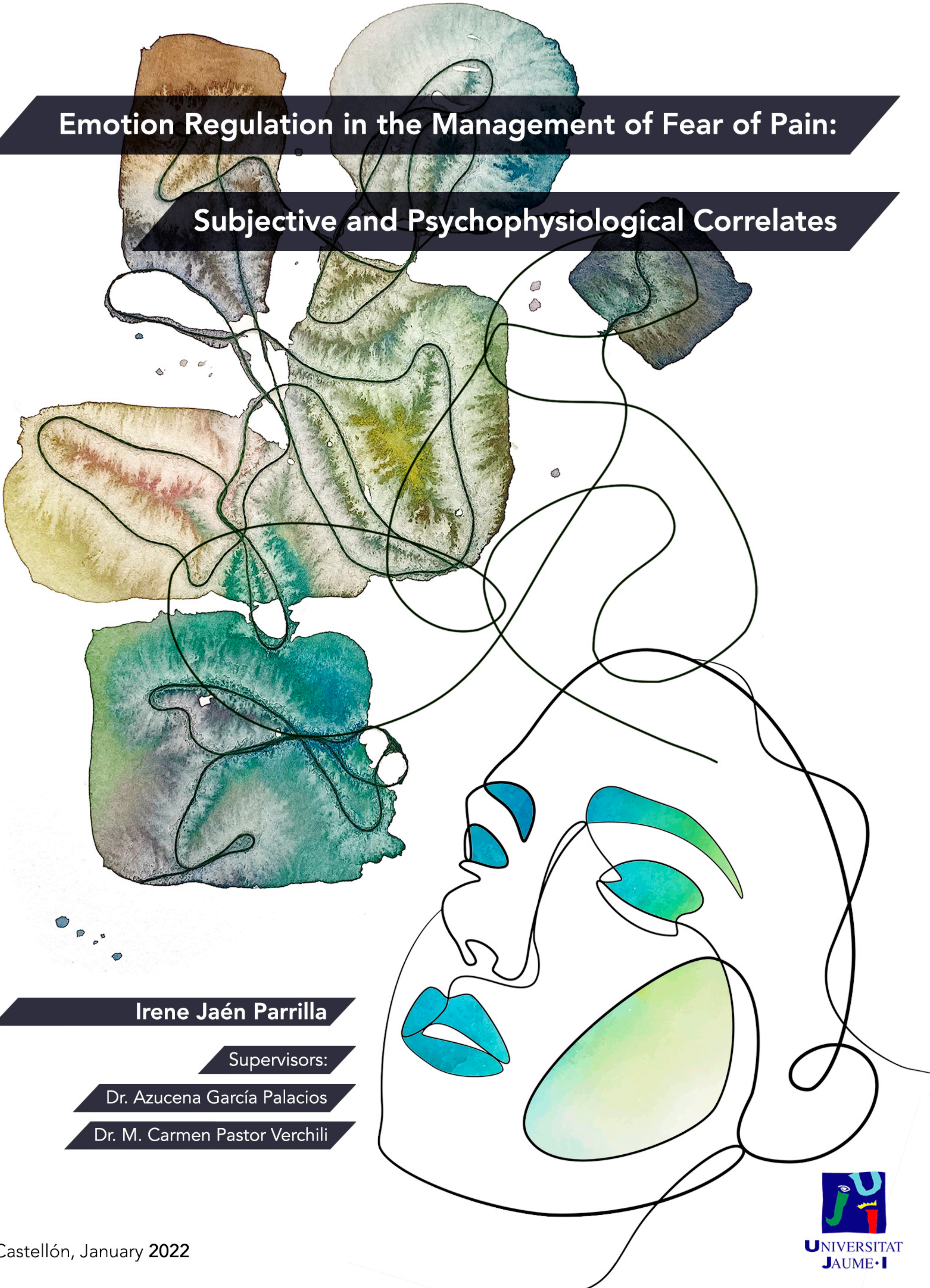
Emotion Regulation in the Management of Fear of Pain: Subjective and Psychophysiological Correlates



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Subjective and Psychophysiological Correlates

Memoria presentada por Irene Jaén Parrilla para optar al grado de doctora por la Universitat Jaume I

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"Fear keeps us focused on the past or worried about the future. If we can acknowledge our fear, we can realize that right now we are okay. Right now, today, we are still alive, and our bodies are working marvellously. Our eyes can still see the beautiful sky. Our ears can still hear the voices of our loved ones."

Thích Nhất Hạnh (2012)

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PRESENTATION

Research on the relationship between emotion regulation and pain has been a topic of great interest over the years. The study of the psychophysiological correlates associated with the modulation of pain and negative emotions has contributed enormously to understand this relationship. However, although anticipation of pain may have a great influence on pain-related outcomes, basic pain research has usually focused on studying the induction phase. Therefore, the present dissertation aims to advance in basic research on the management of pain focusing on the anticipatory fear of pain through emotion regulation.

This doctoral dissertation takes the form of a compendium of four articles (Table 1). At the moment of the preparation of the thesis, two of them have been published in indexed journals, whereas one has been submitted and the other is in preparation process to be submitted to scientifically relevant journals. As the studies were written as separate articles for publication, they are presented in separate chapters that have their own entity and can be read independently. The co-authors of the four studies have expressed their agreement for including the manuscripts as part of the present doctoral dissertation, as well as their express renunciation of presenting it as part of another doctoral dissertation

Additionally, two chapters have been included at the beginning and at the end of the dissertation. The first chapter encompasses a general preface to the doctoral thesis to provide an overview of the field of emotion regulation and their implications on the management of threat of pain, as well as to justify the importance of this research. Thus, this general introduction starts highlighting the relevance of the conceptualization of pain as an emotional experience in which psychological processes can play an important role. For that extent, different theories about pain processes are reviewed. Next, the chapter focuses on fear, one of the emotions most studied in relation to pain. The components of this emotion and the most prominent outcomes are exposed. The following two sections go on to address the relationship between emotion regulation, cognitive flexibility, emotion regulation flexibility, and pain-related outcomes This general introduction ends with two sections defining the general aim of the thesis, the specific research questions, and providing an outline of the thesis pointing out the general objectives addressed in each study.

Finally, the last chapter pretends to summarize and discuss in more detail the overall findings of this research, as well as to propose future directions for research in the field of emotion regulation and fear of pain.

Table 1. Doctoral dissertation as a compendium of publications

Chapter	Article
2	Jaén I, Díaz-García A, Pastor MC, García-Palacios A (2021) Emotion regulation and peripheral psychophysiological correlates in the management of induced pain: A systematic review. *PLoS ONE, 16*(6): e0253509. doi: 10.1371/journal.pone.0253509
3	Jaén, I., Escrig-Ayuso, M.A., Wieser, M.J., García-Palacios, A., Pastor, M.C. (2021). Cognitive reappraisal is not always successful during pain anticipation: Stimulus-focused and goal-based reappraisal effects on self-reports and peripheral psychophysiology. *International Journal of Psychophysiology, 170*:210-217. doi: 10.1016/j.ijpsycho.2021.10.015
4	Jaén, I., Vidal-Arenas, V., Suso-Ribera, C., Pastor, M.C., García-Palacios, A. Psychometric Properties of the Spanish Version of the Cognitive Flexibility Inventory. Submitted to *Current Psychology.*
5	Jaén, I., Peters, M.L., Vancleef, L.M.G., Suso-Ribera, C., Pastor, M.C., García-Palacios, A. When more is worse: the role of cognitive flexibility and the repertoire of emotion regulation strategies in managing daily negative events and fear of pain. In preparation.

SUMMARY

Research have shown the relationship between pain and emotion, proposing emotions as determinants and consequences of the subjective pain experience. Thus, pain can be modulated by positive and negative emotions, with numerous studies showing that inducing negative affect is related to higher pain intensity and lower pain tolerance. One of the emotions that has been identified as a critical one for pain experience is fear of pain, since it has been associated to avoidance behaviours such as disengage of daily activities, contributing to the maintaining and chronicity of pain.

Emotion regulation strategies have shown to be effective in improving pain-related outcomes, as well as fear of pain. Among these strategies, cognitive reappraisal and acceptance have aroused a great interest, due to their role in first line interventions for chronic pain such as Acceptance and Commitment Therapy or Cognitive and Behavioural Therapy, among other approaches.

In laboratory settings, the effects of these strategies have been often studied with experimental paradigms focused on pain induction. However, the effects of emotion regulation strategies using specific paradigms to study fear of pain associated to threat anticipation have been little explored. In addition, although several studies have shown the relevance of cognitive and emotion regulation flexibility for the management of negative emotions and well-being, it has not been explored in relation to fear of pain.

Taking into account the relevance of fear of pain in the development of detrimental pain-related responses and the chronification of pain, the general aim of the present doctoral thesis was to expand the knowledge about the role of emotion regulation in the management of threatening situations arising from a possible future pain. For this purpose, four studies were conducted: a systematic review, two experimental studies, and the validation of a questionnaire of cognitive flexibility.

Overall, results showed that cognitive reappraisal is not necessarily associated with decreased physiological responses in the management of pain. In fact, emotion regulation strategies included in our study might not be effective to

manage fear of pain when the anticipation of thermal aversive stimuli produces low anxiety levels. Likewise, the implementation of larger repertoires of emotion regulation strategies was also not associated with better fear of pain management. Additionally, the results obtained in the present dissertation suggested that individuals tend to use acceptance under low anticipatory fear of pain contexts, which also was the strategy most effective in that context.

Future studies should explore the role of distinct emotion regulation strategies using environments with higher ecological validity, which would allow studying the changing pain characteristics to better understand the influence of context-sensitivity on the emotion regulation process.

RESUMEN

Las investigaciones han demostrado la relación entre el dolor y la emoción, proponiendo las emociones como determinantes y consecuencias de la experiencia subjetiva del dolor. Así, el dolor puede ser modulado por emociones positivas y negativas, con numerosos estudios que muestran que la inducción de afecto negativo se relaciona con una mayor intensidad del dolor y menor tolerancia al dolor. Una de las emociones que se ha identificado como crítica para la experiencia subjetiva del dolor es el miedo al dolor, el cual se ha asociado a conductas de evitación como el abandono de actividades cotidianas, contribuyendo al mantenimiento y la cronicidad del dolor.

Las estrategias de regulación emocional han demostrado ser eficaces para mejorar los resultados relacionados con el dolor, así como el miedo al dolor. Entre estas estrategias, la reevaluación cognitiva y la acceptanción han suscitado un gran interés, dado su papel en intervenciones de primera línea para el dolor crónico como la Terapia Cognitivo-Conductual y la Terapia de Aceptación y Compromiso, entre otros enfoques.

En contextos de laboratorio, los efectos de estas estrategias se han estudiado a menudo con paradigmas experimentales centrados en la inducción del dolor. Sin embargo, los efectos de estrategias de regulación emocional con paradigmas diseñados específicamente para estudiar el miedo al dolor asociado a la anticipación de la amenaza han sido poco explorados. Además, aunque varios estudios han mostrado la relevancia de la flexibilidad cognitiva y la regulación emocional para la gestión de las emociones negativas y el bienestar, no se ha explorado en relación con el miedo al dolor.

Teniendo en cuenta la relevancia del miedo al dolor en el desarrollo de respuestas perjudiciales relacionados con el dolor y la cronificación del mismo, el objetivo general de la presente tesis doctoral fue ampliar el conocimiento sobre el papel de la regulación emocional en la gestión de situaciones amenazantes derivadas de un posible dolor futuro. Para ello, se realizaron cuatro estudios: una revision sistemática, dos estudios experimentales y la validación de un cuestionario para evaluar la flexibilidad cognitiva.

En general, los resultados sugieren que la reevaluación cognitiva no está necesariamente asociada con la disminución de las respuestas fisiológicas en el manejo del dolor. De hecho, las estrategias de regulación emocional podrían no ser eficaces para gestionar el miedo al dolor cuando la anticipación del dolor produce niveles bajos de ansiedad. Asimismo, la implementación de repertorios más amplios de estrategias de regulación emocional tampoco se asoció con un mejor manejo del miedo al dolor. Además, los resultados obtenidos en la presente tesis sugieren que las personas tienden a implementar la aceptación en contextos de bajo miedo al dolor durante la anticipación, la cual también resultó ser la estrategia más eficaz en ese contexto.

Futuros estudios deberían explorar el papel de las distintas estrategias de regulación emocional utilizando entornos con una mayor validez ecológica, los cuales permitan estudiar las características cambiantes del dolor para comprender mejor la influencia de la sensibilidad al contexto en el proceso de regulación de la emoción.

CHAPTER 1

General introduction

Historical background on pain

The conceptualization of pain has undergone major changes over the years. Nowadays, we understand pain as a process in which psychological variables play an important role. However, this has not always been the case. Early frameworks conceptualized pain from a one-dimensional position, in which pain was defined solely as a physiological phenomenon. For instance, in the 17th century, the philosopher René Descartes considered pain as a sensory experience with a direct one-to-one correspondence between pain experience and tissue damage.

> "...If for example the fire comes near the foot, the minute particles of this fire, which as you know have a great velocity, have the power to set in motion the spot of skin of the foot which they touch, and by this means pulling upon the delicate thread which is attached to the spot of the skin, they open up at the same instant the pore against which the delicate thread ends, just as pulling at one end of a rope one makes to strike at the same instant a bell which hangs on the other end..." (Descartes 1667, p. 25.).

From this mechanical model proposed by Descartes, there was a perfect correlation between damage magnitude and the pain that the individual experienced. Thus, the information travelled in only one direction, from peripheral injury to the brain, being impossible the modulation of the stimulus. Therefore, the treatment for pain consisted merely of localizing the pathology and removing it with a remedy or cure.

This model underwent considerable revision and, two centuries after the Descartes theory, different researchers pointed out the importance of the nervous system in the transmission of pain, leading to the study of pain from a neurophysiological perspective. Johannes Müller (1835) proposed *the law of the specific nerve energies*, whereby the nature of the perception was defined by the pathway over which the sensory information is carried. From this theory, the sensory perception did not depend on the origin of the sensation, but of the nervous system that was activated. Thus, each of the five senses had its own sensory nerve with a specific type of activity, which encodes the energies of the stimuli and gives rise to the mental states (Rachlin, 2005). Some years after, in 1894, Von Frey proposed the *theory of the sensations*, raising the existence of specific receptors for each sensation. These receptors transmit signals to a pain centre in the brain that produces the pain perception. Nowadays, this theoretical approach is better known as the *theory of the specificity*. As a result, other theories, known as *pattern theories*, proposed that pain could vary depending on the quality and intensity of the sensory stimulus. However, despite all the advances in the study of pain, these theories continue considering the emotional and affective states as merely reactions to pain (Goldscheider, 1894).

In 1965, *the gate control theory* (Melzack & Wall, 1965) revolutionized the understanding of pain. This theory was framed within the multidimensional models that tried to explain why patients with similar lesions responded differently to the same treatment (e.g., Beecher, 1956). Melzack & Wall (1965) proposed that a gating mechanism, located in the spinal dorsal horn, modulates pain by nerve impulses of A-δ and C-afferent fibers. The activity of these fibers of large and small-diameter act as a gate that prevents or impedes the passage of nerve impulses coming from the nociceptors of the cortex. Therefore, just as there is the neurobiological possibility of opening the door to pain, there is also the possibility of closing the door and inhibiting the pain response.

In this sense, the gate control theory assumed that psychological variables as cognitive processes (i.e., attention), play a fundamental role in the process of pain. Thus, psychological factors act as mechanisms that may open and close the door to pain, due to their response in the nervous system (Melzack & Casey, 1968). Specifically, this theory considers that the pain is explained by the interaction of three dimensions: sensorial-discriminative, cognitive-evaluative, and motivational-affective. The sensorial-discriminative dimension of pain refers to the spatial, temporal characteristics and quality of pain activated by the nociceptors; the motivational-affective dimension of pain, on turn, captures how “bad” or “unpleasant” the pain is, being related to the anticipatory function that is activated when there is a threat of tissue damage, and leading the individual to engage or avoid some behaviours; lastly, the cognitive-evaluative dimension of pain is composed by variables such as attention, beliefs and thoughts about the pain that can modulate the dimensions of pain mentioned above.

In this way, the gate control theory broke with the established medical model, which postulated that pain was directly related to the amount of tissue damage, questioning the management of pain from purely medical perspective, and opening the way for psychology to be part of the pain processing and to play an essential role in pain management.

After the great evolution in the understanding of pain as a multifaceted phenomenon, the anaesthesiologist John Bonica brought together an interdisciplinary group of researchers and clinicals to form, in 1973, the *International Association for the Study of Pain* (IASP). A few years later, in 1978, the sub-committee of the IASP Task Force on Taxonomy, headed by professor Merskey, defined pain as “an unpleasant sensory and emotional experience associated with actual or potential tissue damage, or described in terms of such damage”. This definition was approved one year later and presented in the paper “the need of a taxonomy” published in *Pain* (Bonica, 1979).

More than 40 years have passed without this definition of pain having undergone changes. However, a few years ago the pain definition was modified, since it considered the verbal self-report of pain patients but overlooks non-verbal behaviours. Thus, the pain definition has been redefined and described as “an unpleasant sensory and emotional experience associated with, or resembling that associated with, actual or potential tissue damage" (Raja et al., 2020).

Specifically, six assumptions have been extracted from the actual definition of pain (Raja et al., 2020): (1) pain is a personal experience that is influenced by biological, psychological, and social factors. Thus, the patient ceases to be a passive subject and is considered an active agent in pain management (Vlaeyen et al., 2007); (2) pain and nociception are different phenomena, so pain in not necessarily inferred by sensory neurons. In this sense, it is acknowledged that pain can occur in the absence of physical pathology and its experience depend on the stimulus characteristics and the state of the individual that experience pain. (Price, 2000;

Tracey & Mantyh, 2007); (3) pain is a concept learned through life experiences; (4) whether a person reports pain experience, it should be respected. Thus, if he/she regard their experience as pain and report it in the same ways as pain caused by tissue damage, it should be accepted as pain; (5) pain can affect social and psychological well-being; (6) the inability of some individuals to express pain (e.g., neonates, elderly people) does not negate the possibility to experience pain.

Fear of pain: cognitive, behavioural, and psychophysiological components

The conceptualization of pain as an emotional experience left the door open to a wide range of studies focused on discovering what factors influence pain processing. In this sense, research has consistently reported that emotions are essential for the modulation of pain, so that pain can be reduced by positive emotions and increased by negative ones (Rainville et al., 2005). This fact has increased the interest in exploring which emotions are involved in pain modulation and how to manage them in clinical practice. Among the most studied discrete emotions in relation to pain, research has largely focused on the effects of anxiety and fear (e.g., Wiech & Tracey, 2013).

Although both emotions have some commonalities and have often been used indistinctly, there are several characteristics that differentiate them. *Fear* refers to the alarm generated by an explicit and identifiable threat (Lang et al., 2000) and is characterized by escape or avoidance behaviours (McNaughton & Corr, 2004; Öhman, 1993). In contrast, *anxiety* is conceptualized as a future-oriented emotion that has a prolonged duration, in comparison to fear (Bolles & Fanselow, 1980). Also, anxiety is characterized by the anticipation of a less explicit or identifiable threat (Lang et al., 2000; Epstein, 1972). In this sense, anxiety is a response less intense than fear, being related to worry, apprehension, and nervousness about a situation of uncertain (Hyde et al., 2019) with the function of facilitate approaching danger (McNaughton & Corr, 2004).

Asmundson & Katz (2009) suggested that it would be more appropriate to use the term anxiety to refer to the threat produced by the anticipation of pain because it involves worry about the future. However, many studies and well-known theoretical models have more frequently used the term fear (Lethem et al., 1983; Vlaeyen & Linton, 2000), probably due to the specificity of the threatening stimulus such as pain (Lang et al., 2000), and the common responses of avoidance (Lang et al., 2000; Vlaeyen & Linton, 2000)

As the studies that form part of this dissertation will use an explicit and identifiable threatening stimulus, such as the heat induced pain, the term "fear of pain" has been adopted. Specifically, we will refer to fear of pain as a negative emotional reaction that emerges when stimuli that are related to pain are perceived as a main threat (Leeuw, Goossens, et al., 2007b), being derived from catastrophic beliefs and negative interpretations considering pain as equivalent to harm (Vlaeyen & Linton, 2000). In addition, we will also use this term to refer to specific fears under the umbrella of fear of pain. This is the case of kinesiophobia, which refers to fear of movement or re-injury caracterized by thoughts that movement will cause pain or aggravate the injury, leading to the avoidance of certain activities (Kori et al., 1990).

To better understand the concept of fear of pain, it is essential to know its components. In this sense, just as fear is defined as an emotional state that evokes cognitive, psychophysiological, and behavioural responses (Lang et al., 2000), fear of pain might be understood as an emotional state that is experienced when a threat of being harmed is present, and results in the same three response systems (Biggs et al., 2016). Each of these components are explained in more detail in the following sections.

Cognitive response to fear of pain

A process highly related to fear of pain is **attention** (Crombez et al., 2013). Pain has an inherent threat value that become the focus of attention (Ruiz-Padial & Mercado, 2021) because of its relevance for the goal of the individual (Claes et al., 2014b; Schrooten et al., 2012), especially when the pain is perceived as highly threatening (Crombez et al., 1998). Thus, when individuals are threatened, they respond with an increased vigilance and enhanced psychophysiological responses associated to attention, which tend to facilitate an action of fight or flight (Bradley et al., 2001).

Interestingly, this disposition to act entails an attentional interference in the individual (Crombez et al., 1998), causing a deeper affective processing compared to when the stimuli are ignored (Wiech et al., 2008). In this regard, several studies revealed that the use of distraction to direct attention away from the threatening stimulus during medical procedures or during experimental induced pain reduces fear of pain, as well as decreases pain sensitivity and increases pain tolerance (Niharika et al., 2018; Windich-Biermeier et al., 2007). However, in some cases distraction has shown to be limited. For example, some studies revealed that distraction was only efficient for individuals with low pain-related fear, meanwhile sensory focusing on the sensory aspects of the pain experience might be more beneficial for patients with high pain-related fear (Roelofs et al., 2004).

