in future research. Admittedly, we did not assess whether acceptance was correctly implemented during other conditions in the MCS, while we included distraction and reappraisal. Thus, the implementation of acceptance should also be assessed in future studies. Furthermore, it could be worthwhile including additional strategies in the manipulation check other than the assessed ones, such as suppression, to capture and control for a broader range pain regulation.

Expectancy or demanding effects certainly affected our outcomes, whether deliberately as underlying mechanisms of the ER strategies themselves, or randomly from being triggered by the instructions, the design, or the experimental setting. Our study design did not mask the regulation strategies in a way that expectations towards a particular pain regulation outcome were possible. We even informed the participants about the distinction between regulation strategies and the control condition. In particular, we informed them before the experiment that the control condition "involves no strategy use" while the other conditions involve strategies that they should apply. These instructions alone presumably led to the expectation that strategies should impact the pain perception in a decreasing manner while the control condition should not. Moreover, we only asked the participants how well they regulated after each strategy condition, which could have amplified the expectations.

However, expectations alone cannot explain the effectiveness of pain regulation strategies. For example, the regulation strategy suppression can even increase pain perception and hamper recovery from pain (Masedo & Esteve, 2007; Sullivan et al., 1997), even though participants might have assumed that it would be an effective regulation strategy. Atlas and Wager (2012) reviewed that a verbally instructed placebo analgesia – the expectation of an intervention to relieve pain – affected self-reported pain less effectively than observed or conditioned placebo analgesia. They further raised the question of whether expectancy effects could be a result of cognitive control. They specified their assumption by comparing expectancy effects with attentional control. More particularly, the authors suggested that individuals might focus their attention to the pain directly, when necessary and when feeling unsafe. However, when feeling safe due to a presumed treatment, they might deploy their focus. Furthermore, expectations are considered active mechanisms of pain regulation. In their review, De Raedt and Hooley (2016) concluded that a positive expectation of one's ER abilities could lead to an anticipatory, proactive regulation, resulting in more efficient emotion regulation. Fardo et al. (2015) suggested that expectations are connected to reappraisal and could constitute an underlying mechanism of the strategy. Furthermore, reappraisal might involve expectations not only targeting the evaluation of the pain itself but the expectations towards it (Adamczyk et al., 2020; Fardo et al., 2015). Moreover, reappraisal has been shown to initiate cognitive control in situations perceived as controllable instead of threatening (Wiech et al., 2008). In another review, Zeidan and colleagues (2012) concluded that mindfulness meditation reduces the influence of the expectation of an upcoming pain, which is accomplished by not elaborating – or not judging – the pain. Thus, expectations appear to be one of the underlying mechanisms of some strategies, such as reappraisal and acceptance, fostering effective ER. Nevertheless, it is unlikely they are the only mechanisms leading to effective pain regulation. However, it would be worthwhile incorporating expectations systematically in future studies to figure out to what extent they impact pain regulation. For example, they could be assessed via questionnaires before the experiment.

There are further a few considerations regarding our choice of measurements. First of all, we already mentioned that the assessment of the sensory and affective pain dimensions could be expanded, especially when the strategy acceptance is investigated. Moreover, investigating similar research questions with a chronic pain population might lead to the difficulty that especially pain intensity or unpleasantness cannot be controlled (Ysidron et al., 2021). It could be more beneficial to include measures targeting pain-specific resilience, behavior, cognitive load, or values-based action.

Pain-specific resilience refers to enhanced physical and emotional functioning despite experiencing pain (Slepian et al., 2016). Slepian et al. (2016) developed the Pain Resilience Scale that assesses the perceived ability to regulate emotions and cognition, as well as the behavioral and motivational persistence when experiencing prolonged and high levels of pain. Furthermore, they showed that the Pain Resilience Scale reliably predicted acute, experimental pain in a healthy sample. This dissertation project aimed at investigating regulation strategies in an acute pain context, so assessing pain-specific resilience instead of general resilience might have been more appropriate. More specifically, the Pain Resilience Scale appears to be better suited than the RS-11 and should be considered in future pain regulation research.

As acceptance contradicts experiential avoidance (Hayes et al., 2006), it is conclusive that acceptance appears to be superior to other strategies in pain tolerance tasks (Kohl et al., 2012). Feldner et al. (2006) investigated experiential avoidance and included a measure of ***pain endurance*** in their pain tolerance task. They calculated pain endurance as the difference between the points in time when the pain threshold was achieved and when the pain tolerance was achieved. This method could also be helpful when investigating acceptance-based strategies. Moreover, Feldner et al. (2006) calculated ***pain recovery*** as a difference between pain intensity ratings during the pain tolerance task and 10 s after the task. Interestingly, they showed that experiential avoidance predicted pain tolerance, endurance, and recovery but not pain threshold or intensity. Their findings support our suggestion of including other pain measures according to the theoretical concept behind acceptance and experiential avoidance (see 1.2.2.1). Furthermore, we argued in the discussion of study 3 (see 4.4) that acceptance might actually target neither the sensory nor the affective pain component. Instead, acceptance appears to target pain endurance in experimental tolerance tasks (Kohl, 2012) and focus on the values-based engagement in daily life activities in chronic pain interventions (Kohl et al., 2014; Kratz et al., 2017; Vowles et al., 2007). Therefore, investigating these mechanisms according to the theoretical concept directly in future studies could be revealing.

Consistent with the theoretical concept of acceptance would be the integration of ***values-based tasks*** into pain regulation research. Such values-based tasks have been included in studies (Gutierrez et al., 2004; Paez-Blarrina et al., 2008a; Paez-Blarrina et al., 2008b) comparing acceptance-based and control-based approaches (see 1.3.3.4.). According to Hayes et al. (2006), acceptance promotes values-based action or, in other words, the engagement in activities according to personal goals despite external circumstances such as pain (McCracken & Vowles, 2008). Gutierrez et al. (2004) were one of the first to include a motivational context to the acceptance-based approach by including a valuable goal to motivate the participants to continue working through a pain task consisting of series of electrical pain stimulation. They showed that participants who received a motivation for tolerating pain did so even longer after learning an acceptance-based but not a control-based protocol. However, these methods have not been used for investigating acceptance as a core mechanism, let alone other ER strategies in the context of pain. Nevertheless, values and goals might also interact with other regulatory processes in different ways. Therefore, integrating them into experimental designs could bring further insights for pain regulation research in general.