In addition, some studies have shown that the level of attention to pain is dependent of fear of pain beliefs (Goubert et al., 2004; Keogh et al., 2001; Van Damme et al., 2008; Vancleef et al., 2006). One of the most studied forms of threatening beliefs is **pain catastrophizing**, defined as a tendency to magnify the threat value of pain, an inability to inhibit pain-related thoughts in anticipation or during pain, and feeling helpless when faced with pain (Quartana et al., 2009; Sullivan et al., 1995). Research has shown that the meaning assigned to a painful stimulus could alter the experience of pain. Specifically, experimental studies revealed that catastrophic thinking is associated with higher pain intensity, worrying about pain, helplessness, and dysfunctional attention toward pain (Sullivan et al., 2001). For example, Van Damme et al. (2002, 2004) found that individuals with higher pain catastrophizing tend to exaggerate attentional engagement and/or show a delayed attentional disengagement to painful stimuli. In addition, patients with pain who tend to catastrophize also reported higher pain intensity, felt more disabled, and experienced more psychological distress (Severeijns et al., 2001).

Not surprisingly, pain catastrophizing has shown to be a relevant cognitive process in the interventions for chronic and acute pain (Cassidy et al., 2012; Cimpean & David, 2019; Quartana et al., 2009), and it is a main target in first line interventions for chronic pain management based on Cognitive Behaviour Therapy (CBT; Beck et al., 1979; Ehde et al., 2014) or Acceptance and Commitment Therapy (ACT; Hayes et al., 2004; De Boer et al., 2014). Indeed, some authors as

Burns et al. (2012) argued that the effectiveness of the diverse psychological interventions could be determined to the extent that some aspect of treatment reduces pain catastrophizing.

Behavioural response to fear of pain

When individuals feel fear of pain, they may engage in safety-seeking behaviours such as detection, avoidance, escape, or neutralization strategies to face an aversive stimulus (Deacon & Maack, 2008). These behaviours imply to stay away from those situations or activities associated with threat of suffering, either postponing or preventing the aversive situation (Kanfer & Phillips, 1970).

Although safety behaviours such as escape and avoidance can be functional in the short term, these behaviours have been considered as maintaining mechanisms of anxiety (Rachman et al., 2008) and pain (Vlaeyen & Linton, 2000). Specifically, pain research has revealed that pain avoidance behaviours may paradoxically increase pain-related fear by a mechanism of instrumental of operant conditioning (van Vliet et al., 2021; Volders et al., 2015). For example, people may use their own avoidance to infer that something may be painful, and they must be afraid (Arntz et al., 1995). In addition, van Vliet et al. (2021) revealed that fear of pain increases not only by avoidance, but also by the possibility of avoidance. Furthermore, this relation may be bidirectional, so safety-seeking behaviours are also maintained by the same conditioning process (van Vliet et al., 2021; Volders et al., 2015). Thus, whether the catastrophe does not occur due to the use of safety behaviours, the experience of relief acts as a reinforcer of this behaviours (Salkovskis, 1991).

Research has shown that fearful patients with chronic pain were less likely to engage in behavioural performance compared to non-fearful patients (Leeuw, Goossens, et al., 2007b), being the reduction of physical activity an excellent predictor of disability (Gatchel et al., 2016; Zale et al., 2013). In addition, a study conducted with healthy participants revealed that the anticipation of experimental back pain prompted a protective posture that stiffens the spine. Although spinal splinting can be beneficial in the short term, this posture is associated with compressive cost and predisposes to spinal injury if maintained long term (Moseley et al., 2004). Thus, safety-seeking behaviours have shown to be a key contributor to the transition from acute to chronic pain (Vlaeyen et al., 2016; Vlaeyen & Linton, 2012).

An important note about safety-seeking behaviours and fear of pain is that it is not a one-to-one relationship, but a more complex decision-making can take place. Thus, research has shown that avoidance depends on the individual' values and goals (Karoly et al., 2008; Karsdorp et al., 2013; Wiech & Tracey, 2013). For instance, if the pain experience is needed to survive, the worst pain experience will be perceived as less intense (Wiech & Tracey, 2013). In this sense, some studies showed that avoidance behaviour to pain have shown to be attenuated by reward goals (Claes et al., 2014a; Crombez et al., 2012). These findings highlight the importance of the use of cognitive approaches focused on goals and values to manage fear and avoidance behaviours combined with exposure treatments for pain-related fear.

Psychophysiological responses to fear of pain

Threat anticipation engages neural circuitry that promotes defensive responses (Lang et al., 2000). Different theories, such as the threat imminence model (Blanchard et al., 1990; Fanselow, 1994) and the defense cascade model (Lang, Bradley, & Cuthbert, 1997), suggest that these defensive responses are modulated by the proximity of threat. Specifically, these theories propose three stages depending on the proximity with the negative event (For a review see Hamm, 2020) (Figure 1.1.). The first is the *preencounter stage*, that occurs when the individual is in an encounter in which a threat might occur. This phase is characterized by a generalized hypervigilance to all cues (threatening and neutral) in a potentially dangerous environment (Michalowski et al., 2009). As soon as a threat cue is detected, the individual goes into a *post-encounter stage*, in which a response of defense known as "freezing" is produced (Gladwin et al., 2016; Marks, 1987). This phase is characterized by an increase of selective attention to the threatening stimulus and a progressive augmentation of physiological indices associated with attention such as greater sympathetic arousal (e.g., skin conductance), increased heart rate deceleration, and a potentiation of protective reflexes (e.g., startle reflex). Finally, if the action is possible, a *circa-strike defense stage* is produced, characterized by an increasing in skin conductance and a large acceleration in heart rate to prepare the organism for an effective motor response.

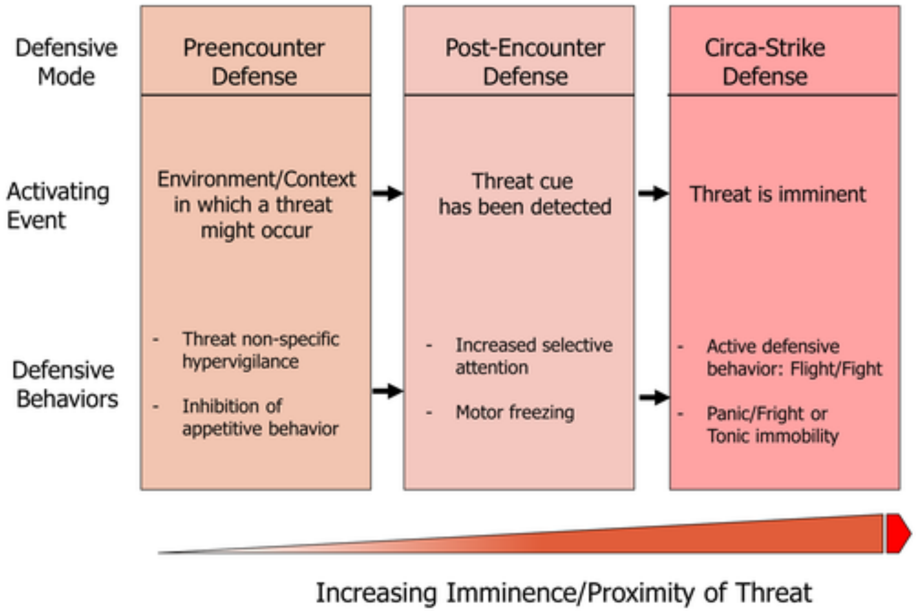

Figure 1.1. The transdiagnostic dimensional model of defensive behaviours (Blanchard et al., 1990; Fanselow, 1994; Lang et al., 1997; Retrieved from Hamm, 2020).

Researchers have extensively studied the neural circuits underlying this defense response, specifically for the post-encounter stage, in which a threat cue is detected but there is no interaction with the threat. Studies with animals showed that when a threat or nociceptive stimuli emerges, the sensory cortex and/or the sensor thalamus are activated (LeDoux, 1990), and project neural activity to the amygdala, which has been repeatedly reported as the centre of the defense system involved in both the expression and acquisition of fear (Davis, 1989, 1997). From the amygdala, three efferent connections are established (see Fanselow, 1994). First, there is a projection to the midbrain central gray region, that mediates freezing and escape behaviours. Secondly, there is a projection to the nucleus reticularis pontis caudalis, responsible for the increased startle reflex (see Davis, 1989, 1997). Finally, there is a projection to the lateral region of the hypothalamus, that mediates the autonomic nervous system being responsible for the autonomic components of the emotional response (i.e., increased blood pressure, skin conductance, heart rate bradycardia, pupil dilatation).

According to the mentioned neurocircuit of defense responses, a study conducted by Mobbs et al. (2009) showed that the defense cascade to pain anticipation increased activity in a set of forebrain structures such as the ventromedial prefrontal cortex, hippocampus, hypothalamus, and amygdala. Also, Phelps et al. (2001) used a threat of shock paradigm in which participants were instructed that they might receive a shock paired to a stimulus (threat condition), but not another (safe condition). They found that the anticipation of a potential shock –although it was never delivered– was associated with increased arousal and activation of the left amygdala.

These findings are consistent with studies conducted with threat of shock paradigms and peripheral physiological measures, which reported that threat conditions are associated to enhanced startle reflex responses (Bradley et al., 2008; Grillon et al., 1991), larger skin conductance responses (Bradley et al., 2008; Kopacz & Smith, 1971), and cardiac deceleration (Bradley et al., 2008), compared to safety conditions. These results were interpreted as increased activation of the defensive motivational system, mediated by subcortical areas involved in the fear response, such as the amygdala (Lang et al., 1997, 2000). Specifically, for heart rate, studies have shown that a cardiac deceleration occurs during the processing of threatening cues (Bradley et al., 2005, 2008). This deceleration has been associated with an increase in attention to the threat stimulus (Lang et al., 1997) and the orientation response to aversive stimuli (Graham & Clifton, 1966). In this regard, experimental studies have shown that the cardiac deceleration that occurs during emotional perception is predominantly mediated by the parasympathetic nervous system, with increased vagal control resulting in decreased heart rate responses (Bradley, 2009; Campbell et al., 1997).

Importantly, the increased physiological arousal in response to the anticipation of pain can produce body sensations that individuals who are hypervigilant can misinterpret as pain, increasing the responses of fear to this body sensations (Nisbett & Schachter, 1966; Weisenberg et al., 1984). These misinterpretations have been associated with individual differences in the propensity to respond to fear of body sensations (anxiety sensitivity) or negative affect (Asmundson et al., 1999). Likewise, people with a high anxiety sensitivity tend to catastrophically misinterpret the increased physiological responses prompted by the anticipation or exposition to a situation related to pain as evidence of impending harm, producing pain, and avoidance (Asmundson & Taylor, 1996).

The role of fear of pain on pain-related outcomes

Fear of pain is one of the psychological factors that has been more studied in relation to pain chronification (den Hollander et al., 2010; Hasenbring et al., 2014; Vlaeyen & Linton, 2000). Indeed, it has been associated with several negative or poor outcomes in a wide variety of chronic and acute pain pathologies, as well as in pain-free samples.

Overall, research has shown that higher fear levels prior to experiencing pain are predictive of higher pain severity and lower pain tolerance (Michaelides & Zis, 2019). Also, fear of pain has shown to be a mediator of the relationship between pain and disability (Michaelides & Zis, 2019). As the fear-avoidance model proposes, the perception of pain as a threatening stimulus can start a vicious fear-avoidance cycle that promotes pain-related fear, and a subsequent increasing of hypervigilance, emotional distress, and pain severity in subacute, acute, and chronic pain samples (Vlaeyen & Linton, 2000; Zale et al., 2013; Zale & Ditre, 2015). All these factors promote avoidance such as disengagement of daily or social activities, exaggerated pain perception, as well as physical and psychological consequences such as depression, loss of mobility, loss of muscular strength, reduced behavioural repertories, and an increased responsiveness to positive and negative reinforcement of the invalid status, which in turn contributes to the maintaining and chronicity of pain (Leeuw, Goossens, et al., 2007a; Vlaeyen & Linton, 2000). Indeed, in chronic pain samples fear of pain appears to be more disabling than pain itself, being fear of physical activity an excellent predictor of such disability (Gatchel et al., 2016; Zale et al., 2013).

Regarding acute pain, literature suggests that lower pain-avoidance beliefs are predictive of a faster return to work (Fritz et al., 2001; Fritz & George, 2002), less disability, and reduced pain intensity (George et al., 2006). Also, research with patients who suffer recurrent headaches showed that disability produced by headache is not fully explained by the intensity or frequency of pain (Stewart et al., 2003). Anxiety and escape/avoidance behaviours may play an important role in this disability (Asmundson et al., 1999), as well as worrying about causes and consequences of headache (Penzien et al., 1985). In this regard, a study revealed that decreases in anxiety predicted reductions in headache-disability, even better than headache frequency or medication usage (Smith and Nicholson, 2006). Moreover, high fear of pain may be even a risk for over-the-counter medication administered for headache (Asmundson et al., 2001).

Additionally, fear of pain is not only present in patients with chronic or acute pain, but it is also present in the general population (Houben et al., 2005; Leeuw, Houben, et al., 2007). On the one hand, some studies conducted with healthy samples showed that fear of pain predicts future disability and health status (Buer & Linton, 2002; Picavet et al., 2002; Severeijns et al., 2002). For example, fear of pain has shown to increase the risk for future low back pain and poor physical functioning (Linton et al., 2000; Van Nieuwenhuyse et al., 2006).

On the other hand, fear of pain has also been related to poor outcomes after medical procedures. For example, a great number of studies focused on post-surgery pain have shown that a higher anxiety level before an operation is associated with higher post-surgery pain and anxiety (Granot & Ferber, 2005; Taenzer et al., 1986). In addition, a meta-analysis conducted by Theunissen et al. (2012) showed that higher levels of anxiety before surgery were associated with higher rates of chronic pain after surgery. In this sense, some authors suggest the need to assess fear and catastrophizing before medical interventions in order to anticipate the expected postoperative pain experience (Granot & Ferber, 2005).

Finally, some studies revealed that fear of pain can be a barrier for accessing the health care system (Gordon et al., 1998; Meng et al., 2007), and it is associated with poor health control, clinical complications, and increased risk of mortality for some pathologies such as diabetes (Fu et al., 2009). For example, fear of pain is a core component of dental fear (Bradley et al., 2008), which have shown to be associated to the delay of treatments that leads to more extensive dental problems and the feedback into the maintenance or augmentation of dental fear (Armfield et al., 2007). Besides, some studies have revealed the importance of managing fear of pain during vaccinations. Specifically, the mismanagement of needle pain can lead to fearful memories of pain over time and increase the distress and fear in future medical procedures (Noel et al., 2018).

In view of this, some studies have suggested the need to offer psychological interventions before medical procedures to prevent and/or reduce fear of (re)injury and long-term sequelae of unmitigated pain (McMurtry et al., 2015; Noel et al., 2018). Although psychological interventions have shown to play an important role in tertiary prevention focused on the consequences of chronic pain, psychological interventions are also important in primary and secondary prevention such as pre-surgical contexts (Fisher & Eccleston, 2021). These interventions may range from psychoeducation to psychological interventions to manage negative thoughts and avoidance behaviours. Indeed, a recent meta-analysis found that psychological interventions significantly reduced acute and subacute pain, disability, and chronic post-surgical pain (Nadinda et al., 2021).

Emotion regulation strategies to manage negative emotions

The ability to respond emotionally to a threatening stimulus is essential for adaptive human function, but the ability to modify these emotions to adapt to the context is equally important. Although feeling fear of pain is essential to prevent harm, sometimes the defensive responses may be excessive and/or not adaptive in the long-term. As shown in previous sections, fear produces cognitive, behavioural, and physiological responses that may be maladaptive for individuals, leading to worsening physical and mental health. Therefore, an effective emotion regulation seems to be essential to manage these emotions and prevent detrimental outcomes.

Emotion regulation has been defined as “the process by which we influence which emotions we have, when we have them, and how we experience and express them” (Gross, 1998). A systematic review conducted by Koechlin et al. (2018) revealed that maladaptive emotion regulation strategies such as expressive suppression may have an important role in the development and maintenance of chronic pain. In contrast, there are several cognitive emotion regulation strategies that have shown to be effective in reducing negative emotions such as fear and anxiety, as well as pain-related outcomes. Among the most studied strategies are cognitive reappraisal (e.g., Ochsner & Gross, 2005; Troy et al., 2018) and acceptance (e.g., Hofmann et al., 2009; Troy et al., 2018), which are core strategies of first line interventions for chronic pain, as well as for anxiety disorders like

Acceptance and Commitment Therapy (ACT; Hayes et al., 1999) or Cognitive and Behavioural Therapy (Beck et a., 1979; Hofmann et al., 2012), among other approaches.

Following the process model of emotion regulation formulated by Gross (1998), there are two kinds of emotion regulation strategies: antecedent- and response-focused strategies. The difference between these two groups of strategies is the moment when they are applied since a psychologically meaninful stimuli is processed. In this sense, antecedent-focused strategies act before the emotional reaction is generated, whereas response-focused strategies target the emotional reactions. According to this classification, *reappraisal* is defined as an antecedent-focused strategy that involves reinterpreting the meaning of a stimulus to change one's emotional responses, whereas *expressive supression* is a response-focused strategy that involves the inhibition of the emotional-expressive behaviour once the emotion has been generated (Gross, 1998).

In the last few years, a considerable number of works have studied voluntary emotion regulation using experimental paradigm designed by Jackson et al. (2000), in which participants must regulate their emotional state in the face of negative stimuli. These studies found that reappraisal is an effective strategy for reducing negative affect –based on subjective self-reports, as well as multiple central and peripheral physiological correlates of regulatory process (Ray et al., 2010; Webb et al., 2012; Zaehringer et al., 2020).

In terms of neural correlates, functional magnetic resonance imaging (fMRI) studies have shown that the use of reappraisal is associated with the activation of both lateral and medial prefrontal regions such as the dorsolateral and ventrolateral areas of the cortex, as well as a decreased activation of the orbitofrontal cortex and the amygdala (Ochsner et al., 2002, 2004). The activation of the dorsolateral region has been associated with the executive control process required to change the meaning of the scene, whereas the decrease of amygdala activation has been linked to a reduction of the negative emotional value (Ochsner et al., 2002). Likewise, a study focused on regulation of conditioned fear (Delgado et al., 2008) revealed that the activation of lateral prefrontal cortex regions by cognitive reappraisal may influence the amygdala, diminishing fear in a similar way to the inhibition process that occurs during fear extinction.

Regarding peripheral psychophysiology, many studies using negative stimuli such as videos or films has shown that reappraisal has been associated with a reduction of startle reflex responses, corrugator electromyography activity, cardiac reactivity and electrodermal responses (Dillon & LaBar, 2005; Driscoll et al., 2009; Eippert et al., 2007; Jackson et al., 2000; Ray et al., 2010). In addition, Lissek et al., (2007) combined both the classic emotion regulation task (Jackson et al. 2000) and the threat of shock paradigm (Grillon et al., 1991). The results of this novel study showed a reduction in startle blink potentiation when participants had to regulate their emotions in the anticipation periods, compared to the non-regulate condition, extending the empirical evidence for voluntary regulation previously found with the Jackson's to the Grillon's threat of shock paradigm.

In contrast to reappraisal, *acceptance* has been commonly defined as a response-focused strategy that aims at engaging in the already generated, ongoing emotional reactions (Hofmann & Asmundson, 2008). However, some studies have also classified acceptance as an antecedent-focused strategy, since it is also used to target the cognitive change of the emotion-eliciting events (Hofmann et al., 2009), or a method of increasing values-based action (Vowles & McCracken, 2010). Thus, some authors have clasified acceptance as a variant form of reappraisal (Webb et al., 2012) or have suggested that it share both antecedent- and response-focused components (Wolgast et al., 2011). Therefore, acceptance can be understood as an antecedent strategy consisting in interpreting the focal emotion in a particular manner (Webb et al., 2012), but also as a response-focused strategy that does not aim to change the meaning of the stimulus but intends that the individual engage in their emotions as an alternative to experiential avoidance (Hayes et al., 1999; Vowles & McCracken, 2010).

Similar to the findings for reappraisal, acceptance has shown to be an effective strategy in reducing anxiety self-reports (Braams et al., 2012), and it has been associated to greater responses in the prefrontal regions implicated in cognitive control (medial, dorsolateral, and ventrolateral prefrontal cortex) (Goldin et al., 2019). However, the use of acceptance has also been associated with the activation of parietal cortex regions that are implicated in mindful attention regulation (Goldin et al., 2019).

According to the neural findings, acceptance has also shown to modulate peripheral psychophysiological correlates associated with negative emotions. However, the psychophysiological findings regarding acceptance reflected strong inconsistencies among studies. For example, the use of this strategy has been associated with decreased respiration rate, electrodermal activity and heart rate (Goldin et al., 2019; Haspert et al., 2020). However, other studies have not found these reductions in cardiovascular measures (Braams et al., 2012), or changes in the electrodermal activity level (Goldin et al., 2019).

Over the years, there has been a great interest in comparing acceptance with reappraisal strategies leading to different investigations, reviews, and meta-analysis (e.g., Goldin et al., 2019; Troy et al., 2018; Webb et al., 2012). Some of these studies found a superiority of acceptance strategies compared to reappraisal (Kohl et al., 2012, 2013), while other works reported that reappraisal is more effective than acceptance (Goldin et al., 2019; Webb et al., 2012). A study conducted by Troy et al., (2018) suggested that reappraisal is more effective for changing subjective negative experience in the short-term, but acceptance seems to be superior at modifying psychophysiological responses. However, the study of Goldin et al. (2019) showed that acceptance was not associated with any reduction on amygdala activation, while reappraisal was. This difference in the subcortical activation may suggest a superiority of reappraisal over acceptance strategies to reduce fear responses. Therefore, there must be other variables that explain why acceptance seems to be able to modulate more effectively several psychophysiological correlates more effectively. In this regard, acceptance is less difficult to deploy than reappraisal (Troy et al., 2018), so the superiority of acceptance to reduce both central and peripheral physiological measures could be explained by a higher effortful processing when reappraisal is used, associated to greater autonomic activation (i.e., heart rate) and mental engagement (i.e., overall greater brain activation).