Research on pain regulation could further include ***cognitive tasks***. According to the process model of ER (see 1.2.1) and current information-processing models (Lang, 2000; Sheppes & Gross, 2011), emotion regulation is more effective when the cognitive load during the strategy implementation is low and, therefore, less cognitive resources are consumed (Gross, 2002; John & Gross, 2004). The process-specific hypothesis (Sheppes & Gross, 2011) states that the cognitive load might indicate whether a strategy is initiated early or late in the emotion-generative process (see 1.2.4) for more details). More specifically, the earlier a strategy is initiated, the less cognitive resources are consumed. Thus, the availability of cognitive resources is a crucial component of effective emotion regulation (Sheppes & Gross, 2013) and, consequently, pain regulation. Therefore, early ER strategies might be less affected by, e.g., higher pain levels than late ER strategies. These temporal dynamics have been investigated mainly by varying the cognitive load by manipulating, e.g., emotional intensities or measuring the time course of physiological or electrocortical indices (see 1.2.4). In this dissertation project, we aimed to investigate the temporal dynamics of the regulation strategies by varying the pain stimulus duration and capturing the timing of the autonomic pain correlates to draw conclusions about their underlying mechanisms and positions in the process model of ER. However, cognitive tasks might examine the consumption of cognitive resources more directly and practically. Nevertheless, such tasks have been mainly used for investigating distraction as they functioned as passive distractors from pain (Buhle & Wager, 2010; Van Damme et al., 2008). However, it could be worthwhile to incorporate, e.g., Stroop or memory tasks in between pain tasks to directly determine possible impacts on the cognitive resources and measure the cognitive load. Previous studies (Sheppes & Meiran, 2008; Thiruchselvam et al., 2011) included such methods to compare reappraisal and distraction by inducing sadness via film clips. They showed that reappraisal led to impaired cognitive resources when initiated late, whereas distraction only impaired memory when initiated late. Ysidron et al. (2021) captured the cognitive performance on a short-term memory task while simultaneously inducing experimental pressure pain to draw conclusions regarding associations with pain resilience and pain catastrophizing assessed previously. Higher resilient and less pain catastrophizing participants showed greater task performance, indicating less impaired executive functioning despite the pain experience. These forms of cognitive tasks could also be employed in pain regulation research, serving as an indicator of cognitive load. Another method which could provide insights about cognitive load is integrating reaction time tasks. If and how these methods could be translated to pain regulation research should be further explored.

Whether using the autonomic measures HR and SC as psychophysiological correlates of pain is suitable as pain regulation measures should be examined in future research. Heart rate variability (HRV) is a promising index to measure ER (Appelhans & Luecken, 2008). In this dissertation project, we forwent the calculation of HRV that requires an interval of a minimum of 10 s (Shaffer & Ginsberg, 2017) due to the analysis of smaller time intervals as we aimed to capture temporal dynamics of the autonomic measures very thoroughly. Furthermore, we did not assess any baseline HRV, which can indicate regulatory capacity or strength (Evans et al., 2014). In a study by Evans et al. (2014), baseline HRV predicted pain tolerance for the control group involving spontaneous coping but not for the mindfulness group, probably due to unfamiliarity with the strategy. They further suggested that baseline HRV might capture the regulatory endurance rather than strength. These assumptions should be further investigated in the pain regulation context by assessing baseline HRV, which could add to the pain endurance measurement we suggested in the preceding paragraph. Cortisol levels could also reflect pain regulation effectiveness or even resilience. Choi et al. (2012) induced stress in healthy participants and administered electrical pain. They showed that the heightened stress led to increased pain ratings and pain thresholds, decreased salivary testosterone levels, and increased salivary cortisol levels. They concluded that acute pain could be managed by controlling stress levels. Mindfulness programs have proven to reduce stress, while cortisol was suggested as a physiological marker for stress (Matousek et al., 2010). Moreover, there have been indices of an association between high trait resilience and lower cortisol levels before a stressful event (Mikolajczak et al., 2008; Sturgeon & Zautra, 2010). Thus, it might be worthwhile to investigate the connections between acceptance- or mindfulness-based strategies, stress and resilience, and pain perception. Consequently, future pain regulation research should explore promising psychophysiological measures such as HRV or cortisol levels to provide further insight into underlying mechanisms of regulation strategies.

Finally, we assessed a mainly well-educated sample consisting of young, healthy adults in all three studies, limiting generalizability to a greater population. For example, age has been shown to impact emotion and pain regulation (Piira et al., 2006; Scheibe et al., 2015), so our results cannot be translated to a younger or older population. The generalizability to a clinical pain population is limited as well. However, Arendt-Nielsen and Yarnitsky (2009) argued that experimental pain induction with a healthy population could serve as a model for clinically relevant pain conditions. Moreover, investigating chronic pain involves challenges such as different pain levels, severity, and locations, which can be controlled by systematically inducing pain in a healthy sample. Thus, using a non-clinical population for investigating underlying mechanisms of pain regulation can be beneficial but should be reproduced with chronic pain patients. Conclusively, the strategies acceptance, distraction, and reappraisal should be implemented with chronic pain patients to unravel different dynamics and warrant transferability.

Another limitation impairing generalizability is the use of electrical pain stimulation in the last two studies of this project. According to Staahl and Drewes (2004), electrical pain does not simulate pain conditions efficiently. Then again, electrical stimuli were suited very well to produce very brief pain stimuli of 20 ms in our studies, which was not possible with our Somedic MSA thermal stimulator. However, heat pain appears to be better suited for simulating pain conditions. Thus, future research might integrate equipment with a more rapid heating rate, e.g., the contact heat-evoked potential stimulator (CHEPS, Medoc, Israel) (Horn-Hofmann et al., 2018) to investigate mechanisms for very brief pain. Moreover, sample sizes in this project were optimized for the analyses comparing means instead of analyses involving correlations. However, correlational analyses yielded promising indications that should be further investigated with larger samples.