Importantly, these findings must be interpreted with caution since acceptance can be understood either as an antecedent or a response-focused strategy. Moreover, some studies that use acceptance as a response-focused strategy combined different components with acceptance such as defusion or mindfulness techniques (Kohl et al., 2013). Therefore, the high variability in the findings of acceptance studies may be explained by different experimental instructions under the acceptance label (see Kohl et al., 2012; Wojnarowska et al., 2020).

Emotional flexibility to manage negative emotions

In addition to the specific emotion regulation strategy that is used in a stressful situation, the adaptation of the strategy to the individual's goals seems to be especially relevant in terms of the strategy effectiveness (Aldao et al., 2015b; Bonanno & Burton, 2013; Kashdan & Rottenberg, 2010b; Lennarz et al., 2019). In this sense, considering emotion regulation strategies as either maladaptive or adaptive has merit but may not capture the more complex process of emotion regulation in daily life. Thus, rather than the strategy being inherently adaptive or maladaptive, the effectiveness of the distinct emotion regulation strategies depends on the interaction of the features of a situation and personality characteristics of the individual regulating his/her emotions (Kobylińska & Kusev, 2019). For example, McRae et al. (2012) showed that reappraisal had different effects when individuals were pursuing different goals. Research has largely focused on two emotional aspects that have been related with the adaptation of the emotion regulation strategy to the environmental demands, namely cognitive flexibility, and emotion regulation flexibility (Bonanno & Burton, 2013; Dennis & Vander Wal, 2010).

On the one hand, **cognitive flexibility** refers to "the ability to switch cognitive sets to adapt to changing environmental stimuli" (Dennis & Vander Wal, 2010, p. 242), being associated to the main use of coping strategies considered as adaptive and a decreased use of maladaptive coping strategies (Dennis & Vander Wal, 2010; Kurginyan & Osavolyuk, 2018). This ability might be an essential aspect for the adaptiveness to pain, as it has been associated with higher perceived pain self-efficacy (Hageman et al., 2014) and a less likelihood of the development of chronic pain after surgery (Attal et al., 2014).

A study conducted by Meesters et al. (2019) revealed that cognitive flexibility was associated with faster recovery from pain unpleasantness. However, in a posterior investigation they did not find this association during pain induction suggesting that being flexible might be more beneficial in the recovery phase because it involves a switch in the affective context to return to the baseline (Meesters et al., 2021). If so, it could be possible that individuals also benefit from cognitive flexibility in anticipation phases in which the stimulus is still not present, and the individual must control their affective state to manage the possibility to feel pain. In addition, a study conducted with rats showed that cognitive flexibility improved the extinction retention memory after fear association (Chaby et al., 2019), so this ability may be proposed as an underlying mechanism implicated in how people manage and face fear of pain.

On the other hand, **emotion regulation flexibility** refers to the ability to implement emotion regulation strategies that are synchronized with contextual demands (Aldao et al., 2015b). Although Bonanno & Burton (2013) suggested that it cannot be conceptualized as an unitary phenomenon, as the ability to be flexible in emotion regulation is determined by three sequential components of regulatory flexibility: (1) the context sensitivity or the ability to evaluate contextual demands; (2) the repertoire or the ability to use a wide range of emotion regulation strategies: and (3) the feedback responsiveness or the ability to maintain or modify the emotion regulation strategy that is needed in function of the emotion regulation effectiveness.

In this sense, Sheppes et al. (2011, 2014) showed that the effectiveness of different strategies may vary depending on the contexts. Thus, in low intensity contexts, when the cognitive demand is low, or when long-term goals are activated, participants tend to choose cognitive reappraisal. In turn, in high intensity contexts, when the cognitive demand is elevated, or when short-term goals are activated, participants prefer to use distraction. Also, controllability of the situation has shown to be especially relevant for the adaptability of one's regulatory efforts. For example, one study revealed that people with greater well-being used reappraisal in situations they perceived as less controllable, compared to more controllable situations (Haines et al., 2016).

Additionally, research has shown that a limited number of strategies has been associated with worse adjustment to stressful events (Orcutt, Bonanno, Hanna, Miron, 2014). In contrast, individuals with a rich repertoire of emotion regulation strategies are more able to implement adaptive strategies flexibly in response to contextual demands, and thus, might benefit from using them (Aldao & Nolen-

Hoeksema, 2012, 2013). Likewise, the tendency of implementing a wide range of emotion regulation strategies has been associated with less affective symptomatology such as depression or anxiety (e.g., Lougheed & Hollenstein, 2012), and greater well-being scores (Bonanno et al., 2004).

Despite the growing interest in the role of flexible emotion regulation, it is a relatively new concept, causing that the relationship between pain and cognitive and emotion regulation flexibility has been little explored yet. Hence, it seems necessary that future studies address the association between limited emotional flexibility and negative outcomes such as fear of pain. This may help to better understand the underlying emotion regulation processes and its implications for the adaptation to specific contexts, making more generalizable the research findings to clinical settings.

General aim and research questions of the thesis

In recent years, there has been an increase in the attention to emotion regulation as a transdiagnostic mechanism for the management of emotional disorders and pain. So far, there is strong evidence suggesting the importance of emotion regulation for the management of negative emotions such as fear, and also pain-related outcomes such as pain intensity or pain tolerance. However, based on the literature review presented in the previous sections, there are several questions that remain unanswered.

(1) Research has mainly focused on exploring the effect of emotion regulation strategies over ongoing negative emotions whereas participants visualize negative stimuli (i.e., pictures, videos) or whereas a pain stimulus is used to trigger aversive reactions. However, the effects of emotion regulation using specific paradigms for inducing threat anticipation have been little explored.

(2) There is a high variability between the findings of different studies when comparing reappraisal and acceptance strategies, that may be derived from the use of different classifications of the acceptance strategy and its combination with other psychological components. This fact highlights the

need to further explore the effects of specific emotion regulation strategies to the management of fear of pain.

(3) A broad range of studies has shown the relevance of cognitive and emotion regulation flexibility for the management of negative emotions and well-being. However, it is a relatively new concept and, so far, it has not been explored in relation to fear of pain.

In view of the above, the **general aim** of the present doctoral thesis is to expand the knowledge about the role of emotion regulation in the management of threatening situations arising from a possible future pain. Considering the gasps gasps and methodological caveat in the literature, we decided to compare different strategies that are commonly used in pain and anxiety interventions in a laboratory task in which threat of pain was induced. In addition, we also aim to explore the role of cognitive and emotion regulation flexibility in the management of the threat of pain.

Specifically, the **research questions** addressed by the present dissertation are the following:

1. Which are the psychophysiological correlates associated with the use of reappraisal and acceptance strategies?
2. Are emotion regulation strategies effective to reduce the fear produced by the anticipation of pain?
3. Do acceptance (conceptualized as an antecedent-focused strategy focused on allowing private experiences as a manner to approaching to goals) and reappraisal lead to different outcomes in terms of subjective and psychophysiological responses?
4. Is the Cognitive Flexibility Inventory a reliable measure to be considered as a predictor variable for the modulation of negative emotions in a Spanish sample?
5. Do cognitive and emotion regulation flexibility predict the modulation of the fear of pain in an anticipation task?

Specific aims and outline of the thesis

To answer each of the above research questions mentioned above, four studies were conducted, which are addressed in separate chapters on the present dissertation.

In order to answer to the first research question, a systematic review focused on the relationship between emotion regulation and peripheral psychophysiological correlates in the management of induced pain is presented in **Chapter 2**. This work aims to synthesize the existing literature on the relationship between emotion regulation (i.e., cognitive reappraisal and acceptance strategies) and common peripheral correlates of the autonomic nervous system (such as HR and EDA), as well as and facial electromyography, (such as affect-modulated startle and corrugator activity), during laboratory tasks where pain was experimentally induced.

Chapter 3 presents an experimental study that aims to answer the second and third research questions. Thus, this research compares two reappraisal strategies that are commonly used for managing the anticipation of pain through evidence-based treatments such as Cognitive Behavioral Therapy (Beck, Rush, Shaw, & Emery, 1979) and Acceptance and Commitment Therapy (Hayes, Strosahl, & Wilson, 1999). More specifically, we compare a situational reappraisal strategy commonly used in traditional Cognitive Behavioral Therapy that is based on changing the negativity of the stimulus, with a mixed reappraisal instruction that combines acceptance and negative functional reappraisal based on the goals, which is closer to 3rd generation therapies as Acceptance and Commitment Therapy. For that purpose, a threat of shock task was conducted. Specifically, our experimental design was a modified and combined version of Grillon et al. (1991) and Lissek et al. (2007) paradigms. More specifically, it consisted in an anticipatory task including cues signalling the possibility of receiving (or not) an aversive stimulus (safe vs. threat trials), in which participants were instructed to down-regulate their emotions through one of the proposed emotion regulation strategies or react naturally (maintain vs. down-regulate).

Next, to answer the fifth research question, **Chapter 4** presents a validation study that was conducted to analyse the psychometric properties of the Cognitive Flexibility Scale (CFI) in a Spanish sample (fourth research question). This scale was posteriorly included in the following experimental study conducted to assess cognitive flexibility with healthy population, which is also part of the current dissertation.

The last study is presented in **Chapter 5** and aims to answer the sixth research question. Specifically, this is an experimental study which aims to test which emotion regulation strategies are more effective for managing negative emotions associated with threat in an anticipation task. To this purpose, a laboratory task was conducted in which participants use their free choice ER strategies to face with anticipatory fear of pain. This paradigm allowed us to identify which strategies or combination of strategies are more effective to manage the anticipatory fear of pain In addition, this study explores whether being more emotionally flexible (i.e., higher cognitive and emotion regulation repertoire) in two contexts (i.e., real life and laboratory settings) is associated with a more successful management of anticipatory fear of pain in the anticipation task.

The thesis ends with **Chapter 6**, which includes a general discussion of the key findings of the current work. In addition, it includes a discussion of the strengths and limitations, future directions, and recommendations for further studies.

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CHAPTER 2

Emotion regulation and peripheral psychophysiological correlates in the management of induced pain: a systematic review

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Abstract

Cognitive reappraisal and acceptance strategies have been shown to be effective in reducing pain experience and increasing pain tolerance. However, no systematic reviews have focused on the relationship between the use of these two strategies and peripheral physiological correlates when pain is experimentally induced. This systematic review aims to summarize the existing literature that explores the relationship between emotion regulation strategies (i.e., cognitive reappraisal and acceptance) and peripheral correlates of the autonomic nervous system and facial electromyography, such as affect-modulated responses and corrugator activity, on laboratory tasks where pain is induced. The systematic review identifies nine experimental studies that meet our inclusion criteria, none of which compare these strategies. Although cognitive reappraisal and acceptance strategies appear to be associated with decreased psychological responses, mixed results were found for the effects of the use of both strategies on all the physiological correlates. These inconsistencies between the studies might be explained by the high methodological heterogeneity in the task designs, as well as a lack of consistency between the instructions used in the different studies for cognitive reappraisal, acceptance, and the control conditions.

Keywords: Emotion regulation, cognitive reappraisal, acceptance, induced pain, psychophysiology.

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Introduction

The conceptualization of pain has undergone a great evolution over the years. The first definitions highlighted a direct correspondence between the damage and the experienced pain. However, the understanding of pain has evolved considerably from its inception, and it is currently considered a multifaceted phenomenon composed of both sensory-discriminative and motivational-affective dimensions [1,2]. Thus, pain is defined as "an unpleasant sensory and emotional experience associated with, or resembling that associated with, actual or potential tissue damage or described in terms of such damage" [3]. This definition recognizes the association between tissue injury and pain, as well as the sensory and emotional dimensions of the experience [4].

A large number of studies have shown the relationship between pain and emotion, proposing emotions as determinants and consequences of the subjective pain experience [5,6]. Thus, pain can be modulated by emotions, with numerous studies showing that inducing negative affect is related to elevated self-reported pain ratings and lower pain tolerance, whereas inducing positive affect is related to less self-reported pain and higher pain tolerance [7–10]. In this line, recent research has proposed that emotion regulation (ER) can be an important factor in the development and management of pain [11].

ER is defined as the ability to modify emotional responses in behavioral, experiential, or physiological domains to achieve one's goals [12,13]. Many studies have shown the efficacy of ER strategies for modulating negative emotions such as anger, fear, or sadness [14,15]. Specifically, acceptance, suppression, avoidance rumination, problem-solving, and cognitive reappraisal were studied and synthesized in a large meta-analysis conducted by Aldao et al. [16], showing that rumination, avoidance, and suppression can be considered maladaptive ER strategies, whereas problem-solving, reappraisal, and acceptance can be classified as adaptive strategies. These latter two strategies (i.e., reappraisal and acceptance) have been widely studied in relation to pain. They are core elements of first-line evidence-based treatments for pain management, such as Cognitive Behavioral Therapy (CBT) [17] and Acceptance and Commitment Therapy (ACT) [18]. Cognitive reappraisal is an antecedent-focused strategy that involves changing the meaning and emotional valence of a stimulus to change its emotional impact [12,19]. For example, in pain research, cognitive reappraisal has been taught to participants using positive self-statements that emphasize the individual's ability to tolerate pain (e.g., "I can stand this") or underestimate the pain ("It's not that bad") [20], reinterpreting sensory experiences (e.g., imagining thermal stimulation as a blanket on a cold day) [21], or changing the meaning of the stimuli to modify the emotional impact of negative stimuli (e.g., "This is good for your health") [22]. Acceptance is a response-focused strategy that does not aim to change the meaning of the stimulus, but rather changes the way the person relates to his/her thoughts and feelings [23]. Hayes et al. [18] refers to acceptance as the willingness to remain in contact with and actively experience particular private experiences that are accompanied by functional behaviors. McCracken, Vowles, & Eccleston [24] argued that acceptance of pain consists of two components. The first component is concerned with the individual engaging in positive and functional activities in a normal way in spite of experiencing pain. The second component has to do with the recognition that avoiding or controlling pain is ineffective. Thus, in the context of pain, studies could instruct participants to notice their thoughts and feelings but continue with the task in order to achieve their goal [25]. Moreover, some studies model their instructions on broader mindfulness-based interventions and include, in addition to acceptance, other mindfulness facets such as observing and non-judging. For example, participants can be instructed to attend to their feelings and accept the experience, without judging the "goodness" or "badness" of this sensation [26].

Laboratory studies have shown that both ER strategies (i.e., reappraisal and acceptance) are effective in down-regulating negative emotions, resulting in less negative self-reports [27,28]. Moreover, these strategies are not only useful for modulating the subjective experience, but they can also produce changes in psychophysiology, including the autonomic nervous system (e.g., electrodermal activity; heart rate) and affect-modulated (e.g., startle reflex) and behavioral (e.g., corrugator) responses [29–31] when facing negative stimuli. In this regard, both reappraisal and acceptance have been shown to be effective in decreasing electrodermal activity and heart rate responses [27,32,33]. Likewise, reappraisal has also been associated with diminished defensive responses such as the startle reflex

[32,34], although the literature shows a lack of agreement in the results [35–39]. Regarding behavioral responses, studies have reported that corrugator activity decreases when participants use reappraisal or acceptance strategies [28].

These two strategies have also been shown to be effective in reducing the pain experience and increasing pain tolerance, measured with subjective ratings [25,40–42]. However, the down-regulation of both negative emotions and pain experience is not always accompanied by the expected psychophysiological responses [43,44]. Mixed results have been reported in this regard, possibly due to the methodological heterogeneity across the studies. Therefore, there is a need to summarize all the studies on the relationship between the use of ER strategies (reappraisal and acceptance) and psychophysiology, in order to identify which ER instructions and other methodological factors influence this relationship. To our knowledge, only one systematic review has summarized the existing studies on the association between ER and pain [11]. However, this review does not include studies with psychophysiological measures. To the best of our knowledge, no systematic reviews have focused on studies that use experimental tasks to assess the relationship between psychophysiological activity and the use of ER strategies, specifically reappraisal and acceptance, for pain management. ER encompasses the measurement of cognitive, behavioral, and psychophysiological responses to an event or stressor [45]. Hence, psychophysiological measures can offer important advantages in the study of ER strategies, providing relevant information about changes in internal experiences that cannot be assessed with subjective measures. For this reason, this review aims to synthesize the existing literature on the relationship between emotion regulation (i.e., cognitive reappraisal and acceptance strategies) and common peripheral correlates of the autonomic nervous system and facial electromyography, such as affect-modulated responses and corrugator activity, during laboratory tasks where pain was experimentally induced.

Methods

Search strategy

A systematic search of the peer-reviewed literature was conducted through different databases: PubMed, Web of Science, PsycINFO and Cochrane Central Database of

Controlled Clinical Trials. Additionally, Google Scholar and citations and reference lists from relevant articles were reviewed (forward and backward snowballing searches). A search for ongoing studies was performed by checking trial registries (ClinicalTrials.gov; isrctn.com). If the full-text version was not available or data were missing or unclear, the study's authors were contacted. The terms combined to conduct the search were: "emotion regulation", "pain", and "psychophysiology measures", as follows: "emotion regulat*" OR "emotional regulat*" OR "emotion dysregulation" OR "emotional dysregulation" OR "self-regulation" OR "emotional modulat*" OR "emotion modulat*" OR "emotion management" OR "emotional management" OR "emotional self-efficacy" OR "reappraisal" OR "cognitive reappraisal" OR "cognitive change" OR "acceptance" OR "affect modulation" OR "affective modulation" AND "pain" OR "pain*" OR "painful stimul*" OR "pain induction" OR "pain-induction" OR "induced pain" AND "psychophysiology" OR "psychophysiological measures" OR "electrodermal activity" OR "galvanic skin response" OR "cardiovascular" OR "cardiac defense response" OR "heart rate" OR "heart rate variability" OR "RMSSD" OR "electromyography" OR "EMG" OR "autonomic responses" OR "peripheral measures" OR "self-report*".

The systematic review protocol was registered in the International Prospective Register of Systematic Reviews (PROSPERO) under registration number CRD42020173613.

Eligibility Criteria

Eligible studies were experimental studies that involved ER strategies, namely acceptance[1] and cognitive reappraisal. The studies could compare these strategies to each other, to other ER strategies, or to a control condition. Acceptance has usually been included in mindfulness-oriented interventions [46,47]. However, acceptance and mindfulness should not be used as interchangeable terms. Some studies have revealed that when a facet of mindfulness (i.e., observe the present moment experience) is applied without acceptance, it does not reduce negative emotional reactions [48,49]. Similarly, Teper & Inzlicht [50] suggested that mindfulness may dampen emotional reactivity to all sorts of external stimuli and, specifically, that the acceptance facet of mindfulness is mainly responsible for this dampening. Because this review focuses on the acceptance facet, studies that incorporated mindfulness-based instructions, but without specifying that acceptance was used, were excluded from this systematic review.

To be included in the systematic review, studies had to target children, adolescents, adults, and the elderly in clinical and non-clinical samples. Only studies with psychophysiological measures and experimentally induced pain were included. Pain induction was considered in any of the following stimulation modalities: electrical stimuli, mechanical stimuli, or thermal stimuli (see 51]). Clinical studies where pain was not induced (i.e., studies with patients who regulate their endogenous pain) were excluded. Furthermore, reviews, meta-analyses, dissertations, study protocols, and conference abstracts were also excluded. Finally, only studies published in English or Spanish were included, with no restrictions based on the year of publication.

Identification and selection of studies

The screening, identification, and selection process was conducted by two independent reviewers (IJ and AD-G). First, studies were screened by reading titles and abstracts to identify potentially relevant articles, and those that were clearly ineligible were rejected. In the second phase, the reviewers independently assessed full-text versions of the relevant articles to determine final eligibility. In addition, the reviewers categorized the studies independently according to the ER instructions used (i.e., cognitive reappraisal or acceptance). The label used in the study was prioritized in the categorization. If a study did not use one of the specific terms used in the search strategy, such as cognitive reappraisal or acceptance, each reviewer classified the instruction independently on the basis of the definitions of cognitive reappraisal and acceptance proposed by Gross [52] and Hayes [23], respectively. After this classification by the authors, agreement was checked. In all the cases, the reviewers agreed on the classification of the strategies. Finally, the final selection of the studies to be included was supervised by two expert evaluators (MP and AG-P).

Data extraction and coding

Data about the included studies were extracted in a data extraction form. The following variables were included: a) study (authors and year of publication); b) population (clinical or non-clinical population); c) aims of the study; d) sample (sample size); e) age (mean age of the sample); f) percentage of females; g) design of the study; h) comparator; i) ER strategy used (including the instructions given); j) moment when the ER strategy is used; k) psychophysiological measures; l) moment when the psychophysiological measures are assessed; m) type of pain induction; and n) main findings. All the variables mentioned above were extracted and coded independently by IJ and AD-G, and disagreements were resolved through discussion with a third author (MP).

Risk of Bias within Studies

Risk of bias was assessed for each study independently by two team members (IJ, AD-G) using the Methodological Index for Non-Randomized Studies (MINORS) [53]. In this review, ten types of biases were evaluated qualitatively: a clear stated aim, criteria for participant inclusion, prospective collection of data, endpoints appropriate for the aim of the study, unbiased assessment until the study endpoint, calculation of the study size, an adequate control group, contemporary groups, baseline equivalence of groups, and adequate statistical analysis. Biases involving follow-up and the percentage of participants lost to follow-up were not assessed in this review because they were not applicable.

Studies were scored on an individual bias by indicating 0 (not reported), 1 (reported but inadequate), or 2 (reported and adequate). Conflicts about ratings were resolved through discussion and consensus.

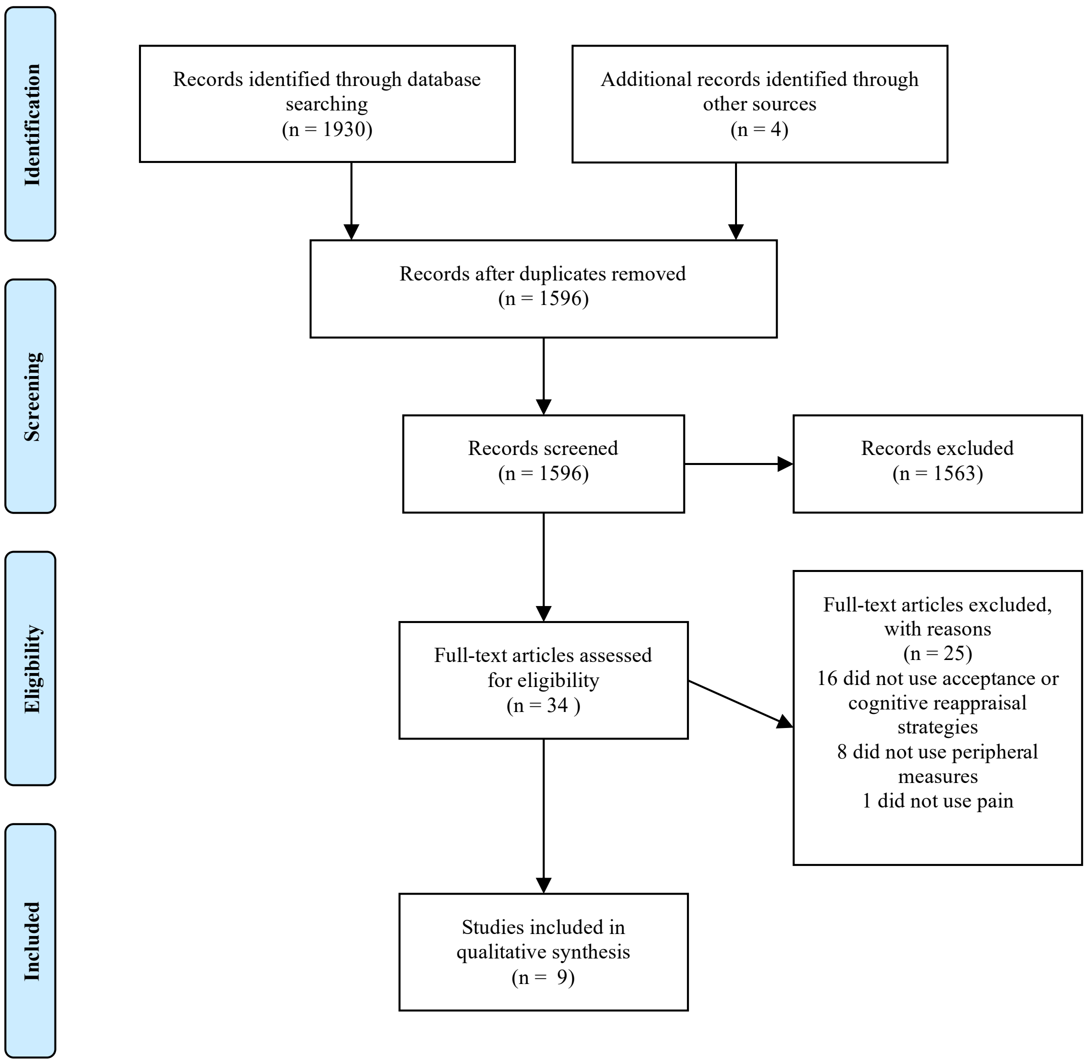
Results

Selection and inclusion of studies

The search in the four electronic databases generated a total of 1930 potential studies (PubMed = 594; Web of Science = 598; PsycINFO = 238; Cochrane Library

= 500). In addition, four studies were obtained through other sources (i.e., Google Scholar and references from relevant articles). Therefore, 1934 records were identified. After retrieving duplicates (n = 338), a total of 1596 studies were screened by two independent researchers (IJ, AD-G), based on titles and abstracts (S1 File). Of them, 34 full-text versions were assessed for eligibility, providing the reasons for exclusion: a) no use of cognitive reappraisal or acceptance strategies (n = 16); b) no use of induced pain (n = 1); and c) no inclusion of peripheral psychophysiological measures (n = 8). Thus, nine studies were selected for final inclusion in this systematic review. The study selection process is presented in the PRISMA flowchart (Figure 2.1).

Figure 2.1. PRISMA Flow diagram



Characteristics of included studies

Relevant characteristics of the included studies are shown in Table 2.1. The research included in this systematic review consisted of experimental studies designed to test whether ER strategies (i.e., acceptance and cognitive reappraisal) influence the pain experience when using experimental tasks with induced pain. All the studies assessed non-clinical populations (i.e., college students, undergraduate university students, members of the general public, community members, and healthy populations). The mean age of the study samples ranged between 18.98 and 27 years, and the majority of the studies had a percentage of female participants, with only one study being conducted entirely with a male-only population.

Regarding the ER strategy used, six studies included reappraisal [54–59], and three included acceptance [60–62]. All the studies compared reappraisal or acceptance to control groups/conditions or other regulatory strategies (i.e., suppression, enhancing negative emotions). No study compared these two strategies with each other.

Of the nine studies included in this review, six focused in the regulation of pain by including at least one of the following subjective ratings of pain: intensity, unpleasantness, tolerance, and threshold [54–57,61,62]. Moreover, some of these studies complemented these measures with affective ratings [54,55]. Nevertheless, three studies focused mainly on the regulation of anticipatory anxiety related to upcoming pain, with two of these studies including only anxiety reports [58,59] and one of them including both anxiety and pain reports [60].

Regarding psychophysiology, all the studies in this review included cardiovascular measures. Specifically, six of the studies included Heart Rate [54–56,58,60,62], one included Pulse Rate [59], one measured Heart Rate Variability [61], and one included the average of the Inter-Beat Interval [57]. In addition to cardiovascular measures, five studies reported skin conductance responses [55,57–59,62], and only one study also included pupil diameter and corrugator activity [56].

Finally, in connection with the type of pain induction used in the experimental task, two of the studies used the cold pressor task [54,61], four used thermal stimulation [55–57,62], and three used electric shock [58–60]. The studies conducted with cold pressor used between-group designs where the comparator was a control group, whereas the studies conducted with thermal and electric stimuli used between- and/or within-group designs in which the comparator might also be an unregulated block or a monitoring control condition.

Emotion regulation instructions

Of the studies that used reappraisal strategies, two included instructions for reinterpreting the emotional stimulus as a good outcome, specifically instructing participants to “imagine the pain from a hot tub” [56] or to “minimize danger and enhance the counterfactual pleasantness of the stimulation” [57]. Another study used a change of perspective, taking a detached observer position as an ER strategy [58]. In this study, they encouraged the participants to distance themselves from their unpleasant feelings and thoughts. Finally, three studies used a combination of reappraisal regulation strategies [54,55,59]. First, Denson et al. [54] provided participants with different instructions based on reappraising emotional responses (e.g., “adopt a neutral and objective attitude toward their performance”) and changing their perspective (e.g., “think about it from a third-person perspective”). Second, participants in the study by Hampton et al. [55] were given instructions to reappraise their emotional responses (e.g., “change your thoughts, and the way you are thinking about your behaviors like facial expressions, and physical reactions like heart rate, in such a way that you don’t feel any discomfort at all”), change the stimulus (e.g., “feeling the warmth of the sun on his or her skin”), and change the perspective (e.g., “others may try to think of this experience as an opportunity to learn about psychological experiments rather than as a painful event”). Finally, Holmes & Houston [59] used an instruction based on reappraising the emotional stimuli (e.g., to think about the shock as a “vibrating sensation”) or change in perspective (e.g., “have a completely detached attitude toward the shock”) strategies.

Regarding acceptance strategies, Braams et al. [60] used brief instructions to “fully experience and accept any feelings and responses...without trying to control, avoid, resist or change them”. Haspert et al. [62] used an acceptance strategy based on Acceptance and Commitment Therapy, focusing on acceptance, mindfulness, and cognitive diffusion processes. Specifically, participants were instructed to accept their feelings, allowing any experience to occur without evaluating it. Furthermore, participants might employ the metaphor of the "cloud in the sky" [63] as a method of detachment. Evans et al. [61] taught participants acceptance strategies based on mindfulness-based stress reduction programs emphasizing a non-judgmental attitude [59].

Control instructions

Emotion regulation studies have used a wide variety of control instructions to draw comparisons with emotion regulation conditions. For example, three studies did not give participants any instructions [54,59,60], whereas others instructed the participants to "perceive" and "sense the pain as it is and not use any strategies" [62] or "try not to regulate or change your sensation" [57]. Moreover, three studies used strategies such as "respond naturally" [55,56,61]. Finally, one study [58] used a control condition based on imagery and instructed participants to focus on the emotion and the way it affects their bodies and minds. It was similar to an emotion regulation condition (i.e., detachment) in terms of subvocal rehearsal, visual imagery, emotional awareness, and acceptance.

The cognitive reappraisal strategy and self-reported and psychophysiological measures

Regarding self-reported measures, two studies found that cognitive reappraisal reduced the subjective emotional experience of the unpleasantness and intensity of pain [55,57]. In addition, one of these studies showed that reappraisal increased the pain threshold and tolerance level [55]. Another study reported that subjective anxiety produced by pain anticipation was lower when participants used the reappraisal strategy, compared to a control condition [58]. Furthermore, one study found that cognitive reappraisal was effective in reducing stress [59]. Finally, one study [54] showed that reappraisal increased feelings of control, challenge, and self-efficacy about the upcoming pain. Furthermore, participants in the reappraisal condition also felt that they had been more efficacious after the pain task than participants in the control condition.

With regard to the psychophysiological effects of cognitive reappraisal, all the studies included cardiovascular measures, four used electrodermal activity, and one included corrugator and pupil diameter. Diminished cardiovascular responses were found in three studies when participants had to reappraise [56,58,59]. In addition to these results, two studies did not find these differences [54,55], and one study found a marginally significant effect [57]. Holmes & Houston [59] found that reappraisal was effective in reducing cardiovascular responses during the stimulation period, but not during the anticipation period. In terms of electrodermal activity, two studies found lower responses when participants were using reappraisal in both the stimulation and anticipation periods, compared to a control condition [58,59]. Likewise, one study reported decreases in skin response activity when participants reappraised, compared to when they up-regulated their emotions, but these results were only marginally significant [57]. Additionally, this study found that electrodermal and cardiovascular responses across the trials predicted the unpleasantness and intensity of pain self-reports. In contrast, one study did not replicate any electrodermal activity effects [55]. Only one study included pupil diameter dilation [56], finding a smaller diameter size when participants had to reappraise, compared to the maintain condition. Moreover, this last study included corrugator electromyography, revealing that the use of reappraisal reduces corrugator activity, compared to the maintain condition.

The acceptance strategy and self-reported and psychophysiological measures

With regard to self-reported measures, one study found that the strategy of acceptance was effective in reducing both pain and anxiety ratings [60]. Although this effect was also found for the suppression condition, acceptance was more effective in reducing anxiety produced by pain anticipation, compared to the control or suppression group. Likewise, another study reported lower pain ratings for acceptance, compared to the control condition [62]. In terms of tolerance, one study found that participants who received brief acceptance instructions had less tolerance to pain during the cold pressor task, compared to a control group that used familiar strategies to cope with pain [61], that is, any coping strategy that came naturally to them.

In terms of psychophysiology, all the studies included cardiovascular measures (i.e., two used Heart Rate, and one used Heart Rate Variability), and one included skin conductance responses. Specifically for cardiovascular measures, the studies found heart rate reductions when the acceptance strategy was used [60,62]. Braams et al. [60] found that acceptance led to reductions in heart rate responses once the shock was delivered (8s following), compared to a control condition. However, no cardiovascular effects of using acceptance were found in previous phases (i.e., preparation and anticipation phases). Furthermore, Evans et al. [61] found that higher Heart Rate Variability predicted greater pain tolerance, but only in the control group that used familiar strategies to manage pain, whereas no correlation was found for the group instructed to *observe, describe, and accept*. According to the authors, these results suggest that unfamiliarity with using acceptance strategies while attempting to tolerate pain may shape self-regulatory strength. Regarding skin conductance, no effect was found when acceptance was used [62].

Table 2.1. Characteristics of included studies

Study	Sample size (N)	Age, M (SD)	% Female	Diagnosis (clinical or non-clinical population)	Aim	Design	ER strategy instructions	Comparator/ Control instruction	Strategy utilization period	Measures	Type of pain stimulation	Main findings
Braams et al., [60]	123	21.7 (5.1)	46.3	Non-clinical population (undergraduates and members of the general public)	To compare differences in pain, anxiety, and associated physiology (i.e., heart rate) between groups using suppression versus acceptance regulation strategies, or a no regulation strategy (i.e., control group) in response to experimentally induced pain	Within and between groups	Acceptance	Control: no instructions	Anticipation and shock phases	Pain and anxiety ratings Heart rate responses	Electric shocks S: right wrist D: 200ms	Acceptance led to comparable reductions in pain reports and cardiac defense responses, compared to the control condition, as well as greater reductions in reports of anticipatory anxiety compared to suppression.
Denson et al., [54] Study 2	90	21.57 (4.20)	57.77	Non-clinical population (undergraduates and members of the general public)	To test the hypothesis that reappraisal would lower psychological threat perceptions and enhance feelings of challenge, self-efficacy, and control over the stressor.	Between groups	Cognitive reappraisal	Control group: no instructions	Anticipation period (to mentally prepare for the cold pressor task over the next 10 min.)	Pain ratings Affect ratings Heart Rate	Cold pressor S: non-dominant hand T: 7 ± 1 ºC D: as long as possible, but no longer than 2 min	Participants in the cognitive reappraisal group reported enhanced anticipatory psychological appraisals of self-efficacy and control and greater post-stressor self-efficacy. Heart Rate effects were not found.
Evans et al., [61]	63	18.98 (1.62)	46	Non-clinical population (undergraduates)	To test two hypotheses regarding the relationships between unfamiliar mindfulness strategies (observe, describe, and accept), HRV, and pain tolerance.	Between-groups	Acceptance	Control group: instructions to respond naturally	During the cold pressure task	Pain tolerance Heart Rate variability	Cold pressor S: hand T: 0.27 ºC D: as long as possible	Mindfulness groups (*observe-only* and *observe, describe, and accept*) showed significantly less pain tolerance compared to the control group Higher Heart Rate Variability predicted greater pain tolerance, only in the control group.

Kalisch et al., [58]	18	27 (7)	55.56	Non-clinical population	To test whether the strategy of detachment attenuates subjective and physiological measures of anticipatory anxiety for pain	Within-groups	Reappraisal	Control group: Actively focus on the emotion	Anticipation	Subjective anxiety Heart rate Skin conductance	Electric shock S: back of the left or right hand (balanced between subjects) D: 1 sec	Subjective anxiety, heart rate, and skin conductance levels were lower when participants had to regulate their emotions through reappraisal strategy, compared to the control condition.
Hampton et al., [55]	142	20.78 (3.20)	68	Non-clinical population (undergraduates)	To examine the effects of emotion suppression and cognitive reappraisal on automatic (i.e., nonverbal) and cognitively mediated (i.e., verbal) pain expressions.	Between-groups	Cognitive reappraisal	Control: instructions to respond naturally	During the painful task	Pain ratings Anxiety and tension scales Heart rate Galvanic skin responses	Thermal pain stimulator S: The volar side of the left forearm, approximately 15 cm above the wrist T: 32℃ to 47℃ D: 5 seconds at 47ºC, with a 7ºC per second ramp-up and ramp-down	Reappraisal induction led to reductions in nonverbal and cognitively mediated (e.g., verbal) and automatic (e.g., facial activity) expressions of pain. However, effects of reappraisal were not found for heart rate and galvanic skin response.
Haspert et al., [62]	30	25.37, (3.58)	53.33	Non-clinical population (undergraduates)	To test the successful reduction of experimentally induced pain through acceptance-based regulation.	Within-subjects	Acceptance	Control: instructions to not regulate	From the 5 sec. before the thermal stimulation to the end of the trial (20 sec)	Pain ratings Heart Rate Skin conductance	Thermal pain stimulation S: The volar forearm of the non-dominant hand T: A level of thermal sensation that went from hot to just painful (from 35 to 49ºC plus 1ºC) D: 10 s	Acceptance was associated with lower pain intensity and unpleasantness. Heart rate was significantly lower during acceptance compared to control trials, whereas skin conductance revealed no significant differences.

Holmes & Houston, [59]	64	Age not reported	50	Non-clinical population (undergraduates)	To examine the effectiveness of specific strategies (redefinition and affective isolation) for handling stress.	Between-groups	Reappraisal	Control: no instructions	Anticipation and pain period	Affective ratings Pulse Rate Skin resistance	Electric shock S: Arm	Reappraisal was effective in reducing self-reported stress and pulse rate, and in increasing skin resistance. Reappraisal was not effective in reducing the pulse rate during the anticipation period, but it was effective during the stimulation period. Skin resistance was effective during both periods.
Lapate et al., [56] Study 2	24	22 (2.1)	0	Non-clinical population (undergraduates)	To examine whether a common self-regulatory ability impacts the experience of both emotion and pain	Within groups	Reappraisal	Control: instructions to respond naturally	From four seconds before the pain stimulus to the end of the thermal stimulation delivery	Pain unpleasant and intensity ratings Heart Rate Pupil diameter	Thermal pain S: Left forearm T: A level of pain rated as “8 out of 10” (with a maximum of 49°C) D:18-12 sec	Reappraisal was associated with less pain unpleasantness and lower heart rate responses to the heat, compared to the enhanced condition. Reappraisal was associated with smaller pupil size and less corrugator activity, compared to the maintain condition. Unpleasantness ratings were positively correlated with heart rate changes.

Matthewson et al., [57] Study 1	41	24,3 (5.6)	48.78	Non-clinical population	To examine whether self-regulation influences pain-related physiology by developing pain predictive physiological markers based on skin conductance responses and electrocardiogram data	Within-groups	Reappraisal	Control: instruction to not regulate	During the thermal stimulation	Electrocardiogram Skin conductance responses Generalized Labeled Magnitude Scale	Thermal pain S: Three sites located on the middle forearm that alternated between runs. T: Six levels of temperature (level 1: 44.3ºC; level 2: 45.3ºC; level 3: 46.3ºC; level 4: 47.3ºC; level 5: 48.3ºC; and level 6: 49.3ºC). D: 12.5 sec seconds, with 3-second ramp-up and 2-second ramp- down periods and 7.5 seconds at target temperature.	Reappraisal produced decreases in intensity and unpleasantness ratings of pain, and it marginally decreased electrocardiogram and skin conductance responses. Electrocardiogram and skin conductance responses predicted self-reports.

S: site where pain stimulation was induced; T: temperature; D: pain duration

Assessment of risk of bias

Table 2.2 summarizes the different biases related to the methodological quality of the studies included in this review, according to the MINORS [53]. All the studies reported a clear and adequate aim, as well as appropriate endpoints in accordance with these aims. Moreover, all the studies had an adequate control group managed in the same period as the experimental group (i.e., contemporary groups). Furthermore, most of the studies reported information about the inclusion criteria, and they performed adequate statistical analyses.

Additionally, only two studies reported information about the calculations of the study size. Regarding the unbiased assessment of the study endpoint, only two of the nine studies reported blind evaluation of objective and/or subjective outcomes. With regard to the baseline equivalence of the groups, three of the nine studies reported on the similarity of the groups. Finally, none of the studies provided information about a protocol established before the beginning of the study.

Discussion

In recent years, an increasing number of studies have focused on psychophysiological measures in order to shed light on the ER process (see [29]). However, to date, there are no systematic reviews that summarize the studies that include experimental tasks to assess the relationship between psychophysiological activity and ER strategies to manage pain. The study of peripheral psychophysiological responses is particularly useful in various pathologies because it allows us to obtain objective measures of psychological processes in a non-invasive way. For this reason, this systematic review aimed to explore the relationship between ER strategies (i.e., cognitive reappraisal and acceptance) and psychophysiological peripheral correlates in laboratory studies where pain was induced.

Table 2.2. Assessment of risk of bias

	Aim	Inclusion	Prospective	Endpoints	Unbiased	Follow-up	Lost-follow-up	Size	Control	Contemporary	Baseline	Statistical analysis
Braams et al. [60)	2	0	0	2	0	NA	NA	0	2	2	0	2
Denson et al. [54]	2	2	0	2	2	NA	NA	0	2	2	2	2
Evans et al. [61]	2	2	0	2	0	NA	NA	0	2	2	2	2
Kalisch et al. [58]	2	2	0	2	0	NA	NA	0	2	2	0	2
Hampton et al. [55]	2	2	0	2	2	NA	NA	0	2	2	2	2
Haspert et al. [62]	2	2	0	2	0	NA	NA	2	2	2	0	2
Holmes & Houston,[59]	2	0	0	2	0	NA	NA	0	2	2	0	1
Lapate et al. [56]	2	2	0	2	0	NA	NA	0	2	2	0	2
Mathewson, et al. [57]	2	2	0	2	0	NA	NA	2	2	2	0	2

Note: Not reported = 0, reported but inadequate = 1, reported and adequate = 2, not applicable = NA

Our findings suggest that both cognitive reappraisal and acceptance strategies are effective in reducing negative pain-related self-reports, such as anxiety, unpleasantness, and intensity of pain. These findings are in line with previous literature that has shown the effectiveness of these strategies in decreasing negative affect produced by unpleasant stimuli (e.g., pictures, films) [29,31]. Although self-reported measures show the efficacy of these ER strategies for managing induced pain, the psychophysiological effects of the use of these strategies are still unclear. In this regard, the results of this systematic review show that, overall, subjective ratings are modulated by the ER strategies, whereas the findings are not the same for the psychophysiology measures.