5.3. Conclusion

In conclusion, this dissertation project provided insights into the effectiveness and the underlying mechanisms of the ER strategy acceptance on acute pain. We could show with three consecutive studies that acceptance effectively reduced the acute pain perception of different durations and partially their psychophysiological markers, especially skin conductance. The strategies distraction and reappraisal yielded similar results, while the three strategies, including acceptance, did not differ significantly from each other. Based on our results and especially the similarities between the strategies, we propose an extension of the process model of ER by Gross (1998b). More specifically, we added the time point “encoding” to the emotion-generative process. We further suggested that the underlying mechanism of acceptance named mindfulness would be placed at this point as an emotion-eliciting situation would be encoded but not evaluated. Moreover, as acceptance appears to consist of various mechanisms, such as counteracting avoidance and attending to the situation consciously, we proposed that acceptance also affects the points “situation selection” and “attentional deployment” in the emotion-generative process. We further concluded that acceptance might have the ability to flexibly adapt to the context, fitting to its subordinate concept of psychological flexibility (Hayes et al., 2006). Correlational analyses support this assumption by providing a relationship between resilience and acceptance in our third study. The concepts of psychological flexibility and resilience are very similar, suggesting that acceptance could enhance them. Translating this inference to pain regulation, acceptance could therefore serve as a protective factor or resilience mechanism protecting from the development of chronic pain (Kröner-Herwig, 2017). Thus, acceptance can be considered an adaptive ER strategy, improving pain management abilities (Koechlin et al., 2018). Hence, integrating acceptance-based training could improve chronic pain interventions and treatments. Future research should further investigate circumstances that foster and facilitate acceptance strategies by integrating a greater variety of pain models and measurements.

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Appendix

Appendix A Studies 1-3: Questionnaire on sociodemographic information.

Lehrstuhl für Psychologie I, Marcusstr. 9-11, 97070 Würzburg

VP-Nummer: ____________
Datum: ____________________

DEMOGRAPHISCHE ANGABEN

1. Alter: _________

2. Geschlecht: □ weiblich □ männlich

3. Familienstand □ ledig □ verheiratet □ in Lebensgemeinschaft lebend
□ geschieden □ verwitwet □ getrennt lebend

4. Schulabschluss: ____

5. Berufsstand: □ erziehend □ berufstätig □studierend □ arbeitslos □ in Ausbildung

6. Gelernter Beruf/Auszubildend in/Studiengang:__________________________

7. Muttersprache: __________________

8. Händigkeit: □ rechts □ links

9. Raucher: □ ja □ nein Zigaretten/ Tag: _______ letzte Zigarette vor___ Stunden

10. Chronische Erkrankungen / Allergien:____
____

11. Chronische Schmerz-Erkrankungen:____
____

12. Akute Erkrankungen: ____

13. Letzte Menstruation vor _____ Tagen

14. Letzter Koffeinkonsum vor ___Stunden

15. Schmerzmitteleinnahme in den letzten 24 Stunden: □ ja □ nein

Wenn JA, welche: ____

16. Welche Medikamente (inkl. „Pille") nehmen Sie regelmäßig ein?
____

17. Welche Medikamente haben Sie in den letzten 24 Stunden eingenommen (mit Mengenangaben):
____
____

18. Haben Sie im Moment Schmerzen? □ ja □ nein

3.Wenn Ja, welche Art von Schmerzen: ____
____

4.Bitte beurteilen Sie die Stärke Ihrer momentanen Schmerzen mit Hilfe der unteren Skala. Kreuzen Sie hierzu die Skala an der Stelle an, die Ihrer aktuellen Schmerzempfindung am ehesten entspricht.

|-------|-------|-------|-------|-------|-------|-------|-------|-------|
0 1 2 3 4 5 6 7 8 9
| |
kein Schmerz der stärkste Schmerz, den ich mir vorstellen kann

19. Wie schätzen Sie Ihre Bewältigungskompetenz gegenüber Schmerzen ein? (soll heißen: Glauben Sie, mit Schmerzen umgehen zu können oder sorgen Sie sich darum, von den Schmerzen überwältigt zu werden?)

|-------|-------|-------|-------|-------|-------|-------|-------|-------|
0 1 2 3 4 5 6 7 8 9
| |
Kann gar nicht damit umgehen habe keine Probleme im Umgang mit Schmerzen

20. Ich finde Schmerzen jedweder Art unerträglich □ ja □ nein

Appendix B Study 1: Participant information and informed consent.

Julius-Maximilians-
UNIVERSITÄT
WÜRZBURG

Lehrstuhl für Psychologie I - Prof. Dr. Paul Pauli
Biologische Psychologie, Klinische Psychologie und Psychotherapie

Dr. Matthias Wieser & Dr. Philipp Reicherts
(Lehrstuhl für Psychologie I, Arbeitsgruppe Prof. Dr. Paul Pauli, Marcusstr. 9-11, 97070 Würzburg)
Tel.: 0931-31 2426

Informationsblatt

Titel der Studie: ***Der Einfluss von kognitiven Strategien auf die Schmerzwahrnehmung***

Forschungsprojekt: **"Emotion und Schmerz: Neuronale Grundlagen der Schmerzmodulation durch reflektive und impulsive Prozesse" im Rahmen der Forschergruppe Emotion und Verhalten: Reflektive und impulsive Prozesse (DFG)**

Ziel der Untersuchung:
Diese Studie untersucht die Wirkung von kognitiven Strategien auf Ihr Schmerzempfinden. Sie werden aus der Teilnahme keinen unmittelbaren Nutzen für sich ziehen können. Wir hoffen jedoch, dass die Ergebnisse zur Aufklärung der Beziehung zwischen unterschiedlichen Strategien und Schmerz beitragen, was z. B. für Schmerzpatienten sehr wichtig sein könnte.