Literature indicates that successful emotion regulation is commonly related to a reduction in sympathetic activity [65]. In this line, some studies included in this systematic review have found that the use of cognitive reappraisal was associated with decreases in electrodermal responses and pupil diameter, which might reflect a reduction in the emotional arousal associated with sympathetic activity [66,67]. Likewise, cardiovascular and corrugator responses were also reduced when participants were instructed to reappraise. In this regard, cardiovascular responses (e.g., heart rate) have been associated with parasympathetic activation of the autonomic system, and they are sensitive to valence changes in relation to a negative stimulus [68]. Moreover, corrugator activity has been widely used as an index of affective responses, so that higher activity is associated with greater displeasure [69]. Therefore, the findings obtained in some studies included in this systematic review [56,58,59] might indicate that cognitive reappraisal leads to reductions in the affective valence produced by pain. However, other studies did not show this association; instead, they found that cognitive reappraisal leads to marginal or no effects on the autonomic measures (i.e., electrodermal activity and heart rate). Similarly, all the studies included in this review reported that the use of acceptance instructions for the management of pain was associated with reductions in heart rate responses, compared to control conditions. However, no effects of acceptance on electrodermal responses were found. These findings might suggest that acceptance would be effective strategies for reducing the unpleasantness of experiencing pain, but the influence of these strategies in modulating the activation level in response to the emotional experience is less clear.

Regarding the inconsistencies found in the different studies, several explanations can be identified. First, the ER instructions given in the studies included in this review differ greatly. For example, some studies used cognitive reappraisal as a strategy focused on the reinterpretation of negative aspects of the stimulus [57], whereas other studies refer to cognitive reappraisal when participants are instructed to take a detached perspective [58]. In addition, detachment is a method that is also used in the instructions for acceptance [62]. The lack of consistency in the operationalization of reappraisal and acceptance and the similarities in their instructions in the different experimental tasks make it difficult to determine whether the effects are produced by a cognitive change or an experiential change. As Hayes [70] claims, accepting implies making contact with the stimulus functions of events directly and automatically, without acting based on their derived verbal functions. However, some authors refer to acceptance as a type of reappraisal focused on revaluating the emotional response [30]. In the same way, whereas some studies use long periods for acceptance training, allowing an experiential change, other studies use briefer acceptance instructions that are sometimes combined with a cognitive diffusion process. This process has some similarities with those commonly used as cognitive restructuring, such as taking a detached perspective. Divergences in ER instructions could also imply differences in autonomic, cognitive, and brain recruitment that may be reflected in different pain processing and psychophysiological results [27,30]. For this reason, it would be advisable to improve the conceptualization of these two ER strategies in order to draw firmer conclusions about the differential effects of the specific processes used in these studies. Furthermore, we encourage future researchers to specify the components of interest in the study design phase. For example, if mindfulness instructions are given, it would be advisable to report which specific facets the participants are supposed to implement during the task.

Additionally, relevant methodological differences have been found in the control conditions between studies. Whereas some studies did not give any instructions, other researchers instructed participants to respond to the pain as they normally would, or they gave them instructions that might be similar to mindfulness approaches where participants should observe and not judge their emotions. Previous literature reported that different control instructions can result in differences in self-reports and physiological activation [71]. Moreover, a meta-analysis conducted by Zaehringer et al. [25] revealed that the effects on electrodermal and cardiovascular measures were significant when the instruction to "view" was given, but null effects were found when the instruction was "respond naturally". In this regard, some studies included in this review [55,61] did not find significant physiological differences between the reappraisal and control conditions when participants were instructed to "respond naturally". We argue that, in the control condition, participants could be using another adaptive ER strategy or the strategies they are used to, thus being more flexible in their ER. These issues might also provide a plausible explanation for the fact that some studies were able to find significant differences between strategies such as reappraisal and suppression (considered adaptive and maladaptive strategies, respectively), but they were not able to find differences between adaptive strategies compared to control conditions [52]. Therefore, we conclude that the use of a control instruction telling participants to focus on the stimulus without regulating or trying to change their emotions might be a better comparator of an emotion regulation condition than "respond naturally". Future research should study plausible divergences in the different control conditions commonly used in emotion regulation tasks.

A second possible reason for the inconsistencies found is that the individual differences in the ER style may influence self-regulatory efficacy during the experimental task [72,73]. Evans et al. [61] suggested that unfamiliarity with using acceptance strategies while attempting to tolerate pain may shape the self-regulatory strength and produce less tolerance to it. However, Hampton et al. [55] did not find a relationship between self-reported reappraisal tendencies and the pain threshold and tolerance. Future studies should provide a more detailed description of the participants' familiarity with the ER strategy to better understand the results obtained.

Third, the type of design could have an impact on the effect size of the results because within designs imply that the participant changes the strategy during the task [30]. Participants might guess that the researcher is comparing different conditions, and results could be biased by effort, attention, or expectation processes. For this reason, it is important to make an additional effort in this direction, and future studies are needed to optimize the designs for studying the effects of ER and better understanding which cognitive processes are modulating these effects.

Finally, another reason for the inconsistencies found in the studies included in this review could be the type of task and pain stimulation used. In this regard, different methodologies were used. For example, reappraisal has been demonstrated to be less effective than other strategies such as distraction in intense emotional situations [69]. Furthermore, Matthewson et al., [57] revealed that self-regulation effects on autonomic measures are stronger as the unpleasantness and intensity of the stimulus increases. Therefore, future studies should include characteristics of the stimulus (e.g., type of stimulation, temperature, intensity, or unpleasantness) as moderators of ER success. Additionally, it is important to determine the specific moment when the ER strategy starts to be implemented because studies have shown different psychophysiological results in anticipatory and pain periods [59,60].

Previous research using self-report measures has shown the superiority of acceptance over cognitive restructuring for increasing tolerance to experimentally induced pain [25]. Nevertheless, in this systematic review, no study compared these two strategies, which highlights the lack of research on the emotion regulation and pain relationship using objective psychophysiological measures.

Regarding the assessment of risk of bias, the overall quality of the studies included in this systematic review was acceptable, specifically regarding the aim and the adequacy of the endpoints for the aim of the study. However, some studies did not properly report the inclusion criteria and sample size calculation. In addition, it is worth noting that no studies reported a protocol established before the beginning of the study. For this reason, we encourage authors to register study protocols that include methodological aspects, in order to improve the methodological quality of experimental studies. This would facilitate future replication of the studies and systematic reviews of the literature and reduce publication bias.

This work has some strengths and limitations. To our knowledge, this is the first review to systematically summarize the literature on the relationship between peripheral psychophysiology and two of the most widely used ER strategies (cognitive reappraisal and acceptance) in pain management. Moreover, this review conforms to PRISMA guidelines and has a previous record in PROSPERO. Nevertheless, our findings reveal a lack of studies in this field, which makes it difficult to draw clear conclusions about the effects of ER strategies on peripheral measures when participants are managing pain. In addition, it is possible that some studies were not located and have not been included in this review. Given that the review was conducted with three databases and there were language restrictions (English and Spanish), some studies might have been left out.

Furthermore, another limitation is related to the lack of consistency in the terms used for the strategies across the studies. For example, some studies used "suppress" or "down-regulate" when referring to reappraisal strategies [56,57]. Likewise, in numerous studies, the ER strategy used was open, not well-defined, or mixed with other strategies [75,76], and so these studies were excluded from this review. In addition, acceptance is a strategy that is often included in mindfulness programs, but all the studies that used mindfulness were excluded if they did not specify that a component of acceptance was included. Finally, our study only focuses on reappraisal and acceptance strategies, leaving out other ER strategies that may be of interest.

Conclusions

The present review confirms that there are few studies focusing on psychophysiological activity and pain management through reappraisal and acceptance strategies. However, there is a growing interest in this topic.

Although cognitive reappraisal and acceptance strategies appear to be associated with decreased psychological responses, these findings are not found in all the studies. The inconsistencies found in this systematic review, in terms of ER concepts, instructions, and length of training in ER strategies, among other issues, indicate a lack of agreement about the procedures to follow in laboratory settings that can result in differences in physiological responses. Therefore, one important conclusion from this review is the need to advance toward a more standardized methodological framework in this line of research. Likewise, methodological factors, such as stimulus characteristics (e.g., type of pain, intensity) and the moment when the strategy is used, should be carefully explored to achieve a better understanding of the modulators that can underlie the effectiveness of ER strategies for pain.

In addition, further research is needed to determine the role of cognitive reappraisal and acceptance strategies in peripheral psychophysiological responses. Specifically, it would also be necessary to evaluate an aspect that was not considered in any of the psychophysiological studies included in this review, that is, comparing these two strategies and determining which one is more effective in managing pain. Importantly, new research should focus on comparing specific components or subtypes of both strategies (e.g., willingness, attention, taking a detached perspective), in order to determine the relationship of each cognitive process on the psychophysiological correlates.

Footnotes

[1] Acceptance has usually been included in mindfulness-oriented interventions [72,73]. However, acceptance and mindfulness should not be used as interchangeable terms. Some studies have revealed that when a facet of mindfulness (i.e., observe the present moment experience) is applied without acceptance, it does not reduce negative emotional reactions [74,75]. Similarly, Teper & Inzlicht [76] suggested that mindfulness may dampen emotional reactivity to all sorts of external stimuli and, specifically, that the acceptance facet of mindfulness is mainly responsible for this dampening. Because this review focuses on the acceptance facet, studies that incorporated mindfulness-based instructions, but without specifying that acceptance was used, were excluded from this systematic review.

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CHAPTER 3

A comparison of stimulus-focused and goal-based reappraisal in the anticipation of pain: Self-reported and peripheral psychophysiological correlates

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Abstract

The present study aims at comparing the effects of two subtypes of cognitive reappraisal (i.e., stimulus-focused vs. goal-based reappraisal) to reduce anticipatory anxiety of pain. Affective ratings, startle reflex, and autonomic measures (electrodermal and heart rate changes) were used as a measure of emotion regulation success. A total of 86 undergraduate students completed an anticipatory task in which they had to regulate their negative emotions or react naturally when faced with the possibility of receiving a painful thermal stimulus. Participants were randomly assigned to two experimental groups to compare the situation-focused and goal-based strategies explored here. Our results revealed enhanced self-reported anxiety, electrodermal activity and eyeblink response when participants tried to voluntarily down-regulate their negative emotions, compared to the control instruction. Differences between both cognitive reappraisal groups were not found. These unexpected findings suggest that brief reappraisal instructions may not necessarily be favorable for regulating emotions during anticipation of aversive events. Moreover, these results are further explained in terms of the pain expectation, the painful stimuli modality, and emotion regulation instructions.

Keywords: Emotion Regulation; Reappraisal; Pain Anticipation; Subjective Ratings; Psychophysiology

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Introduction

Current models describe pain as a multidimensional and complex experience that involves not only sensory components, but also affective, cognitive, and evaluative factors (Melzack & Wall, 1965). One of the factors that has been identified as a critical one for pain experience is fear of pain. The Fear-avoidance model (Vlaeyen & Linton, 2000) propose that, when individuals misinterpret pain as a catastrophizing situation, the perception of pain as a threatening stimulus increases, resulting in fear of pain. This fear of pain leads to hypervigilance, emotional distress, and increased pain severity in subacute, acute, and chronic pain (Jackson, Wang, Wang, & Fan, 2014; Vlaeyen & Linton, 2000; Zale, Lange, Fields, & Ditre, 2013). Thus, a vicious fear-avoidance cycle is created, that promotes avoidance behaviours such as disengage of daily activities and disability, contributing to the maintaining and chronicity of pain (Leeuw et al., 2007; Vlaeyen & Linton, 2000). Therefore, the reduction of fear-avoidance beliefs and catastrophizing has become a main target in first line interventions for chronic pain management (Vlaeyen et al., 2002; Williams & McCracken, 2004).

One of the psychological mechanisms that has shown to be effective to reduce fear is cognitive reappraisal (Liao & Zheng, 2016; Wolgast et al., 2011). This strategy involves reframing a stimulus or situation to change the emotional experience (Gross, 1998). Research has used this strategy in several ways giving rise to different classifications of cognitive reappraisal instructions (see Webb et al., 2012; McRae et al., 2012). Importantly, previous studies focused on reappraising negative emotions have shown that the use of different reappraisal subtypes can lead to different effects on subjective and psychophysiological responses. For example, McRae et al. (2012) showed that reappraisal strategies focused on increasing positivity were more effective than reappraisal focused on decreasing negative circumstances, increasing valence responses such as positive affect but prompting smaller decreases in skin conductance (i.e., arousal). Cristea et al. (2012) compared positive reappraisal with negative functional reappraisal. This is, comparing a reappraisal focused on changing the negative aspects of the situation, with a reappraisal strategy focused on enhancing a functional emotional mode that allows the individual to engage in goal-directed behaviours where the situation maintains its negative character. This study revealed that negative functional reappraisal was more efficient to reduce negative emotions than positive reappraisal, as well as to reduce irrational beliefs and increase rational beliefs. However, they did not include psychophysiological responses in their study.

Specifically in pain research, several laboratory studies have also shown the efficacy of cognitive reappraisal strategies for reducing self-reported pain, autonomic responses to painful stimulation, as well as for increasing pain tolerance level in response to induced pain (Fardo et al., 2015; Hampton et al., 2015; Lapate et al., 2012). However, any research has not compared reappraisal strategies for the management of pain or fear of pain so far. In addition, research focused on the peripheral physiological effects of using ER strategies on threatening feelings produced by the anticipation of a pain stimulus is still scarce and has shown inconsistent results. For example, Kalisch et al. (2005) found that emotional detachment –a modality of reappraisal that consists of denying the relevance of the stimuli taking a detached perspective– reduced heart rate and electrodermal activity when participants were threatened by the possibility of receiving an electric pain stimulus. Also, Holmes & Houston (1974) conducted a task composed of anticipation and stimulation (electric shocks) periods, in which reappraising the stimuli ("these aren't shocks; they are vibrations") was effective in reducing electrodermal activity during anticipation and stimulation periods. However, heart rate differences were found for induction, but not for anticipation periods. In this sense, the inconsistences found in previous studies suggest that emotion regulation success depend not only on the emotion regulation strategy that is used, but also on the moment when reappraisal is implemented (Jaén et al., 2021a).

In addition, the high heterogeneity in the reappraisal instructions used in laboratory settings, as well as the lack of consistency in the operationalization of the emotion regulation strategies makes it difficult to draw general conclusions on each strategy (Jaén et al., 2021a). Consequently, there is the urgent need to deepen our understanding of the mechanisms underlying clinical interventions to manage negative emotions, and to examine the commonalities and differences of each of these specific processes (Jaén et al. 2021a; Arch & Crascke, 2008).

The present study aimed to progress on this goal, testing the effects of two types of cognitive reappraisal to manage anticipatory anxiety of pain through self-reports, autonomic measures of emotion (i.e., electrodermal activity and heart rate changes) and startle reflex modulation. In this way, this study aims to compare two reappraisal strategies that are commonly used for managing the anticipation of pain through evidence-based treatments such as the Cognitive Behavioral Therapy (Beck, Rush, Shaw, & Emery, 1979) and the Acceptance and Commitment Therapy (Hayes, Strosahl, & Wilson, 1999). More specifically, we compare a situational reappraisal strategy commonly used in the traditional Cognitive Behavioral Therapy that is based on changing the negativity of the stimulus through decatastrophizing, with a mixed reappraisal instruction that combines acceptance with negative functional reappraisal based on the goals, which is closer to 3rd generation therapies as the Acceptance and Commitment Therapy. This last strategy encourages the individual to accept the subjective experiences such that the individual is not dominated by thoughts, so that s(he) recognizes that the threat can be true, but it is accepted, in such a way that it facilitates to engage with the task. From now on, we will refer to these two strategies as stimulus-focused reappraisal and goal-based reappraisal, respectively. According to previous literature (McRae et al., 2012; Cristea et al., 2012), we hypothesize that both reappraisal strategies will be effective in reducing anticipatory anxiety. The emotion regulation success will be reflected by lower anxiety self-reports in the down-regulate condition, compared to the control condition, in which participants were instructed to react naturally. In addition, following the cascade model (Lang et al., 1997) the success in regulation will be physiologically associated to a decreased defensive response. This will be reflected in lower startle reflex and electrodermal activity, as well as an increased heart rate bradycardia. In addition, we expect that goal-based reappraisal will be more effective than stimulus-focused reappraisal in reducing anxiety self-reports and as well as modulating valence measures (i.e., reducing startle reflex and increasing heart rate bradycardia). Also, goal-based reappraisal will produce more decreases than stimulus-focused reappraisal in the arousal measure (i.e., electrodermal activity) when faced with the possibility to receive a painful thermal stimulus.

Method

Participants

An optimal sample size of 66 participants was calculated *a priori* using G*Power (Faul et al., 2009), assuming a small to medium effect size of Cohen's *f* of 0.2 (Braams et al., 2012; Jaén et al., 2021b), an alpha error of 0.05 and a power of 0.95. Because potential drop-out was considered, the final sample was incremented with 20 participants. Thus, a total of 86 undergraduate students (69.4% females) of the Universitat Jaume I were recruited to participate in our study, with a range age of 19 to 30 (*Mean*=20.15; *SD*=2.08). Exclusion criteria were: (a) inability to understand or speak Spanish well enough to understand the task; (b) current cardiovascular disorder; (c) medical or psychological disease; (d) current use of medications that affect psychophysiological measures; (e) diagnostic of chronic pain. From the initial sample, one participant was excluded because of general methodological failures during startle reflex data acquisition, and further 17 participants due to excessive noise in the raw EMG signal collection. Additionally, 8 participants were excluded as they responded in the post-experimental query that spontaneously switched to another ER strategy during the task. Therefore, statistical analyses were conducted with 78 participants for affective ratings, heart rate, and electrodermal activity, whereas 60 participants were finally included for startle reflex data analyses. This study has been carried out in accordance with the Declaration of Helsinki for experiments involving humans. Ethical approval from the Deontological Committee at Universitat Jaume I was obtained, and all participants provided informed consent forms before starting the experiment.

Stimuli and design

Our experimental design is a modified, combined version of Grillon et al. (1991) and Lissek et al. (2007) paradigms. More specifically the current experiment consisted in an anticipatory task including cues signalling the possibility of receiving (or not) an aversive stimulus (safe vs. threat trials), in which participants had to regulate their emotions or react naturally (maintain vs. down-regulate). The task was composed of 4 blocks with 9 trials each (3 safe, 3 threat/maintain, 3 threat/decrease). An extra pain trial was presented at the end of the task.

Additionally, 3 practice trials were included at the beginning of the task after instructing the participants about how to regulate their emotions and how to rate the stimuli.

Each trial started with a fixation cross in the centre of a black screen, followed by another screen with a coloured frame (blue/yellow) around, which indicated whether the painful stimulus will be delivered or not (safe/threat periods). Frame colours (blue/yellow) signalling safety or threat trials were counterbalanced across participants to control for colour effects. Each black screen with the coloured-framed around contained also a word written in white letters in the centre of the screen (maintain/ decrease), which indicated to participants what to do during the 12-s that was presented. Then, subjective ratings of both *anxiety* and *effectiveness using the strategy* were collected using a 10-point scale. For *anxiety* ratings, 0 was "I do not feel anxious" and 9 "I feel extremely anxious", whereas for *effectiveness using the strategy* 0 was "I was not effective using the strategy" and 9 corresponded to "I was very effective using the strategy". Inter-stimulus interval (ITI) ranged at 15 or 18-s to reduce its predictability along the task.

Digitized probes (50ms, 105dB) were presented binaurally over Sennheiser HD-25 headphones. A total of 24 probes were presented at 6 or 10-s after cue onset to prompt startle reflex responses. Moreover, 2 additional probes were included in the practice trials to reduce overall blink amplitude before the task began. During ITIs, 8 probes were presented at 9-s from trial onset.

Thermal pain stimulation

Thermal pain was induced to participants by using a thermal stimulator TSA-II (Medoc, Ramat Yishai, Israel) with a 3x3 cm2 surface thermode. Prior to the task, a work-up procedure was conducted to determine their threshold tolerance, based on three trials in which the sensor heated at a rate of 1.0º C per second from a baseline of 32º, and increased to a maximum temperature of 50º (Hampton et al, 2015). Participants were instructed to press a button to stop the increase when they reached a level of thermal sensation that went from hot to just painful. The average of these three temperatures plus 1º was used as the pain threshold for the pain trial presented at the end of the task. This trial was used to prevent participants from thinking that there was no aversive stimulus during the task, asking them at the end of the task how many thermal heat stimuli they had received and how intense and unpleasant they found it.

Psychophysiological data acquisition and reduction

Raw signals were recorded using the Biopac MP150 system, and EMG100C, GSR100C, and ECG100C amplifiers. Acqknowledge 4.2 software was used to collect, rectify, integrate, and smooth the physiological data. Psychophysiological data reduction and obtaining parameters of interest for each measure for subsequent statistical analysis was conducted using Matlab R2018a and JMP Pro 15 software.

Eyeblinks were recorded electromyographically through the orbicularis oculi muscle using two Ag/AgCl electrodes (4-mm diameter) placed directly below the left eye. The raw EMG signal was continuously sampled at 2000 Hz and filtered online with a high-pass (30 Hz) and a low-pass (500 Hz) filter, being then integrated and rectified also online using Root Mean Square (RMS) integration with a time constant of 20 ms. Blink responses were visually inspected, with peaks detected using Acqknowledge 4.2 software. Eyeblink amplitude was calculated as the difference between baseline (average over 20 ms before the startle probe onset) and peak (within 21 to 180ms after probe onset). Trials in which eyeblinks were outside this range or could not be discerned from surrounding noise were classified as missing in the posterior statistical analyses. Raw values were standardised (separately for each participant) based on the mean and standard deviation of blinks elicited during ITIs. Blinks were expressed as T-scores ([z * 10] + 50). In this standardisation technique, a T-score of 50 indicates reflexes identical to those elicited during the ITI, and experimental blinks are not in the same distribution as the reference (ITI), providing independent standardisation (Bradford, Starr, Shackman, & Curtin, 2015).

Electrodermal activity (EDA) was recorded through two Lead110S-R electrode leads with disposable snap electrodes placed on the left palm hand. Electrodes were attached 10 minutes before beginning the experiment to ensure the stability of the recording. Previously, the hand was gently cleaned using a tissue with distilled water. The signal was recorded using a sampling rate of 2000 Hz with a low-pass filter (10Hz) and DC recording (high-pass). Data were reduced offline for each trial by averaging EDA corresponding to half-second bin periods across the 12s of trial duration, and change scores were calculated as the difference between baseline (1-s prior to cue onset) and each 0.5-s bin. Logarithms of raw scores, log (EDA changes +1), were calculated to normalize the data distribution.

Electrocardiogram (ECG) was recorded though the Lead II derivation, using Ag/AgCl electrodes (6-mm diameter) filled with electrolyte paste. A sampling rate of 2000 Hz was used to obtain the raw ECG-signal, which was band-pass filtered (0.5–35 Hz). HR was obtained online from the ECG-signal, which measured the time interval between consecutive R waves (cardiac period). R-waves were detected and interbeat intervals were obtained using the Acqknowledge 4.2 software. Visual inspection was conducted, and artifacts correction was performed prior to statistical analyses. HR data were reduced as half-second bins periods across the cue presentation (12s). For each trial, change scores were calculated as the difference between baseline (1s prior to excerpt onset) and each half-second bin.

Procedure

Before arriving at the laboratory, participants were assigned randomly to one of these two experimental groups: stimulus-focused reappraisal and goal-based reappraisal. After signing the written consent, the thermic sensor was attached in the middle of their left forearm and the participants completed the work-up procedure, to determine their pain threshold. Afterward, they were instructed about the task structure and completed a practice session where they were trained on the ER instructions as well as the anxiety and effectiveness ratings.

Regarding the ER instructions, participants received the following instruction: *when you perceive physical sensations and/or physiological changes, react naturally, without getting involved in them or rejecting them.* This condition was signalled with the word “Maintain” on the screen. Regarding the “Decrease” instruction, participants in the goal-based reappraisal group were instructed to *think that they agree with feeling pain, because it is something important for them.* Conversely, participants in the stimulus-focused reappraisal group were instructed to *think that it was not so terrible and there were no negative consequences from* *experiencing pain*. Reappraisal strategies were discussed during the practice session to ensure that those used during the task were consistent with the condition strategy. For example, for the goal-based reappraisal group, the reason why the participants would accept pain was discussed with them before starting the study (e.g., monetary retribution, collaboration with research, learning about research procedures). If, during training, participants' responses suggested that they were using another strategy (e.g., distraction or suppression) the experimenter offered corrective instructions and explained again the strategy described above. Then, the anticipation task started, which lasted approximately between 25-30 min in total. After the task, participants completed a post-experimental query developed ad-hoc for this study in which they should describe what they did meanwhile the instructions of maintain and decrease were shown on the screen.

Data analysis

In order to test and compare the effects of using each cognitive reappraisal subtype on self-reported measures and startle reflex responses, two separate 3 (C*ondition:* safe-maintain, threat-maintain, threat-down) x 2 (G*roup:* stimulus-focused reappraisal, goal-based reappraisal) repeated measures ANOVAs were performed with Condition as within-subjects factor and ER Group as between-subject factor. For electrodermal activity and heart rate, two separate mixed repeated measures ANOVAs 3 x 20 x 2 (Condition x Time x Group) were conducted, with Condition and Time as within-subject factors and ER Group as between-subjects factor [1]. Means (SD) and confidence intervals by condition for each measure are reported in Table 3.1.

Assumptions of normality, homoscedasticity, sphericity, and equality of variances were explored using the Mauchly test and the Greenhouse-Geisser correction, where appropriate. *Post-hoc* comparisons were performed with pairwise t-tests when significant differences in main effects were found. Partial eta squared (η_p^2) and Cohen's *d* are reported as measures of effect size. All statistical tests were conducted using SPSS IBM Statistics version 23.

Table 3.1. Means (± SD) and confidence intervals (CI) for subjective ratings and psychophysiological measures during emotion regulation, separately for each cue condition.

	All			Stimulus-focused reappraisal			Goal-based reappraisal		
		95% CI			95% CI			95% CI	
	Mean (SD)	Lower	Upper	Mean (SD)	Lower	Upper	Mean (SD)	Lower	Upper
Anxiety ratings									
Safe-Maintain	1.39 (1.60)	1.03	1,75	1.28 (1.53)	.77	1.78	1.51 (1.67)	1.00	2.03
Threat-Maintain	3.34 (2.09)	3.13	4.07	3.37 (2.11)	2.70	4.03	3.32 (2.09)	2.65	4.00
Threat-Down	3.60 (2.09)	2.87	3.82	3.75 (2.06)	3.09	4.41	3.44 (2.14)	2.77	4.13
Effectiveness ratings									
Safe-Maintain	7.76 (1.41)	7.44	8.06	8.02 (1.11)	7.58	8.46	7.48 (1.64)	7.03	7.93
Threat-Maintain	7.57 (1.30)	7.27	7.86	7.73 (1.26)	7.32	8.14	7.40 (1.35)	6.98	7.82
Threat-Down	7.61 (1.28)	7.32	7.90	7.67 (1.30)	7.27	8.08	7.54 (1.26)	7.13	7.95
Startle reflex									
Safe-Maintain	49.64 (8.36)	47.47	51.83	49.41 (8.54)	46.38	52.44	49.90 (8.30)	46.77	53.03
Threat-Maintain	53.58 (9.35)	51.13	56.00	54.14 (9.77)	50.75	57.52	52.99 (9.02)	49.49	56.49
Threat-Down	55.15 (10.29)	52.44	57.80	55.92 (9.98)	52.20	59.64	54.32 (10.73)	50.47	58.17
EDA									
Safe-Maintain	-0.04 (0.04)	-.07	-.01	-.04 (.04)	-.08	.002	-.05 (.04)	-.09	-.01
Threat-Maintain	0.02 (0.03)	-.03	.07	-.02 (.02)	-.09	.05	.05 (.05)	-.02	.12
Threat-Down	0.13 (0.08)	.05	.21	.09 (.06)	-.03	.20	.17 (.10)	.05	.29
HR									
Safe-Maintain	-0.34 (0.67)	-.81	.13	-.49 (.78)	-1.15	.16	-.19 (.59)	-.87	.48
Threat-Maintain	1.00 (1.02)	-1.05	-.49	-.85 (1.08)	-1.56	-.14	-1.15 (1.00)	-1.88	-.42
Threat-Down	-0.60 (1.00)	-1.08	-.12	-1.01 (1.23)	-1.68	-.34	-.19 (.78)	-.88	.50

Results

Anxiety and effectiveness ratings

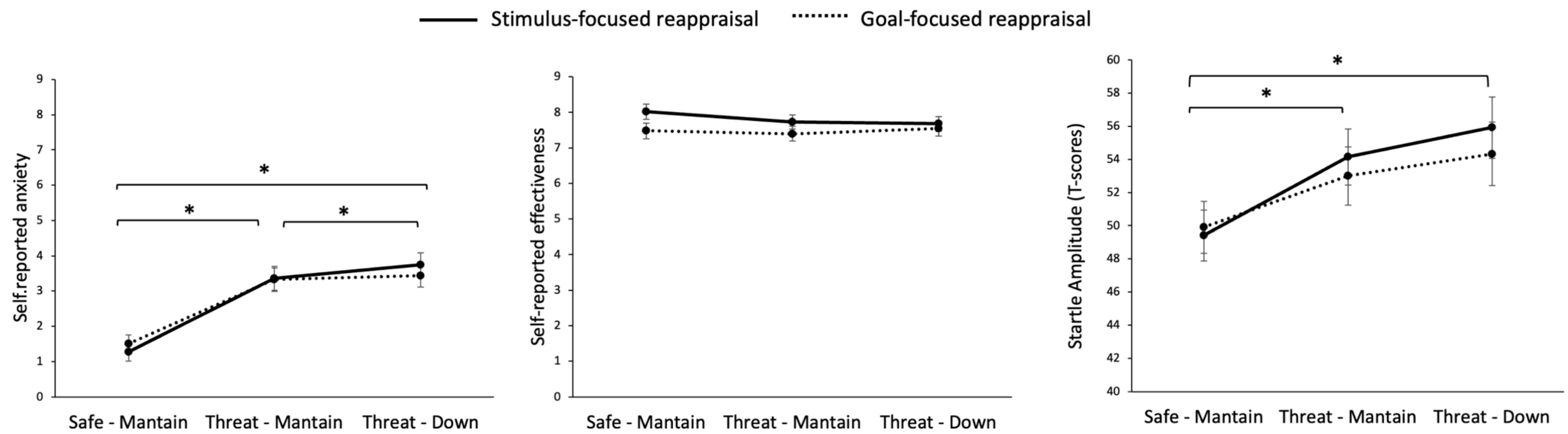
For *anxiety ratings*, a main effect was found for Condition, $F(2, 103)= 120.13$, $p < .0001$, $\eta_p^2 = .61$, but not for ER group ($F < 1$) (see Figure 3.1). The Condition x ER group interaction was not significant either, $F(2, 103) = 1.52$, $p = .22$, $\eta_p^2 = .2$. Post-hoc comparisons showed that reported anxiety was significantly lower in Safe-maintain compared to Threat-maintain, $t\ (77) = 10.93$, $p < .0001$, $d = 7.08$, and Threat-down, $t\ (77) = 12.09$, $p < .0001$, $d = 8.39$, conditions. In addition, anxiety during Threat-down trials was rated higher compared to Threat-maintain condition, $t\ (86) = 2.95$, $p = .01$, $d = 1.16$.

In terms of *effectiveness*, no significant main effects for Condition, $F(2, 119)= 1.69$, $p= .19$, $\eta_p^2 = .02$, nor for ER group, $F(1, 76) = 1.48$, $p= .23$, $\eta_p^2 = .02$ were found (see Figure 3.1). The interaccion Condition x ER group was again not statistically significant, $F(2, 119) = 1.82$, $p = .17$, $\eta_p^2 = .02$.

Startle reflex

A main effect for Condition was found, $F(2, 116) = 15.85$, $p < .0001$, $\eta_p^2 =.22$ (Figure 3.1). However, the repeated measures ANOVA reflected no significant main effect for ER group, nor for the Condition x ER Group interaction (*Fs* < 1). Post-hoc tests showed enhanced eyeblink amplitude for both Threat-maintain, $t(59) = 4.01$, $p < .001$, $d= 0.55$), and Threat-down, ($t(59) = 4.96$, $p < .0001$, $d= 0.70$, conditions as compared to Safe-Maintain trials . However, differences between Threat-down and Threat-maintain conditions were not statistically significant, $t(59) = 1.76$, $p =.08$, $d= 0.18$.

Figure 3.1. Self-reported anxiety, effectiveness and startle reflex responses for each group and condition. (a) Self-reported anxiety (b) Effectiveness (c) Startle reflex reactivity. *p < .01.



Electrodermal activity

The results for the repeated measure ANOVA showed a main effect of Condition, $F(2, 152) = 13.32$, $p < .0001$, $\eta_p^2 = .15$, and Time, $F(19, 127) = 7.22$, $p < .01$, $\eta_p^2 = .08$ (Figure 3.2). However, no main effect was found for ER group, $F(1, 76) = 1.22$, $p = .27$, $\eta_p^2 = .02$. The interaction between Condition x Time was significant, $F(3, 255) = 7.41$, $p < .0001$, $\eta_p^2 = .09$. For all groups an EDA increase is shown from the seconds 2 to 4 (Figure 3.2). As shown in Table 3.2, post-hoc comparisons showed that electrodermal activity was enhanced for Threat-maintain condition compared to Safe-maintain from 3.5 to 6.5 s, and from 9 to 10 s. Likewise, increased EDA was found for Threat-down condition compared to Safe-maintain control condition from 2.5 to 10 s. Unexpectedly, Threat-Down also prompted significantly higher EDA changes compared to Threat-maintain by the end of the trial (from 9 s to 10 s).

Heart rate

The analyses performed for Heart Rate revealed no main effects for Condition, $F(2, 152) = 2.16$, $p = .119$, $\eta_p^2 = .03$, nor for ER group ($F < 1$) (see Figure 3.2).. However, a main effect was found for Time, $F(3, 223) = 29.56$, $p < .0001$, $\eta_p^2 = .29$. In addition, the interaction Condition x Time was marginally significant, $F(38, 592) = 1.85$, $p = .068$, $\eta_p^2 = .02$. As shown in Table 3.3, post-hoc comparisons showed that greater HR changes for Threat-maintain compared to Safe-maintain condition from 5 to 10 s. Differences between Safe-maintain and Threat-down conditions, as well as between Threatening trials (maintain vs. down-regulate) did not reach the significant level. These results suggested that certain HR acceleration was specifically found when naturally reacting to the plausible upcoming pain stimulus during threatening trials compared to the safe control condition.

Figure 3.2. Mean time course of electrodermal and heart rate with standard error bars for the first 10 sec of the instruction screen presentation. $^{*}p < .05$ in Safe-Maintain vs. Threat-Maintain/Down; $^{\#}p < .05$ in Threat-Maintain vs. Threat-Down.

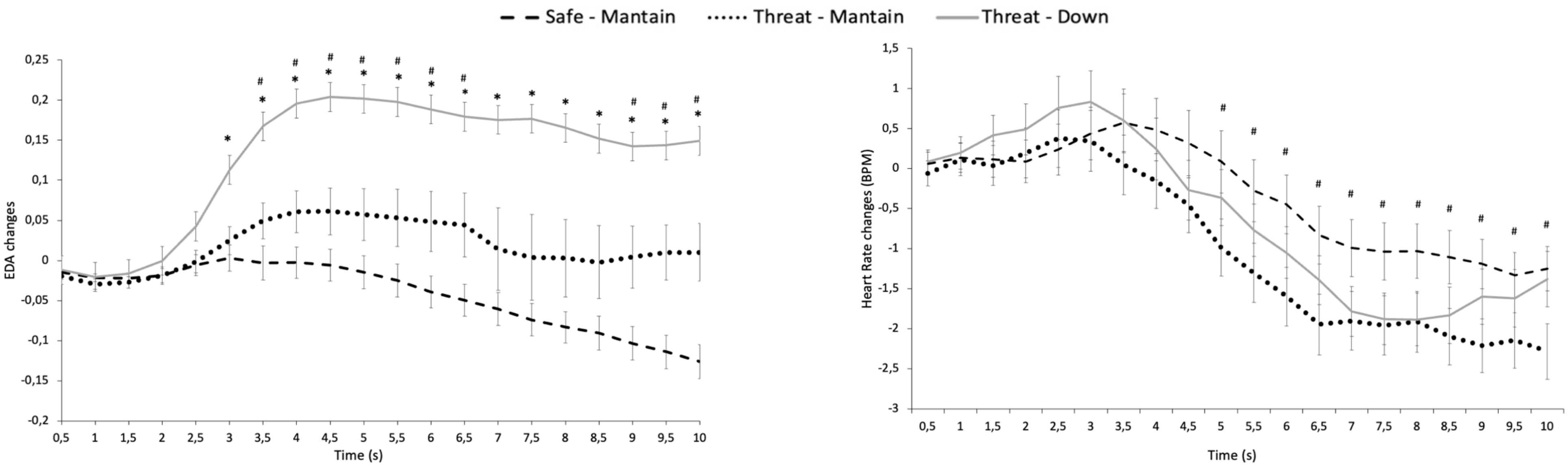


Table 3.2. Post-hoc t-test comparisons between experimental conditions (Safe/Maintain, Threat/Maintain, Threat/Down-regulate) for each half second bin period during 10 s after cue onset for electrodermal changes.

	Safe-Maintain vs. Threat-Maintain				Safe-Maintain vs. Threat-Down				Threat-Maintain vs. Threat-Down			
			95% CI				95% CI				95% CI	
Time (s)	***t* (77)**	***p***	**Lower**	**Upper**	***t* (77)**	***p***	**Lower**	**Upper**	***t* (77)**	***p***	**Lower**	**Upper**
0.5	1,120	,27	-,003	,012	-0,72	0,47	-0,012	0,005	1,377	0,17	-0,003	0,018
1	1,122	,27	-,006	,022	-0,183	0,86	-0,015	0,013	1,067	0,29	-0,008	0,026
1.5	,590	,56	-,013	,023	-0,538	0,59	-0,0256	0,015	0,927	0,36	-0,012	0,034
2	,005	,99	-,027	,027	-1,226	0,22	-0,0483	0,011	1,118	0,27	-0,014	0,051
2.5	-,231	,82	-,041	,032	-2,179	0,03	-0,0925	-0,004	2,056	0,04	0,001	0,087
.3	-1,044	,30	-,062	,019	-3,23	<0.01	-0,1773	-0,042	2,918	<0.01	0,028	0,149
3.5	-1,997	,05	-,105	<-,001	-3,834	<0.01	-0,2594	-0,082	3,008	<0.01	0,039	0,196
4	-2,280	,03	-,119	-,008	-3,933	<0.01	-0,299	-0,098	2,915	<0.01	0,0428	0,228
4.5	-2,135	,04	-,129	-,005	-3,774	<0.01	-0,320	-0,099	2,859	<0.01	0,043	0,242
5	-2,086	,04	-,141	-,003	-3,744	<0.01	-0,332	-0,101	2,912	<0.01	0,046	0,243
5.5	-2,059	,04	-,153	-,003	-3,745	<0.01	-0,341	-0,104	2,938	<0.01	0,048	0,243
6	-2,231	,03	-,167	-,009	-3,875	<0.01	-0,345	-0,111	2,907	<0.01	0,044	0,236
6.5	-2,231	,03	-,178	-,010	-3,903	<0.01	-0,346	-0,112	2,911	<0.01	0,043	0,228
7	-1,287	,20	-,189	,041	-4,017	<0.01	-0,353	-0,119	3,084	<0.01	0,057	0,266
7.5	-1,303	,20	-,197	,041	-4,287	<0.01	-0,368	-0,134	3,22	<0.01	0,066	0,280
8	-1,699	,09	-,188	,015	-4,185	<0.01	-0,367	-0,131	3,318	<0.01	0,065	0,260
8.5	-1,838	,07	-,184	,007	-4,093	<0.01	-0,361	-0,125	3,378	<0.01	0,063	0,245
9	-2,616	,01	-,190	-,026	-4,204	<0.01	-0,362	-0,129	3,318	<0.01	0,055	0,22
9,5	-3,226	<0.01	-,201	-,048	-4,325	<0.01	-0,376	-0,139	3,296	<0.01	0,053	0,214
10	-3,260	<0.01	-,219	-,053	-4,349	<0.01	-0,402	-0,149	3,019	<0.01	0,047	0,231

Table 3.3. Post-hoc t-test comparisons between experimental conditions (Safe/Maintain, Threat/Maintain, Threat/Down-regulate) for each half second bin period during 10 s after cue onset for heart rate changes.

	Safe-Maintain vs. Threat-Maintain				**Safe-Maintain vs. Threat-Down**				**Threat-Maintain vs. Threat-Down**			
			95% CI				95% CI				95% CI	
Time (s)	***t* (77)**	***p***	**Lower**	**Upper**	***t* (77)**	***p***	**Lower**	**Upper**	***t* (77)**	***p***	**Lower**	**Upper**
0.5	.66	.51	-.25	.50	-0.1	0.90	-0.47	0.41	0.67	0.51	-0.30	0.60
1	.09	.93	-.49	.54	-0.23	0.82	-0.57	0.45	0.30	0.77	-0.48	0.64
1.5	.29	.77	-.47	.63	-0.97	0.34	-0.92	0.32	1.15	0.26	-0.28	1.04
2	-.31	.76	-.79	.58	-1.09	0.28	-1.13	0.33	0.79	0.43	-0.45	1.03
2.5	-.33	.74	-.96	.69	-1.13	0.26	-1.44	0.40	0.92	0.36	-0.45	1.22
3	.21	.84	-.79	.98	-0.75	0.46	-1.44	0.65	1.17	0.25	-0.34	1.31
3.5	1.16	.25	-.38	1.43	-0.05	0.97	-1.15	1.10	1.24	0.22	-0.33	1.44
4	1.41	.16	-.26	1.55	0.45	0.66	-0.84	1.33	0.85	0.40	-0.54	1.34
4.5	1.61	.11	-.19	1.74	1.08	0.29	-0.50	1.68	0.38	0.71	-0.80	1.18
5	2.36	.02	.17	1.97	0.92	0.36	-0.52	1.41	1.29	0.20	-0.34	1.59
5.5	2.21	.03	.10	1.95	1.14	0.26	-0.37	1.37	1.15	0.25	-0.39	1.45
6	2.60	.01	.27	2.03	1.39	0.17	-0.26	1.45	1.21	0.23	-0.36	1.45
6.5	2.54	.01	.24	1.99	1.36	0.18	-0.26	1.38	1.24	0.22	-0.33	1.44
7	2.16	.03	.07	1.75	1.82	0.07	-0.08	1.66	0.28	0.78	-0.74	0.97
7.5	2.14	.04	.06	1.78	1.89	0.06	-0.05	1.73	0.19	0.85	-0.77	0.93
8	2.09	.04	.04	1.72	1.89	0.06	-0.05	1.75	0.06	0.95	-0.88	0.94
8.5	2.38	.02	.16	1.83	1.65	0.10	-0.15	1.62	0.56	0.58	-0.68	1.20
9	2.71	<0.01	.27	1.77	0.99	0.33	-0.41	1.22	1.37	0.17	-0.28	1.50
9.5	2.17	.03	.07	1.56	0.71	0.48	-0.51	1.08	1.13	0.26	-0.40	1.45
10	2.74	<0.01	.28	1.78	0.33	0.74	-0.65	0.92	1.97	0.05	-0.01	1.82

Discussion

The present study aimed to explore the effects of two subtypes of reappraisal on subjective measures and peripheral physiology during an experimental task in which participants anticipated an upcoming painful thermal stimulation. To our knowledge, this is the first study that compares the effect of these two cognitive reappraisal strategies on self-reports and psychophysiological correlates of pain anticipation.