Ablauf der Untersuchung:
Es wird untersucht, inwiefern die persönliche Schmerzempfindung vom Einsatz unterschiedlicher Strategien beeinflusst wird. Dazu sollen Sie zunächst einige Fragebögen ausfüllen, in denen wichtige Daten bezüglich Ihrer Person festgehalten werden. Während der Untersuchung werden Sie Hitzereize am Unterarm verabreicht bekommen. Die thermischen Reize sollen leicht schmerzhaft sein und sind von kurzer Dauer.
Nach jedem Durchgang sollen Sie angegeben, wie intensiv bzw. unangenehm Sie den Hitzereiz empfunden haben.
Damit Sie sich den Untersuchungsablauf vorstellen können, präsentieren wir Ihnen Beispiele für die Hitzereize und lassen Sie einen Übungsdurchlauf machen. Die Stärke der thermischen Reize wird individuell ermittelt und vor Versuchsbeginn anhand ihrer persönlichen Schmerzschwelle festgelegt. Die thermischen Reize sollen dabei lediglich leicht schmerzhaft für Sie sein. Insgesamt wird die Untersuchung ungefähr 1,5 Stunden dauern.
Die schmerzhaften thermischen Reize könnten bei Ihnen unangenehme Empfindungen hervorrufen, die aber normalerweise nur von kurzer Dauer sind. Die thermischen Reize können zu Hautrötungen führen, die in der Regel aber nach kurzer Zeit wieder abklingen. In seltenen Fällen kann es unter Verwendung der Apparatur auch zu leichten Verbrennungen kommen, die Gestaltung des Experiments beugt dieser Folge aber weitestgehend vor. Sollten Sie während der Untersuchung Beschwerden oder unangenehme Empfindungen haben, so sagen Sie es bitte sofort der Versuchsleiterin.

Wir weisen Sie ausdrücklich darauf hin, dass diese Untersuchung ausschließlich psychologischer Grundlagenforschung dient und ein unmittelbarer Nutzen für Sie durch die Teilnahme nicht zu erwarten ist.

Die Teilnahme an der Untersuchung ist völlig freiwillig. Sie können jederzeit - ohne Angabe von Gründen - die Teilnahme abbrechen. Alle Daten, die erhoben werden, dienen ausschließlich Forschungszwecken, werden vertraulich behandelt und ohne Angabe des Namens unter einer Codenummer abgespeichert. Das Blatt mit Ihren persönlichen Angaben wird nach der Erhebung vom Fragebogen getrennt und gesondert aufbewahrt, so dass eine Zuordnung nur noch über den gemeinsamen Code möglich ist. Sollte nicht vorher gezielt die Löschung der Daten verlangt werden, werden diese für unbestimmte Zeit für wissenschaftliche Analysen aufbewahrt.

Bei Unklarheiten oder Fragen wenden Sie sich bitte jeder Zeit an die Versuchsleitung.

Einverständniserklärung

Ich habe das Informationsblatt zur Studie „***Der Einfluss von kognitiven Strategien auf die Schmerzwahrnehmung***" ausführlich gelesen und verstanden. Ich bin darüber informiert worden, dass ich jederzeit aus der Untersuchung ausscheiden kann, ohne dass mir persönliche Nachteile entstehen.

Ich willige ein, an der Untersuchung teilzunehmen und erkläre mich damit einverstanden, dass meine Daten zu Forschungszwecken verwendet und anonym gespeichert werden.

Würzburg, den:………………………… Unterschrift:………………………………………………..

Geburtsdatum:…………………………

Name und Anschrift (Druckschrift): ……………………………………………………………………
……………………………………………………………………
……………………………………………………………………

Unterschrift der Untersuchungsleitung: ……………………………………

Appendix C Study 2: Participant information and informed consent.

Julius-Maximilians-
UNIVERSITÄT
WÜRZBURG

Lehrstuhl für Psychologie I - Prof. Dr. Paul Pauli
Biologische Psychologie, Klinische Psychologie und Psychotherapie

Prof. Dr. Matthias Wieser[1], Dr. Philipp Reicherts[2] & Valentina Haspert[2]
([1]Institute of Psychology (IOP), Faculty of Social Sciences, Erasmus University Rotterdam, [2]Lehrstuhl für Psychologie I, Arbeitsgruppe Prof. Dr. Paul Pauli, Universität Würzburg)
Tel.: 0931-3185496

Informationsblatt

Titel der Studie: ***Der Einfluss von kognitiven Strategien auf die Schmerzwahrnehmung***

Forschungsprojekt **"Emotion und Schmerz: Neuronale Grundlagen der Schmerzmodulation durch reflektive und impulsive Prozesse" im Rahmen der Forschergruppe Emotion und Verhalten: Reflektive und impulsive Prozesse (DFG)**

Ziel der Untersuchung:
Diese Studie untersucht die Wirkung von kognitiven Strategien auf Ihr Schmerzempfinden. Sie werden aus der Teilnahme keinen unmittelbaren Nutzen für sich ziehen können. Wir hoffen jedoch, dass die Ergebnisse zur Aufklärung der Beziehung zwischen unterschiedlichen Strategien und Schmerz beitragen, was z. B. für Schmerzpatienten sehr wichtig sein könnte.

Ablauf der Untersuchung:
Es wird untersucht, inwiefern die persönliche Schmerzempfindung vom Einsatz unterschiedlicher Strategien beeinflusst wird. Dazu sollen Sie zunächst einige Fragebögen ausfüllen, in denen wichtige Daten bezüglich Ihrer Person festgehalten werden. Während der Untersuchung werden Sie Hitzereize am Unterarm und elektrische Reize am Unterschenkel verabreicht bekommen. Die Reize sollen leicht schmerzhaft sein, sie sind aber von kurzer Dauer und absolut ungefährlich.
Nach jedem Durchgang sollen Sie angegeben, wie intensiv bzw. unangenehm Sie den Hitzereiz empfunden haben.
Damit Sie sich den Untersuchungsablauf vorstellen können, präsentieren wir Ihnen Beispiele für die Hitzereize und elektrischen Reize und lassen Sie einen Übungsdurchlauf machen. Die Stärke der thermischen und elektrischen Reize wird individuell ermittelt und vor Versuchsbeginn anhand ihrer persönlichen Schmerzschwelle festgelegt. Die thermischen und elektrischen Reize sollen dabei lediglich leicht schmerzhaft für Sie sein. Insgesamt wird die Untersuchung ungefähr 2 Stunden dauern.
Diese Reize können bei Ihnen unangenehme Empfindungen und in seltenen Fällen auch Hautrötungen hervorrufen, die aber normalerweise nur von kurzer Dauer sind und in der Regel nach wenigen Minuten wieder abklingen. In seltenen Fällen kann es unter Verwendung der thermischen Apparatur auch zu leichten Verbrennungen kommen, die Gestaltung des Experiments beugt dieser Folge aber weitestgehend vor. Sollten Sie während der Untersuchung Beschwerden oder unangenehme Empfindungen haben, so sagen Sie es bitte sofort der Versuchsleiterin.

Wir weisen Sie ausdrücklich darauf hin, dass diese Untersuchung ausschließlich psychologischer Grundlagenforschung dient und ein unmittelbarer Nutzen für Sie durch die Teilnahme nicht zu erwarten ist.

Die Teilnahme an der Untersuchung ist völlig freiwillig. Sie können jederzeit - ohne Angabe von Gründen - die Teilnahme abbrechen. Alle Daten, die erhoben werden, dienen ausschließlich Forschungszwecken, werden vertraulich behandelt und ohne Angabe des Namens unter einer Codenummer abgespeichert. Das Blatt mit Ihren persönlichen Angaben wird nach der Erhebung vom Fragebogen getrennt und gesondert aufbewahrt, so dass eine Zuordnung nur noch über den gemeinsamen Code möglich ist. Sollte nicht vorher gezielt die Löschung der Daten verlangt werden, werden diese für unbestimmte Zeit für wissenschaftliche Analysen aufbewahrt.

Bei Unklarheiten oder Fragen wenden Sie sich bitte jeder Zeit an die Versuchsleitung.

Einverständniserklärung

Ich habe das Informationsblatt zur Studie ***„Der Einfluss von kognitiven Strategien auf die Schmerzwahrnehmung"*** ausführlich gelesen und verstanden. Ich bin darüber informiert worden, dass ich jederzeit aus der Untersuchung ausscheiden kann, ohne dass mir persönliche Nachteile entstehen.

Ich willige ein, an der Untersuchung teilzunehmen und erkläre mich damit einverstanden, dass meine Daten zu Forschungszwecken verwendet und anonym gespeichert werden.

Würzburg, den:………………………… Unterschrift:……………………………………………….

Geburtsdatum:………………………….

Name und Anschrift (Druckschrift): ……………………………………………………………………

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Appendix D Study 3: Participant information and informed consent.

Julius-Maximilians-
UNIVERSITÄT
WÜRZBURG

Lehrstuhl für Psychologie I - Prof. Dr. Paul Pauli
Biologische Psychologie, Klinische Psychologie und Psychotherapie

Dr. Matthias Wieser & Dr. Philipp Reicherts
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Tel.: 0931-31 2426

Informationsblatt

Titel der Studie: ***Der Einfluss von kognitiven Strategien auf die Schmerzwahrnehmung***

Forschungsprojekt: **"Emotion und Schmerz: Neuronale Grundlagen der Schmerzmodulation durch reflektive und impulsive Prozesse" im Rahmen der Forschergruppe Emotion und Verhalten: Reflektive und impulsive Prozesse (DFG)**

Ziel der Untersuchung:
Diese Studie untersucht die Wirkung von kognitiven Strategien auf Ihr Schmerzempfinden. Sie werden aus der Teilnahme keinen unmittelbaren Nutzen für sich ziehen können. Wir hoffen jedoch, dass die Ergebnisse zur Aufklärung der Beziehung zwischen unterschiedlichen Strategien und Schmerz beitragen, was z. B. für Schmerzpatienten sehr wichtig sein könnte.

Ablauf der Untersuchung:
Es wird untersucht, inwiefern die persönliche Schmerzempfindung vom Einsatz unterschiedlicher Strategien beeinflusst wird. Dazu sollen Sie zunächst einige Fragebögen ausfüllen, in denen wichtige Daten bezüglich Ihrer Person festgehalten werden. Während der Untersuchung werden Sie kurze und etwas längere Hitzereize am Unterarm verabreicht bekommen. Die thermischen Reize sollen leicht schmerzhaft sein.
Nach jedem Durchgang sollen Sie angegeben, wie intensiv bzw. unangenehm Sie den Hitzereiz empfunden haben.
Damit Sie sich den Untersuchungsablauf vorstellen können, präsentieren wir Ihnen Beispiele für die Hitzereize und lassen Sie einen Übungsdurchlauf machen. Die Stärke der thermischen Reize wird individuell ermittelt und vor Versuchsbeginn anhand ihrer persönlichen Schmerzschwelle festgelegt. Die thermischen Reize sollen dabei lediglich leicht schmerzhaft für Sie sein. Insgesamt wird die Untersuchung ungefähr 2 Stunden dauern.
Die schmerzhaften thermischen Reize könnten bei Ihnen unangenehme Empfindungen hervorrufen, die aber normalerweise nur von kurzer Dauer sind. Die thermischen Reize können zu Hautrötungen führen, die in der Regel aber nach kurzer Zeit wieder abklingen. In seltenen Fällen kann es unter Verwendung der Apparatur auch zu leichten Verbrennungen kommen, die Gestaltung des Experiments beugt dieser Folge aber weitestgehend vor. Sollten Sie während der Untersuchung Beschwerden oder unangenehme Empfindungen haben, so sagen Sie es bitte sofort der Versuchsleiterin.

Wir weisen Sie ausdrücklich darauf hin, dass diese Untersuchung ausschließlich psychologischer Grundlagenforschung dient und ein unmittelbarer Nutzen für Sie durch die Teilnahme nicht zu erwarten ist.

Die Teilnahme an der Untersuchung ist völlig freiwillig. Sie können jederzeit - ohne Angabe von Gründen - die Teilnahme abbrechen. Alle Daten, die erhoben werden, dienen ausschließlich Forschungszwecken, werden vertraulich behandelt und ohne Angabe des Namens unter einer Codenummer abgespeichert. Das Blatt mit Ihren persönlichen Angaben wird nach der Erhebung vom Fragebogen getrennt und gesondert aufbewahrt, so dass eine Zuordnung nur noch über den gemeinsamen Code möglich ist. Sollte nicht vorher gezielt die Löschung der Daten verlangt werden, werden diese für unbestimmte Zeit für wissenschaftliche Analysen aufbewahrt.

Bei Unklarheiten oder Fragen wenden Sie sich bitte jeder Zeit an die Versuchsleitung.

Einverständniserklärung

Ich habe das Informationsblatt zur Studie ***„Der Einfluss von kognitiven Strategien auf die Schmerzwahrnehmung"*** ausführlich gelesen und verstanden. Ich bin darüber informiert worden, dass ich jederzeit aus der Untersuchung ausscheiden kann, ohne dass mir persönliche Nachteile entstehen.

Ich willige ein, an der Untersuchung teilzunehmen und erkläre mich damit einverstanden, dass meine Daten zu Forschungszwecken verwendet und anonym gespeichert werden.