In terms of ER effects, this study showed that the use of both stimulus-focused reappraisal and goal-based reappraisal during the anticipation of pain were associated with higher anxiety levels measured by self-reports in comparison to reacting naturally to the plausible upcoming pain stimuli. These results are in contrast with previous literature that revealed reductions in subjective and psychophysiological responses when voluntarily down-regulating their emotions (i.e. Holmes & Houston, 1974; Kalisch et al., 2005). The findings obtained in our research suggest that reappraisal strategies might not be effective when instructions are brief, and/or the anticipation of pain produces a low anxiety level. Clinical experience shows that ER strategies are sometimes difficult to learn, so the instructions used in this study were brief and could be unfortunately insufficient to obtain the benefits found in other studies exploring cognitive reappraisal (e.g., Holmes & Houston, 1974; Kalisch et al., 2005; Lapate et al., 2012). Also, it may be possible that the cognitive demands of using an ER strategy, which may be not familiar to participants, diminish the self-regulatory resources during anticipatory processes, increasing in turn the participants emotional arousal and the corresponding associated autonomic changes (see Evans et al., 2014). Accordingly, the down-regulate threatening condition was in fact accompanied here by greater subjective anxiety ratings and electrodermal reactivity. Therefore, we encourage to compare the effects of reappraisal subtypes using more comprehensive training sessions rather that brief reappraisal instructions in which emotion regulation is initiated by an explicit and conscious instruction.

Regarding the anxiety level produced by the stimulus, it was low for all the conditions. Previous studies focused on anticipatory phases usually use electric shocks (Braams, et al., 2012; Holmes & Houston, 1974; Kalisch et al., 2005).

However, in this study we use thermal stimulation. Heat stimulation has shown to be perceived as less unpleasant than other modalities of pain (Rainville et al., 1992), which might indeed affect studies like the present one that intended to induce fear to the pain stimuli. In this line, a recent study revealed that emotion regulation success is associated with high levels of stress (Langer et al., 2020). Therefore, results of the present study might indicate that reappraisal strategies may not be effective for managing anticipation of pain when anxiety is low. In addition, some studies have reported that the presentation of warning cues is related to changes in the state of attention (Correa et al., 2006; Weinbach & Henik, 2012). To this extent, it is possible that in the context of low anxiety levels, the instructions regarding the down-regulation condition might lead to enhanced alertness and preparation to use the reappraisal strategy, compared to the control condition. Thus, the observed higher subjective anxiety and enhanced autonomic activity –potentially linked to increases in emotional intensity– might be resulting from top-down processes occurring during the expectancy periods.

Finally, empirical evidence supports that different control instructions can also result in differences in subjective experience and physiological activation (Diers et al. (2014). The instructions given for the control condition (threat-maintain) in this study could be similar to mindfulness approaches where participants are instructed to observe their emotions using cognitive defusion. Subjective anxiety and psychophysiological responses could have been diminished during this threatening control condition due to the use of a more familiar and/or flexible approach somehow similar to mindfulness techniques, which have shown to be beneficial for managing pain (Zeidan et al., 2010). Also, a meta-analysis conducted by Zaehringer et al. (2020) revealed no significant effects of reappraisal decreasing autonomic measures (i.e., skin conductance and heart rate) when the control instruction was "respond naturally". Additionally, it is important to note that the sample included in this study was composed of healthy participants, who could make an effective use of their ER resources during the maintenance condition or could not benefit from voluntary ER instructions. For example, Kohl et al. (2012) found that the strategy of acceptance was more effective limiting acute distress in clinical but not healthy samples. Therefore, in our study, differences between the maintain and down-regulation threatening trials could have been diminished by the characteristics of the experimental sample.

Regarding the comparison between both reappraisal subtypes, we expected to find that goal-based reappraisal would be more effective than stimulus-focused reappraisal, similarly to the results obtained by Cristea et al. (2012) and McRae et al. (2012). However, our study did not find differences between both ER strategies neither in self-reported ratings nor in the psychophysiological measures. In this sense, it is worth mentioning that in the emotion regulation tasks conducted by those authors participants had to reappraise their emotions meanwhile they were watching videos and pictures, respectively. However, in this study the reappraisal instruction was not implemented during the presentation of a negative stimulus, but participants had to use it in an anticipation task. Therefore, differences between our study and those previous works could be related to the use of different paradigms in which the negative stimulus is present or is being anticipated. Specifically, goal-based reappraisal could be more beneficial than stimulus-focused reappraisal when the negative stimulus is present than in the anticipatory period. For example, an individual may find it more difficult and/or less beneficial to make a stimulus less negative when it is already present. However, stimulus-focused reappraisal could be as effective as goal-based reappraisal during the anticipation, being the differences between both reappraisal instructions diminished or disappeared. If so, these finding would have clinical relevance, since it would mean that goal-based reappraisal trainings are more beneficial for managing fear of pain when it is most of the time present (i.e., chronic pain), meanwhile both strategies are equally effective for managing the anticipation of a future pain, as fear of medical procedures.

Of note, our study has some limitations. First, a between-group design was used to compare the reappraisal strategies instead of a within-subject design in which participants would have had to switch the strategy in different trials. In this line, the fact that the participants could only use one brief strategy during the entire task provides methodological accuracy but at the cost of less ecological validity, since the experience of the threat of pain management could vary with respect to what each person experiences naturally in daily life. Future studies should adapt the research designs allowing the participants to flexibly use a variety of ER strategies.

For example, studying the emotion regulation strategies in a natural context or adapting the ER strategy in the task to the participant's thoughts. Another limitation of the present study is that the assessment of the usual ER strategies used by the participants was not included in the experimental protocol. Previous literature has shown that the strategies that are regularly used in daily life could moderate the efficacy of the instructions provided to regulate emotions in laboratory settings (Mauersbergern et al., 2018). Therefore, it would be important for future investigations to assess the frequency of use of individuals' regulatory strategies to achieve a better understanding of the emotion regulation processes.

Conclusions

In conclusion, the present study found that the use of reappraisal strategies during anticipation of pain increased self-reported anxiety, electrodermal activity, and startle reflex responses. Moreover, this study did not find differences between stimulus-focused and goal-based reappraisal. The results obtained in this research suggest that reappraisal strategies might not be effective when instructions are brief, and the anticipation of pain produces low anxiety levels. Also, we highlight the difficulty of finding adequate control conditions to compare emotional regulation strategies. Future research should design new paradigms that allow a greater control of the comparator conditions to study the specific psychological processes that underlie each specific ER instruction and which strategies are more effective to manage fear of pain.

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Footnotes

[1] For statistical analyses, trials in which probes were presented at 6 s after the cue onset were eliminated so that these auditory stimuli did not affect neither EDA nor HR results. In addition, time course analyses for both autonomic measures were performed including only 10 s after cue onset, instead of the 12s corresponding to the total trial duration, to avoid the effects of the probes presented at 10s during the anticipatory periods.

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CHAPTER 4

Psychometric Properties of the Spanish Version of the Cognitive Flexibility Inventory

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Abstract

Introduction: Cognitive flexibility has been suggested to be a transdiagnostic process underlying psychopathology. Because there are no measures of cognitive flexibility ready to be used in Spanish populations, the aim of this study was to adapt the Cognitive Flexibility Inventory (CFI) into the Spanish language and examine its psychometric properties in a sample of Spanish individuals. **Methods**: Participants were 300 undergraduate students (mean age= 22.66, SD= 4.92; 76% women). An Exploratory Structural Equation Model was carried out to test the latent structure of the questionnaire. We also calculated the questionnaire's reliability (Cronbach's alpha and test-retest estimates), as well as sources of construct validity evidence with measures of emotion regulation, attributional style, and depression. **Results**: We replicated the original bifactorial model of the CFI (Alternatives and Control scales) and obtained good fit indices. One item was excluded due to problematic factor loadings, so the final version had 19 items. Evidence for the construct validity of the CFI was obtained. The Cronbach's alphas and test-retest coefficients were above.86 and .67, respectively. **Conclusions**: The 19-item Spanish version of the CFI obtained satisfactory psychometric properties (evidence of validity and reliability), so this might be a suitable measure for the assessment of cognitive flexibility in young adults in Spain.

Keywords: Cognitive Flexibility, internal consistency, construct validity evidence, young adults.

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Introduction

Cognitive flexibility (CF) has been defined by many authors as the ability that enables people to effectively adjust their cognitive process to changing environmental demands (Deák, 2003; Dennis & Vander Wal, 2010). In recent years, this ability has been considered to be an essential mechanism associated with mental health (Bonanno & Burton, 2013; Gentili et al., 2019; Bonanno et al., 2013; Kashdan & Rottenberg, 2010; Wersebe et al., 2018). However, one of the major problems of this construct has been the lack of consensus about its definition and measurement. For example, the same term has been used to refer to different constructs due to the different psychological traditions that considered cognitive flexibility a focus of study (Ionescu, 2012, 2017).

A first example of the previous is the definition of CF as a cognitive mechanism of executive functioning (Geurts et al., 2009; Miyake et al., 2000). According to this view, CF has been generally measured using neurocognitive tests, such as the Wisconsin Card Sorting Test, the Stroop colour test, or the Trail Making Test, which assess the flexible/perseverative response pattern of an individual when conducting tasks that require shifting mental sets in response to stimuli. In addition to these, experimental psychologists have also developed task-switching variants of these neuropsychological tests that involve switching between different mental operations in response to task cues (Allport et al., 1994; Rogers & Monsell, 1995; Waugh et al., 2011).

Another conceptualization of CF refers to the rigidity or the ability to adapt our thoughts and behaviours to better respond to the context (Deák, 2003; Garcia-Garcia et al., 2010). When assessing this conceptualization of CF, authors usually rely on self-report measures, such as the Cognitive Flexibility Scale (CFS; Martin & Rubin, 1995) and the Cognitive Flexibility Inventory (Dennis & Vander Wal, 2010), which have become the most popular. Compared to the majority of neuropsychological tests, these self-report measures are significantly faster to administer and score and are less sensitive to practice effects (McCaffrey et al., 1992). This view of CF as an ability to flexibly change one's thoughts and obtain different interpretations of a situation when needed is also more consistent with the perspective of modern psychological treatments are based (Boisseau et al., 2010).

The CFS is one of the first self-report measures of CF. This scale evaluates CF linked to interpersonal communication competence, so the authors proposed that cognitive flexibility should be considered to be an essential component of this interpersonal ability (Martin & Anderson, 1998; Martin & Rubin, 1995). This, however, has been argued to be a limitation to the study of CF, since it is not clear whether communication flexibility can be compared to the CF required to change and replace maladaptive cognitions effectively (Dennis & Vander Wal, 2010). As a consequence, Dennis and Vander Wal (2010) developed the Cognitive Flexibility Inventory, an alternative measure of CF that can be administered for research and clinical purposes to evaluate an individual's ability to think adaptively and flexibly when facing stressful life events.

The Cognitive Flexibility Inventory (Dennis & Vander Wal, 2010) is a brief self-report measure composed of two subscales: Alternatives and Control. The Alternatives subscale measures the tendency to perceive multiple alternative explanations of life events and generate multiple solutions to difficult situations (e.g., "I consider multiple options before making a decision"), whereas the Control subscale was developed to test the tendency to perceive difficult situations as controllable (e.g., "I feel I have no power to change things in difficult situations"). The original English scale (Dennis & Vander Wal, 2010) supported this two-factor structure, and had good evidencies of internal consistency (>.84) and test-retest reliability (r = .81). The scale has now been adapted into Chinese (Wang et al., 2016), Japanese (Oshiro et al., 2016), Iranian (Shareh et al., 2014), Russian (Kurginyan & Osavolyuk, 2018), and Italian (Portoghese et al., 2020). However, some inconsistences have been found in the latent structure in the cross-cultural adaptations. For example, a three-factor structure (i.e., Control, Alternatives, and Alternatives for human behaviours) was reported in the Iranian version (Shareh et al., 2014). In addition, while the Russian (Kurginyan & Osavolyuk, 2018) and the Italian (Portoghese et al., 2020) adaptations replicated the original two-factor structure of the scale, they differed in the number of items that composed the two-factor structure. Specifically, item 1 ("I am good at 'sizing up' situations") was problematic in both adaptations. This item loaded into the Control subscale in the Russian version (Kurginyan & Osavolyuk, 2018), while it had high cross-loading into both factors in the Italian version, which led the authors to remove this item from their adaptation of the inventory (Portoghese et al., 2020).

Regarding the construct validity of the Cognitive Flexibility Inventory according to external criteria, the different versions of the questionnaire have shown that CF is positively associated with the use of more adaptive coping efforts and less maladaptive strategies (Kurginyan & Osavolyuk, 2018). In addition, research with the Cognitive Flexibility Inventory has indicated that depressed individuals perform poorly in CF (Dennis & Vander Wal, 2010), which supports the idea that CF might be an underlying mechanism in emotional disorders such as depression (Boisseau et al., 2010).

Research has also tested the construct validity of the Cognitive Flexibility Inventory in relation to other measures of CF, such as the Attributional Styles Questionnaire (ASQ; Peterson et al., 1982). Surprisingly, though, these studies showed a negative association between the Cognitive Flexibility Inventory and the ASQ, thus suggesting that CF in the Cognitive Flexibility Inventory would be related to greater cognitive rigidity as evaluated in the ASQ (Dennis & Vander Wal, 2010; Kurginyan & Osavolyuk, 2018). Some studies have used the ASQ as a measure of CF using the intra–individual standard deviation for the stable and global items associated with the six negative events (Fresco et al 2017a,b). However, previous validations considered extreme scores as indicavive of less CF for the operationalization of CF (Dennis & Vander Wal, 2010; Kurginyan & Osavolyuk, 2018), which might not be adequate as a measure of CF and might explain the surprising findings reported in past research.

As mentioned earlier, CF has been evaluated using either neurophysiological or self-report measures depending on how CF is conceptualized. While both definitions of CF clearly bear some similarities, it is important to take into account that being skilled at one type of ability does not necessarily indicate proficiency in another, which supports this idea that both types of CF should be differenciated (Johnco et al., 2014). Specifically, it has been suggested that shifting tasks may be associated with the psychological trait of CF, whereas questionnaires would reflect the state of CF in reaction to affective states (Dennis & Vander Wal, 2010). These results highlight the importance of methodological rigour when selecting the adequate measure to assess a specific type of CF.

Various neuropsychological tests of CF have been already translated and validated to be used in Spanish populations. However, Spanish adaptations of self-report measures that evaluate the flexibility required to successfully modify and restructure maladaptive beliefs with a more adaptive thinking are still missing. This is important because CF is a core mechanism of change in therapies such as the Cognitive Behavioural Therapy (Beck et al., 1979), as well as in more modern, transdiagnostic treatments, such as the Unified Protocol (Boisseau et al., 2010), which propose that CF would be a transdiagnostic process underlying psychopathology (Morris & Mansell, 2018). Therefore, the adaptation of a measure of CF to the Spanish population would be important to provide both clinicians and researchers with a self-report measure that helps assessing problems in CF before an intervention, as well as the therapeutic success in improving CF in persons with emotional disorders (i.e., anxiety and depression disorders).

The present study will adapt the Cognitive Flexibility Inventory into Spanish and examine its psychometric properties in a sample of young adults in Spain. Because there is no evidence about the structure of the Cognitive Flexibility Inventory in the Spanish population and considering the aforementioned inconsistencies in the internal structure of this measure in prior cross-cultural validations, we will use an Exploratory Structural Equation Modelling (ESEM) to investigate the internal structure of the scale. We will also examine sources of construct validity of the scale, together with estimates of its internal consistency and stability over time (test-retest). We expect to find empirical evidence that supports the two-factor solution obtained in the original version of the scale (Dennis & Vander Wal, 2010). We also anticipate that we will observe significant positive associations (i.e., convergent construct validity) between the Cognitive Flexibility Inventory and the use of adaptive coping strategies and favorable attributional styles (a construct closely related to flexibility in cognitive thinking). We also expect to observe a negative relationship between CF and depressive symptomatology, in line with previous research (Dennis & Vander Wal, 2010; Gülüm & Dağ, 2012; Kurginyan & Osavolyuk, 2018; Shareh et al., 2014).

Method

Participants

Participants were 300 undergraduate Spanish students from the Jaume I Univeristy Their age ranged from 22 to 41 years (Mean age= 22.66, *SD*= 4.92). The sample size was stablished based on the rule of 10:1 ratio (Nunnally, 1978), as well as the graded scale of sample sizes for scale development, which suggest using a minimum of 300 paticipants to obtain adequate results in the validation of scales (Guadagnoli & Velicer, 1988). The majority of the participants were females (*n*= 228; 76%). Some participants (*n*=89) completed the Cognitive Flexibility Inventory but not the measures used for construct validity, so the exact sample size will be reported for each analysis when corresponding. The Cognitive Flexibility Inventory was administered again one month after the first administration to obtain evidence of test-retest reliability and was completed by a subsample of 85 participants (Mean age= 23.81; *SD*= 4.81; 80% females, *n*= 68).

Instruments

Spanish version of the Cognitive Flexibility Inventory (Dennis & Vander Wal, 2012). This is a 20-item questionnaire composed of two subscales: Alternatives (13 items) and Control (7 items). The Alternatives subscale evaluates the ability to find multiple explanations to a problem and to produce different solutions in front of difficult situations. The Control subscale measures the tendency to perceive situations as controllable. Items are scored using a 7-point Likert scale, which ranges from 1 (strongly disagree) to 7 (strongly agree). Higher scores in both scales reflect greater CF. Internal consistency for the Alternatives and Control subscales in previour research were .86 and .91, respectively (Dennis & Vandel Wal, 2012). The translation into Spanish language was conducted following the back translation method (Brislin, 1973; Supplemental 4.1). First, two of the authors in the present study who are psychologists and native Spanish-speakers and proficient in English translated the English version into Spanish. Second, a native-English-speaking professional translator who was not familiar with the questionnaire translated the questionnaire from Spanish to English. Then, the scale was translated again into

Spanish and discrepancies from the original and the back-translated items were discussed and resolved between all the study authors.

The *Attributional Styles Questionnaire* (ASQ; Peterson et al., 1982) consists of twelve different hypothetical life events (6 positive and 6 negative). Individuals are asked to describe a plausible cause if these events happened to them. These causes are rated on a 7-point scale following these anchors: (1) internal or external, (2) stable or unstable, and (3) global or specific. Two composite indexes can be obtained based on the scores of the positive and negative situations, one for positive attributional style and one for negative attributional style, respectively. Reliability coefficients (Cronbach's alpha) in the present study for positive and negative events were .81 and .74, respectively.

The *Cognitive Emotion Regulation Questionnaire* (CERQ; Garnefski et al., 2001) is a 36-item scale that evaluates the cognitive aspects of emotion regulation. Specifically, the questionnaire comprises 9 subscales, each consisting of different ways in which an individual can think after experiencing threatening or stressful events: Acceptance, Positive reappraisal, Positive refocusing, Putting into perspective, Catastrophizing, Self-Blame, Other-blame, Rumination, and Refocusing on Planning. Each scale consists of four items measured on a 5-point scale, ranging from 1 (almost never) to 5 (almost always). Higher scores indicate more frequent use of that strategy. Reliability coefficients (Cronbach's alpha) of the nine CERQ subscales in this study ranged from .62 to .88.

The *Beck Depression Inventory – II* (BDI-II; Beck et al., 1996) measures the severity of the depression symptomatology during the last week. The BDI-II is composed of 21 items that reflect cognitive, behavioural, emotional, and somatic symptoms common to depression. Items are rated on a 3-point scale. Higher scores indicate higher severity of the depression symptomatology. The Cronbach's alpha of the scale in the present study was .92.

Procedure

The study was advertised using printed posters at the Jaume I University. Once the participants contacted the researchers by email, they were provided with the web link to a Qualtrics survey with all the questionnaires. The participants completed all the measures on the same administration. The Cognitive Flexibility Inventory was administered again one month after the first administration to obtain evidence of test-retest reliability. Once the participants finished the study, they received 10 euros in compensation for their participation in the study. Participants who completed the second assessment received 10 additional euros. The present study was approved by the ethical committee from the author's University. All the participants gave their written informed consent to participate into the study.

Data analysis

To investigate the internal structure of the Cognitive Flexibility Inventory, we used an Exploratory Structural Equation Modeling (ESEM) analysis with two latent factors (to replicate the original structure) using Mplus 8.4. We used a weighted least square mean and variance adjusted (WLSMV) estimator due the non-normal distribution of the data. To investigate the fit of the data to the models, we used the Comparative Fit Indexes (CFI), the Tucker-Lewis Index (TLI), and the Root Mean Square Error of Approximation (RMSEA) indices. For interpretation purposes, CFI and TLI >.90 and >.95 indicate acceptable and optimal fits, respectively (Marsh et al., 2004). RMSEA values ≤.10 indicate an acceptable fit (Weston & Gore, 2006). Confidence intervals (95%) were also calculated and reported. Cronbach's alpha and omega were used to examine the internal consistency of our adaptation of the Cognitive Flexibility Inventory. Cohen's *d* were calculated to compare the effects sizes of the means obtained in each subscale by sex. In addition, intra-class correlation coefficients (ICC; CI 95%) were used to explore the temporal stability of the Cognitive Flexibility Inventory in a one-month retest. Finally, sources of construct validity were analysed by computing Pearson correlations between the Cognitive Flexibility Inventory and measures of cognitive emotion regulation (CERQ), attributional styles (ASQ), and depression symptomatology (BDI-II). Reliability and construct validity analyses were conducted using SPSS v.26.

Results

Descriptive analysis of the items

The distributional properties of the 20 items of Spanish version of the Cognitive Flexibility Inventory (i.e., means, standard deviations, skewness, and kurtosis) are presented in Table 4.1. Specifically, skewness ranged from -1.41 to 0.58 and kurtosis ranged from -1.20 to 3.53. Thus, we obtained asymmetric values for items 3, 13, 15 and 18. Item 3 revealed a leptokurtic distribution.