Die ergänzende Information für Studienteilnehmer gemäß Europäischer Datenschutz-Grundverordnung (DSGVO) (siehe nächste Seite) habe ich gelesen und zur Kenntnis genommen.

Würzburg, den:………………………… Unterschrift:………………………………………………..

Geburtsdatum:…………………………

Name und Anschrift (Druckschrift): ………………………………………………………………………

………………………………………………………………………

………………………………………………………………………

Appendix E Study 1: MCS

Lehrstuhl für Psychologie I, Marcusstr. 9-11, 97070 Würzburg

VP-Nummer: ________

Datum: ____________________

Nachbefragungsbogen

3.Die Instruktionen zu AKZEPTIEREN waren klar verständlich und ich wusste daraufhin, wie ich vorgehen soll.

Unklar 1-----2------3-----4-----5-----6-----7-----8-----9 Klar

Wenn eher unklar, warum? ____

____

4.Wie gut ist es Ihnen gelungen, die Strategie AKZEPTIEREN anzuwenden?

Gar nicht 1-----2------3-----4-----5-----6-----7-----8-----9 Sehr gut

Wenn eher nicht gelungen, warum? ____

____

5.Die Instruktionen zu WAHRNEHMEN waren klar verständlich und ich wusste daraufhin, wie ich vorgehen soll.

Unklar 1-----2------3-----4-----5-----6-----7-----8-----9 Klar

Wenn eher unklar, warum? ____

____

6.Wie gut ist es Ihnen gelungen, die Instruktionen zu WAHRNEHMEN in die Tat umzusetzen?

Gar nicht 1-----2------3-----4-----5-----6-----7-----8-----9 Sehr gut

Wenn eher nicht gelungen, warum? ____

____

7.Haben Sie versucht, sich von den Hitzereizen abzulenken?

Gar nicht 1-----2------3-----4-----5-----6-----7-----8-----9 Äußerst

Wenn ja, womit?____

____

8.Welcher Konfession bzw. Religionsgemeinschaft gehören Sie gegenwärtig an?

□ katholisch □ evangelisch □ andere, nämlich__________________

□ keiner, ggf. frühere Religionszugehörigkeit ______________________________

9.Einmal abgesehen von Ihren Ansichten über Kirchen und andere religiöse Organisationen: Glauben Sie an eine höhere Wirklichkeit, die man unterschiedlich bezeichnen kann, z. B. Gott (Allah, Jahwe, ...), höheres Wesen, Göttliches, Absolutes?

□ ja, ich glaube an eine solche höhere Wirklichkeit

□ nein, ich glaube nicht an eine solche höhere Wirklichkeit

□ ich bin mir da nicht sicher

10.Welcher der folgenden Begriffe charakterisiert Ihre Glaubenseinstellung am besten?

□ spirituell □ religiös □atheistisch* □ agnostisch** □ unbestimmt

□ keine davon, sondern ______________________

11.Geben Sie bitte an, wie bedeutsam Spiritualität bzw. Religiosität gegenwärtig für Ihr persönliches Leben ist.

□ gar nicht □ wenig □ mittelmäßig □ ziemlich □ sehr

12.Gibt es noch etwas, das Sie uns in Bezug auf die Schmerzreize und/oder die Versuchsinstruktionen mitteilen möchten?

____

____

13.Gibt es noch etwas, das Sie uns in Bezug auf die Untersuchung generell mitteilen möchten?

____

____

14.Worin könnte Ihrer Meinung nach die Versuchsabsicht bestehen?

____

____

Vielen Dank, dass Sie an der Untersuchung teilgenommen haben!

* Ein Atheist ist ein Anhänger des Atheismus – einer Weltanschauung, bei der die Existenz eines Gottes verneint oder verleugnet wird.

** Agnostisch beschreibt eine Person als den Agnostizismus vertretend, d.h. sie hält die Existenz einer Gottheit oder einer anderen höheren Macht für nicht beweisbar. Deren Existenz wird somit nicht verleugnet, aber eben auch nicht für gesichert gehalten.

Quelle: http://neueswort.de

Appendix F Study 2: MCS

Lehrstuhl für Psychologie I, Marcusstr. 9-11, 97070 Würzburg

VP-Nummer: __________

Datum: ______________________________

Nachbefragungsbogen

3.Die Instruktionen zu AKZEPTIEREN waren klar verständlich und ich wusste daraufhin, wie ich vorgehen soll.

Unklar 1-----2------3-----4-----5-----6-----7-----8-----9 Klar

Wenn eher unklar, warum? ____

____

e gut ist es Ihnen gelungen, die Strategie AKZEPTIEREN anzuwenden?

Gar nicht 1-----2------3-----4-----5-----6-----7-----8-----9 Sehr gut

Wenn eher nicht gelungen, warum? ____

____

5.Die Instruktionen zu VORSTELLEN waren klar verständlich und ich wusste daraufhin, wie ich vorgehen soll.

Unklar 1-----2------3-----4-----5-----6-----7-----8-----9 Klar

Wenn eher unklar, warum? ____

____

e gut ist es Ihnen gelungen, die Instruktionen zu VORSTELLEN in die Tat umzusetzen?

Gar nicht 1-----2------3-----4-----5-----6-----7-----8-----9 Sehr gut

Wenn eher nicht gelungen, warum? ____

____

7.Die Instruktionen zu WAHRNEHMEN waren klar verständlich und ich wusste daraufhin, wie ich vorgehen soll.

Unklar 1-----2------3-----4-----5-----6-----7-----8-----9 Klar

Wenn eher unklar, warum? ____

____

e gut ist es Ihnen gelungen, die Instruktionen zu WAHRNEHMEN in die Tat umzusetzen?

Gar nicht 1-----2------3-----4-----5-----6-----7-----8-----9 Sehr gut

Wenn eher nicht gelungen, warum? ____

____

9.Haben Sie versucht, sich von den Schmerzreizen abzulenken?

Gar nicht 1-----2------3-----4-----5-----6-----7-----8-----9 Äußerst

Wenn ja, womit?____

____

10.Welcher Konfession bzw. Religionsgemeinschaft gehören Sie gegenwärtig an?

□ katholisch □ evangelisch □ andere, nämlich____________________

□ keiner, ggf. frühere Religionszugehörigkeit ____________________________________

11.Einmal abgesehen von Ihren Ansichten über Kirchen und andere religiöse Organisationen: Glauben Sie an eine höhere Wirklichkeit, die man unterschiedlich bezeichnen kann, z. B. Gott (Allah, Jahwe, ...), höheres Wesen, Göttliches, Absolutes?

□ ja, ich glaube an eine solche höhere Wirklichkeit

□ nein, ich glaube nicht an eine solche höhere Wirklichkeit

□ ich bin mir da nicht sicher

12.Welcher der folgenden Begriffe charakterisiert Ihre Glaubenseinstellung am besten?

□ spirituell □ religiös □atheistisch* □ agnostisch** □ unbestimmt

□ keine davon, sondern ________________________

13.Geben Sie bitte an, wie bedeutsam Spiritualität bzw. Religiosität gegenwärtig für Ihr persönliches Leben ist.

□ gar nicht □ wenig □ mittelmäßig □ ziemlich □ sehr

* Ein Atheist ist ein Anhänger des Atheismus – einer Weltanschauung, bei der die Existenz eines Gottes verneint oder verleugnet wird.

** Agnostisch beschreibt eine Person als den Agnostizismus vertretend, d.h. sie hält die Existenz einer Gottheit oder einer anderen höheren Macht für nicht beweisbar. Deren Existenz wird somit nicht verleugnet, aber eben auch nicht für gesichert gehalten.

Quelle: http://neueswort.de

ab es einen Schmerzreiz (Hitze vs. elektrisch) den Sie besser regulieren konnten? Wenn ja, welchen und mit welcher Strategie ist es Ihnen am besten gelungen, diesen zu regulieren?

____

____

ibt es noch etwas, das Sie uns in Bezug auf die Schmerzreize und/oder die Versuchsinstruktionen mitteilen möchten?

____

____

16.Gibt es noch etwas, das Sie uns in Bezug auf die Untersuchung generell mitteilen möchten?

____

____

17.Worin könnte Ihrer Meinung nach die Versuchsabsicht bestehen?

____

____

Vielen Dank, dass Sie an der Untersuchung teilgenommen haben!

Appendix G Study 3: MCS

Lehrstuhl für Psychologie I, Marcusstr. 9-11, 97070 Würzburg

VP-Nummer: ____

Datum: ____

Nachbefragungsbogen

3.Die Instruktionen zur STRATEGIE waren klar verständlich und ich wusste daraufhin, wie ich vorgehen soll.

Unklar 1-----2------3-----4-----5-----6-----7-----8-----9 Klar

Wenn eher unklar, warum? ____

gut ist es Ihnen insgesamt gelungen, die STRATEGIE anzuwenden?

Gar nicht 1-----2------3-----4-----5-----6-----7-----8-----9 Sehr gut

Wenn eher nicht gelungen, warum? ____

5.Die Instruktionen zu WAHRNEHMEN waren klar verständlich und ich wusste daraufhin, wie ich vorgehen soll.

Unklar 1-----2------3-----4-----5-----6-----7-----8-----9 Klar

Wenn eher unklar, warum? ____

gut ist es Ihnen gelungen, die Instruktionen zu WAHRNEHMEN in die Tat umzusetzen?

Gar nicht 1-----2------3-----4-----5-----6-----7-----8-----9 Sehr gut

Wenn eher nicht gelungen, warum? ____

7.Haben Sie versucht, sich von den Schmerzreizen abzulenken? (Falls die geforderte Strategie „Vorstellen" war, bitte Frage überspringen)

Nie 1-----2------3-----4-----5-----6-----7-----8-----9 Sehr häufig

Wenn ja, womit? ____

8.Haben Sie versucht, die Schmerzreize zu akzeptieren? (Falls die geforderte Strategie „Akzeptieren" war, bitte Frage überspringen)

Nie 1-----2------3-----4-----5-----6-----7-----8-----9 Sehr häufig

Anmerkung: ____

9.Haben Sie versucht, Ihre Bewertung der Schmerzreize zu verändern? (Falls die geforderte Strategie „Neubewerten" war, bitte Frage überspringen)

Nie 1-----2------3-----4-----5-----6-----7-----8-----9 Sehr häufig

Wenn ja, wie haben Sie die Reize umbewertet? ____

10.Haben Sie versucht, die Schmerzreize zu unterdrücken?

Nie 1-----2------3-----4-----5-----6-----7-----8-----9 Sehr häufig

Anmerkung: ____

11.Haben Sie versucht, noch andere Strategien anzuwenden, als die, die sie anwenden sollten?

Nie 1-----2------3-----4-----5-----6-----7-----8-----9 Sehr häufig

Wenn ja, welche? ____

12. Welche von den folgenden Entspannungsübungen oder -trainings haben Sie schon mal gemacht?

□ keine □ Yoga □ Meditation
□ Achtsamkeit □ andere, nämlich ____

13. Haben Sie die unter Punkt 10 angegebene Entspannungsübung in letzter Zeit (letzten 8 Wochen) geübt? Wenn ja, wie häufig praktizieren Sie diese?

□ keine / nie □ 1-2 x Monat
□ 3-4 x Monat □ 2-3 x Woche □ Häufiger als 3 x Woche

14.Welcher Konfession bzw. Religionsgemeinschaft gehören Sie gegenwärtig an?

□ katholisch □ evangelisch □ andere, nämlich ____
□ keiner, ggf. frühere Religionszugehörigkeit ____

15.Einmal abgesehen von Ihren Ansichten über Kirchen und andere religiöse Organisationen: Glauben Sie an eine höhere Wirklichkeit, die man unterschiedlich bezeichnen kann, z. B. Gott (Allah, Jahwe, ...), höheres Wesen, Göttliches, Absolutes?

□ ja, ich glaube an eine solche höhere Wirklichkeit
□ nein, ich glaube nicht an eine solche höhere Wirklichkeit
□ ich bin mir da nicht sicher

16.Welcher der folgenden Begriffe charakterisiert Ihre Glaubenseinstellung am besten?

□ spirituell □ religiös □atheistisch* □ agnostisch** □ unbestimmt
□ keine davon, sondern ____

17.Geben Sie bitte an, wie bedeutsam Spiritualität bzw. Religiosität gegenwärtig für Ihr persönliches Leben ist.

□ gar nicht □ wenig □ mittelmäßig □ ziemlich □ sehr

* Ein Atheist ist ein Anhänger des Atheismus – einer Weltanschauung, bei der die Existenz eines Gottes verneint oder verleugnet wird.

** Agnostisch beschreibt eine Person als den Agnostizismus vertretend, d.h. sie hält die Existenz einer Gottheit oder einer anderen höheren Macht für nicht beweisbar. Deren Existenz wird somit nicht verleugnet, aber eben auch nicht für gesichert gehalten.

Quelle: http://neueswort.de

t es noch etwas, das Sie uns in Bezug auf die Schmerzreize und/oder die Versuchsinstruktionen mitteilen möchten?

____

19.Gibt es noch etwas, das Sie uns in Bezug auf die Untersuchung generell mitteilen möchten?

____

20.Worin könnte Ihrer Meinung nach die Versuchsabsicht bestehen?

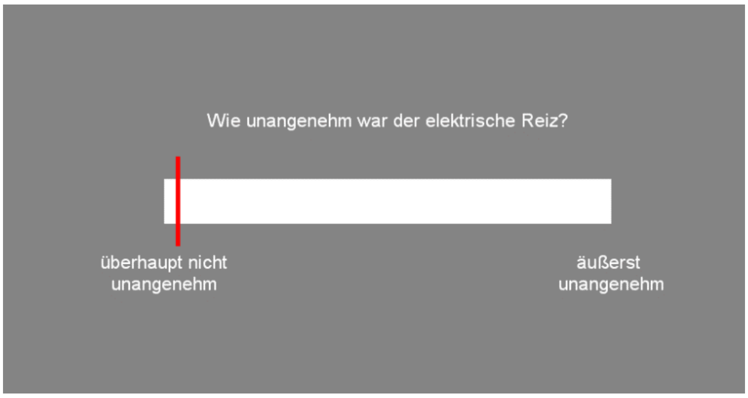
____ **Vielen Dank, dass Sie an der Untersuchung teilgenommen haben!**

Appendix H Example for electrical threshold procedure.

	1. Increasing	2. Decreasing	3. Increasing
…			
2.8 mA			
2.6 mA	5	6	
2.4 mA	**4**	5	5
2.2 mA	4	5	**4**
2.0 mA	4	4	4
1.8 mA	4	4	4
1.6 mA	3	**4**	3
1.4 mA	3	3	3
1.2 mA	3		
1.0 mA	2		

Note. The threshold currents are 2.4 mA for the first sequence (increasing column), 1.6 mA for the second sequence (decreasing column) and 2.2 mA for the third sequence (increasing column). The threshold ratings and currents are marked in bold. The mean threshold current is 2 mA.

Appendix I Studies 1-2: Example of a VRS (pain unpleasantness).



Appendix J Study 3: Example of an NRS (pain unpleasantness).

Publication list

Peer reviewed

Haspert, V., Wieser, M. J., Pauli, P., & Reicherts, P. (2020). Acceptance-Based Emotion Regulation Reduces Subjective and Physiological Pain Responses. *Frontiers in psychology*, 11, 1514. https://doi.org/10.3389/fpsyg.2020.01514

Talks

Haspert, V., Reicherts, P., Pauli, P., & Wieser, M. J. (2017, May). Akzeptanzbasierte Strategien reduzieren die Wahrnehmung von Hitzeschmerz. *Talk at the 19th annual conference "DGPSF 2017" in Hannover.*

Poster presentations

Haspert, V., Reicherts, P., Pauli, P., & Wieser, M. J. (2019, June). How does the effectiveness of pain regulation strategies (acceptance, reappraisal and distraction) vary across pain stimulation of different duration? *Poster presentation at the 45th conference "Psychologie und Gehirn" in Dresden.*

Haspert, V., Reicherts, P., Pauli, P., & Wieser, M. J. (2018, September). Regulating Pain with Acceptance-based Strategies and Distraction. *Poster presentation at the IASP World Congress on Pain 2018 in Boston, USA.*

Haspert, V., Reicherts, P., Pauli, P., & Wieser, M. J. (2018, June). Acceptance-based strategies and distraction decrease pain perception. *Poster presentation at the 44th conference "Psychologie und Gehirn" in Gießen.*

Haspert, V., Reicherts, P., Pauli, P., & Wieser, M. J. (2017, October). Acceptance-based strategies reduce heat pain perception. *Poster presentation at the "SPR" annual meeting in Vienna*.

Haspert, V., Reicherts, P., Pauli, P., & Wieser, M. J. (2017, May). Akzeptanzbasierte Strategien reduzieren die Wahrnehmung von Hitzeschmerz. *Poster presentation at the 19th annual conference "DGPSF 2017" in Hannover.*

Haspert, V., Reicherts, P., Pauli, P., & Wieser, M. J. (2016, May). The regulation of heat pain using acceptance-based strategies. *Poster presentation at the 42nd conference "Psychologie und Gehirn" in Berlin.*

Haspert, V., Reicherts, P., Pauli, P., & Wieser, M. J. (2015, October). Regulation of pain with cognitive strategies: Acceptance vs. Reappraisal vs. Suppression. *Poster presentation at the Summer School "9 Years of Emotions - from the molecular basis to the emotional experience" in Marktbreit.*

Curriculum Vitae

Affidavit

I hereby confirm that my thesis entitled “Improving acute pain management with emotion regulation strategies: A comparison of acceptance, distraction, and reappraisal” is the result of my own work. I did not receive any help or support from commercial consultants. All sources and/or materials applied are listed and specified in the thesis.

Furthermore, I confirm that this thesis has not yet been submitted as part of another examination process neither in identical nor in similar form.

____________________ ____________________

Place, Date Signature

Eidesstattliche Erklärung

Hiermit erkläre ich an Eides statt, die Dissertation „Besserer Umgang mit akutem Schmerz mithilfe von Emotionsregulationsstrategien: Ein Vergleich von Akzeptanz, Ablenkung und Reappraisal“ eigenständig, d.h. insbesondere selbstständig und ohne Hilfe eines kommerziellen Promotionsberaters, angefertigt und keine anderen als die von mir angegeben Quellen und Hilfsmittel verwendet zu haben.

Ich erkläre außerdem, dass die Dissertation weder in gleicher noch in ähnlicher Form bereits in einem anderen Prüfungsverfahren vorgelegen hat.

____________________ ____________________

Ort, Datum Unterschrift