Table 4.1. Descriptive analysis of the items of the Spanish version of the Cognitive Flexibility Inventory

	Mean	SD	Skewness	Kurtosis
Item 1	5.47	1.08	-0.86	1.16
Item 2	4,14	1.77	0.01	-1.20
Item 3	5.91	1.04	-1.41	3.53
Item 4	3.69	1.72	0.31	-1.13
Item 5	5.52	1.14	-0.62	-0.13
Item 6	4.67	1.41	-0.42	-0.20
Item 7	3.37	1.74	0.43	-1.00
Item 8	6.16	1.42	-0.99	0.83
Item 9	3.24	1.56	0.35	-0.70
Item 10	5.80	1.15	-1.00	0.86
Item 11	3.29	1.59	0.56	-0.78
Item 12	6.30	0.78	-0.84	-0.08
Item 13	5.56	1.18	-1.11	1.54
Item 14	5.60	1.19	-0.91	0.63
Item 15	5.58	1.14	-1.16	1.62
Item 16	5.09	1.12	-0.10	-0.59
Item 17	3.51	1.46	0.34	-0.78
Item 18	5.49	1.15	-1.25	2.00
Item 19	5.48	1.14	-0.95	1.27
Item 20	5.59	1.15	-0.98	1.07

Structural validity evidence

The tested two-factor model obtained between acceptable and optimal fit indices were observed (CFI= .938; TLI= .922; RMSEA= .098; CI 90%= .090-.106). As shown in Table 4.2, all the items were statistically significantly loaded into one of the two factors proposed by the original version of the Cognitive Flexibility Inventory and had loadings over .40. Item 15, which originally belonged to the Control scale, had cross-loadings in both factors, but had a higher loading into the

Alternatives factor. Then, a new ESEM analysis was carried out to test the new structure based on 19-items (i.e., without Item 15). Results showed good fit indices (CFI= .948; TLI= .934; RMSEA= .094; CI 90%= .085- .103), and also salient loaddings of each item for corresponding sub-scale (Alternatives, > .39, Control, >.66; see Table 2). Therefore, following analyses were conducted based on the 19-item structure.

Table 4.2. Standardized factor loadings from the exploratory structural equation model of the Cognitive Flexibility Inventory assuming a two-factor structure

	20-items form				19-items form			
	Alternatives		Control		Alternatives		Control	
	Λ	**95% CI**	**Λ**	**95% CI**	**Λ**	**95% CI**	**Λ**	**95% CI**
Item 1	.51***	0.43, 0.57	.19***	0.12. 0.28	0.493***	0.42, 0.56	0.178	0.10, 0.26
Item 3	.65***	0.59, 0.10	-.11*	-0.19, -0.02	0.650***	0.59, 0.71	-0.111	-0.20, -03
Item 5	.68***	0.63, 0.73	-.01	-0.08, 0.07	0.683***	0.63, 0.74	-0.013	-0.09, 0.06
Item 6	.55***	0.49, 0.74	.16***	0.08, 0.25	0.557***	0.49, 0.62	0.157	0.07, 0.24
Item 8	.43***	0.35, 0.52	-.07	-0.16, 0.03	0.440***	0.36, 0.53	-0.072	-0.16, 0.02
Item 10	.39***	0.30, 0.50	-.05	-0.14, 0.06	0.388***	0.29, 0.49	-0.058	-0.16, 0.04
Item 12	.59***	0.52, 0.67	.05	-0.04, 0.17	0.586***	0.51, 0.66	0.048	-0.06, 0.15
Item 13	.81***	0.77, 0.85	-.34	-0.11, 0.04	0.815***	0.76, 0.86	-0.032	-0.11, 0.04
Item 14	.85***	0.82, 0.89	-.05	-0.11, 0.03	0.855***	0.82, 0.89	-0.047	-0.12, 0.02
Item 15	.48***	-0.58, -0.44	-.12**	-0.39, -0.23	-	-	-	-
Item 16	.63***	0.59, 0.71	.10*	0.06, 0.22	0.632***	0.57, 0.69	0.099	0.02, 0.18
Item 18	.80***	0.75, 0.83	.11**	0.04, 0.18	0.788***	0.75, 0.83	0.096	0.03, 0.17
Item 19	.77***	0.71, 0.83	.15***	0.07, 0.22	0.767***	0.72, 0.81	0.139	0.06, 0.22
Item 20	.86***	0.83, 0.90	.08**	0.03, 0.14	0.866***	0.82, 0.90	0.080	0.02, 0.14
Item 2	.02	-0.06, 0.10	.75***	0.70, 0.80	0.026	-0.05, 0.11	0.751	0.70, 0.26
Item 4	.10*	0.01, 0.15	.81***	0.77, 0.86	0.096**	0.03, 0.17	0.814	0.77, 0.86
Item 7	.12**	0.03, 0.19	.77***	0.72, 0.82	0.126**	0.04, 0.21	0.768	0.72, 0.82
Item 9	-.04	-0.13, 0.05	.72***	0.66, 0.78	-0.027	-0.12, 0.06	0.723	0.67, 0.78
Item 11	.12***	0.04, 0.18	.90***	0.87, 0.93	0.128***	0.05, 0.20	0.902	0.87, 0.93
Item 17	.04	-0.04, 0.83	.67***	0.61, 0.73	0.039	-0.04, 0.12	0.664	0.60, 0.73

Note: p<.05*; p<.01**; p<.001***

Reliability evidence and descriptive coefficients

Cronbach's alpha and omega indices for each factor are presented in Table 4.3. All coefficients, both in the total sample and across sex were above of .86. We did not observe sex differences in the Cognitive Flexibility Inventory subscales. One-month retest correlations ranged from .67 to .90.

Table 4.3. Descriptive for Females and Males and Reliability Coefficients

	Cronbach's Alpha (95% CI)	Omega (95% CI)	Test-Retest ICC (95% CI)	Mean score (SD)	Cohen's *d* (a-b)
Alternatives					
Total	.87 (.86,.90)	.88 (.86, .90)	.85 (.77, .90)	77.21 (10.07)	
[a]**Females**	.89 (.86,.91)	.89 (.86, .91)	.86 (.77, .91)	77.09 (10.30)	.05
[b]**Males**	.86 (.80,.90)	.86 (.78, .90)	.67 (.07, .88)	77.61 (9.36)	
Control					
Total	.89 (.87,.91)	.89 (.88, .91)	.90 (.85, .94)	22.55 (8.60)	
[a]**Females**	.89 (.86,.91)	.89 (.87, .91)	.90 (.84, .94)	22.68 (8.59)	.06
[b]**Males**	.91 (.87,.94)	.91 (.87, .94)	.90 (.71, .96)	22.18 (8.70)	

Construct validity evidence

To evaluate the construct (convergent and divergent) validity of the Spanish version of the Cognitive Flexibility Inventory, bivariate correlations were conducted with measures of emotion regulation, attributional styles, and depression (Table 4.4). The results showed that the two subscales were generally positively associated with the use of adaptive cognitive emotion regulation strategies and inversely related to maladaptive forms of emotion regulation. Specifically, the Alternatives subscale was positively related with Positive refocusing, Positive reappraisal, Putting into perspective, Rumination, and Refocusing, while negatively linked to Catastrophizing, and Other-Blame. The Control subscale was positively associated with Positive reappraisal, Positive refocusing, and refocusing on planning, while negatively associated with Rumination, Catastrophizing and Self-Blame.

Finally, both the Alternatives and the Control subscales were positively associated with the positive-composite attributional style, but negatively linked to the negative-composite attributional style and the severity of depression symptoms. The strength of the correlations was generally small, except for a moderate correlation between the Alternatives scale and the CERQ-RP.

Table 4.4. Sources of construct validity of the Cognitive Flexibility Inventory in relation to other measures

	1	2	3	4	5	6	7	8	9	10	11	12	13
1.CFI Alternatives	1												
2. CFI Control	.15*	1											
3. CERQ-A	.10	-.08	1										
4. CERQ-PR	.21***	.16**	.16**	1									
5. CERQ-PRC	.34***	.20***	.26***	.50***	1								
6. CERQ-PP	.24***	.09**	.30***	.36***	.56***	1							
7. CERQ-SB	.072	-.20***	.14**	-.10	-.01	.20	1						
8. CERQ-R	.19***	-.07	.16**	-.01	.13*	-.01	.31***	1					
9. CERQ-C	-.20***	-.30**	.11*	-.13*	-.21***	-.22***	.32***	.27**	1				
10. CERQ-OB	-.09	-.01	.-02	-.04	-.07	-.05	-.08	.13**	.25***	1			
11. CERQ-RP	.49***	.19***	.22	.34***	.59***	.36***	.04	.22***	-.18***	.01	1		
12. ASQ Positive style	.28***	.20**	-.01	.26***	.31***	.04	-.10	.19**	-.09	-.03	.20**	1	
13. ASQ Negative Style	-.14*	-.19**	-.03	-.19**	-.15*	-.07	.39***	.12	.30***	.04	-.19**	.09	1
14. BDI-II Depression	-.22**	-.34***	-.05	-.32***	-.39***	-.22***	.39***	.24**	.52**	.07**	-.42**	-.23***	.40***

Note: *CFI* Cognitive Flexibility Inventory*; CERQ-A* Acceptance, *CERQ-PRC* Positive reappraisal, *CERQ-PR* Positive refocusing, *CERQ-PP* Putting into perspective, *CERQ-C* Catastrophizing, *CERQ-SB* Self-Blame, *CERQ-OB* Other-blame, *CERQ-R* Rumination, and *CERQ-RP* Refocusing on Planning; , *ASQ* Attributional Styles Questionnaire, *BDI-II* Beck Depression Inventory-II. *$p< .05$, ** $p< .01$, *** $p< .001$

Discussion

This study aimed to adapt the Cognitive Flexibility Inventory into the Spanish language and examine its psychometrics properties in a sample of young adults in Spain. Following the original developments by Dennis and Vander Wal (2010), we found an acceptable model fit for a two-factor structure of the inventory. However, our analyses suggested a modified two-factor version composed of 14 items in the Alternatives subscale and 6 items in the Control subscale. Similar to previous adaptations of the Cognitive Flexibility Inventory (Kurginyan & Osavolyuk, 2018), we found a problematic item in the scale. Specifically, item 15 ("I am capable of overcoming the difficulties in the life that I face") loaded on the Alternatives factor as opposed to the Control factor, which is inconsistent with the distribution proposed in the original English version (Dennis & Vander Wal, 2010). After a discussion about the meaning of Item 15 in the Spanish version and the theoretical implications of changing the structure of the Cognitive Flexibility Inventory based on analytical evidence only, the authors of the present study eliminated this item from the scale. Consequently, we obtained a 19-item version of the Cognitive Flexibility Inventory for Spanish speakers, which shown better fit indices than 20-item form, as well as reliability and validity evidence.

It is important to note that item 15 is the only direct item that originally belonged to the Control subscale, whereas all items in the Alternative subscale are direct. Evidence has suggested that there is a possible acquiescence bias when items are positively worded, which can affect the reliability and dimensionality of the test by secondary sources of variance when combining direct and reverse items (Checa & Espejo, 2018; Suárez-Alvarez et al., 2018). In fact, the inclusion of positive and negative items when measuring two poles of similar constructs may result in a two-factor structure in which positive and negative items load on different factors (Brown, 2003; Fresco et al., 2002; Spector et al., 1997). In this sense, although the literature recommends combining direct and inverted items to control for response style bias, the use of reverse items without the application of a method of bias control would not be recommended (Vigil-Colet et al., 2020). Therefore, it would be advisable that future studies explore the psychometric properties of the Cognitive Flexibility Inventory by controlling for these plausible response style biases combining positive and negative items for both the Alternatives and Control subscales (i.e., rephrasing helf of the items in both scales).

Encouragingly, our analyses showed evidence of reliability for both subscales, with salient internal consistency coefficients across dimensions (> .86). These findings are similar to those obtained by other adaptations of the Cognitive Flexibility Inventory, which support the reliability of the internal consistency of the scale (Gülüm & Dağ, 2012; Kurginyan & Osavolyuk, 2018; Oshiro et al., 2016; Portoghese et al., 2020). Another interesting finding was that we did not find differences in CF between men and women, which is consistent with previous research (Martin & Rubin, 1995). In addition, retest analyses also showed evidence about the internal stability of the Cognitive Flexibility Inventory, thus supporting the idea that CF -as evaluated with this inventory- is likely to be a relatively stable over time. This is important for clinical purposes, as it suggests that cognitive inflexibility should be a therapeutic target as it might remain relatively stable unless it is addressed with psychological treatment.

The findings of this study also provided evidence of the construct (convergent/divergent) validity of the Cognitive Flexibility Inventory in relation to other psychological constructs (emotion regulation, attributional style, and depressive symptoms). Previous validation studies of the Cognitive Flexibility Inventory also evidenced that CF is positively associated with the use of adaptive coping styles and negatively related to the severity of depression symptomatology (Dennis & Vander Wal, 2010; Kurginyan & Osavolyuk, 2018). The present study and previous results are consistent with the idea that cognitive inflexibility might be a transdiagnostic process associated with the use of certain emotion regulation strategies and a better emotional adaptation to face difficulties, which is in line with the theoretical model of psychopathology proposed by the Unified Protocol for the transdiagnostic treatment of emotional disorders (Boisseau et al., 2010).

Interestingly, an unexpected positive association was found between cognitive flexibility and rumination. Specifically, higher cognitive flexibility was associated with higher rumination, which has been considered a maladaptive strategy of emotion regulation (Aldao et al., 2010). Rumination can be defined as a repetitive thinking about the reasons and consequences of one's problems without taking action (Nolen-Hoeksema et al., 2008). This construct consists of two components:

brooding and reflection. The former increases depressive feelings by comparison of one's current situation with some unachieved standard, whereas the latter appears to be related to engaging in cognitive problem solving to alleviate one's depressive symptoms (Bastin et al., 2014; Treynor et al., 2003). Therefore, engaging in adaptive reflection for responding to contextual demands could be adaptive (Martin & Tesser, 1996), and it could help understand the positive association between cognitive flexibility and rumination. In any case, this interesting finding should be better explored in further research.

Regarding the association between the Cognitive Flexibility Inventory subscales and the measure of attributional styles, we found that the Cognitive Flexibility Inventory was directly associated with the positive-composite score of the ASQ and inversely associated with its negative-composite scale. Past research had combined positive and negative attributional scores to obtain a total measure of CF (Dennis & Vander Wal, 2010; Kurginyan & Osavolyuk, 2018; Teasdale et al., 2001). However, the ASQ was not developed to be a measure of CF, so the total score may not be appropriate and suitable for this purpose (Fresco et al., 2007). This might explain, for example, why past research has obtained unexpected findings when exploring the relationship between the Cognitive Flexibility Inventory and the ASQ (Dennis & Vander Wal, 2010; Kurginyan & Osavolyuk, 2018), which was interpreted as evidence that CF in the Cognitive Flexibility Inventory was associated with more inflexibility in the ASQ. We urge researchers who aim to explore the construct validity of the Cognitive Flexibility Inventory or other measures of CF in relation to the ASQ to use the positive- and negative-composite styles scores of the ASQ calculated in the present study, as opposed to a supposedly global measure of CF. By doing this, we obtained coherent findings indicating that individuals with higher CF tend to perceive that the causes of positive events are stable, controllable, and dependent on themselves, whereas high scores in the Cognitive Flexibility Inventory were associated with a view of negative events as more dependent on causes that are external, unstable, and context-specific.

The present study might have made some important contributions to the literature into CF. However, a number of limitations should also be considered. For instance, while this instrument might be especially useful for clinical practice, the validation was conducted among college students. Previous validations of the Cognitive

Flexibility Inventory have also been conducted with non-clinical samples (Dennis & Vander Wal, 2010; Gülüm & Dağ, 2012; Kurginyan & Osavolyuk, 2018; Oshiro et al., 2016; Portoghese et al., 2020; Shareh et al., 2014), which might be a good starting point for further research. However, it would be recommended to test the validity and reliability of this measure in a clinical sample, including individuals suffering from affective disorders characterized by rigid thinking (e.g., depression, generalized anxiety disorder, or obsessive-compulsive disorder), and particularly to compare CF in clinical and non-clinical populations. In addition, further studies are needed to confirm the current structure of the Spanish version of the Cognitive Flexibility Inventory using confirmatory factor analyses in larger samples.

Despite these limitations, the results of the present investigation might be important for research and clinical purposes. In particular, this study showed evidence of the validity and reliability of the Spanish adaptation of the Cognitive Flexibility Inventory among youth adults. This might be important for professionals who implement psychotherapies directed to improve CF as a core mechanism underlying psychopathology in Spanish-speaking countries. So far, there has been a significant gap in terms of robust measures of CF to test whether the efforts made with clinical interventions resulted in the expected changes in this hypothesized underlying psychological mechanism. Accordingly, our findings would be relevant for the scientific community interested in a wide range of different disorders, as this instrument could help to assess the ability to cognitively adapt and face adverse events, which is a core trait to predict greater therapeutic success in a wide range of psychotherapeutic approaches.

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CHAPTER 5

When more is worse: the role of cognitive flexibility and the repertoire of emotion regulation strategies in managing daily negative events and fear of pain

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Abstract

Introduction: Cognitive Flexibility (CF) and the Emotion Regulation (ER) repertoire have been associated with a more adaptive management of negative emotions. However, the role of these constructs in the management of fear of pain remains unexplored. There is also a lack of laboratory studies focused on the study of fear of pain that enable participants to be flexible in the use of ER strategies. The present study aimed (1) to examine the role of CF and ER repertoire in the management of negative emotions in a daily life and in a pain anticipation task conducted at the laboratory, and (2) to identify which ER profiles were associated with a better management of fear of pain. **Method:** Eighty-five participants completed a set of questionnaires and a two-week daily Electronic Diary Study where they reported the emotion regulation strategies that they used daily to face negative events. Next, participants took part in a pain anticipation task where they reported their spontaneous ER strategies. Self-reported anxiety and electrodermal activity and heart rate responses were also measured. **Results:** The use of a larger ER repertoire to manage negative events in daily life was associated with a worse management of anticipatory fear of pain in a laboratory task. The ER profile characterized by a higher use of acceptance showed low emotional intensity and less effectivity in the management of anticipatory fear of pain. **Conclusions:** The ability to use different ER strategies does not necessarily imply that the chosen strategy is the most adaptive one. Also, we encourage further research to explore the role of CF and the ER repertoire in contexts with higher emotional intensity.

Keywords: Emotion regulation flexibility, repertoire, psychophysiology, fear of pain.

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Introduction

Over the years, numerous studies have investigated the effects of distinct emotion regulation (ER) strategies on the management of negative emotions (Zaehringer et al., 2020). The study of emotion regulation strategies has often been conducted though self-reported measures, but also in laboratory contexts using a variety of different emotional stimuli such as pictures (Jackson et al., 2000; Sánchez et al., 2019), film clips (Gross & Levenson, 1995), or electric shocks (Lissek et al., 2007). These laboratory studies have revealed that emotion regulation strategies are not only useful to modulate self-reports when facing negative stimuli, but they are also associated with the modulation of psychophysiological correlates, including the autonomic nervous system (e.g., electrodermal activity; heart rate), affect-modulated (e.g., startle reflex) and behavioural (e.g., corrugator) responses. For example, the use of ER strategies such as acceptance, reappraisal, and distraction have been associated with reductions of cardiac reactivity and electrodermal responses (Driscoll et al., 2009; Eippert et al., 2007; Goldin et al., 2019; Ray et al., 2010; Strauss et al., 2016).

The growing accessibility to mobile applications has led to an increase in the development of studies focused on investigate ER strategies in daily lives through ecological settings such as electronic diary studies (EDSs) or ecological momentary assessment (EMA; Colombo et al., 2019, 2020). Overall, these ecological studies have shown that the use of ER strategies considered as "adaptive" are associated with good outcomes, whereas the use of "maladaptive" ER strategies are associated with poor outcomes (Aldao et al., 2010). For example, Southward et al. (2019) showed that the use of acceptance, positive refocusing, reappraisal, and distraction in daily life were associated with better mood, whereas the use of suppression and blame others were associated with worse mood. Also, Brans et al. (2013) showed that rumination and suppression, were associated with increases in negative affect.

In the last years, research has shown that, rather than using a single strategy to regulate all negative emotions, which has been the mainstream in past laboratory research, successful ER requires being flexible to adapt our behaviour to changing environmental demands (Aldao et al., 2015a; Bonanno & Burton, 2013; Kashdan & Rottenberg, 2010a). This flexibility has been reflected in two popular constructs, namely Cognitive Flexibility (CF; Dennis & Vander Wal, 2010) and ER flexibility (Aldao et al., 2015; Bonanno & Burton, 2013). CF has been defined as "the ability to switch cognitive sets to adapt to changing environmental stimuli" (Dennis & Vander Wal, 2010; p. 242). CF is essential to successfully challenge and restructure maladaptive beliefs into a more adaptive thinking style (Dennis & Vander Wal, 2010), which helps understand why this ability is a key mechanism of change in most Cognitive Behavioural Therapies (Shapero et al., 2018). Similar to CF, ER flexibility refers to the ability of an individual to implement ER strategies that are synchronized with contextual demands (Aldao et al., 2015a). One of the components of ERF that has received most attention in research is the ER repertoire, referred as one's ability to use a wide range of ER strategies (Bonanno & Burton, 2013). In this sense, research has suggested that individuals with a wider repertoire of ER strategies are more capable of implementing adaptive strategies flexibly in response to contextual demands, and therefore might be more successful in self-regulating their emotions (Aldao et al., 2015a; Aldao & Nolen-Hoeksema, 2012). Accordingly, the use of a larger repertoire of ER strategies has been associated with less psychological distress (Lam & McBride-Chang, 2007), whereas the use of a limited ER repertoire has been associated with more severe anxiety and depression symptomatology (Lougheed & Hollenstein, 2012).

Importantly, although most of the research is focused on the study of the emotion regulation strategies in the presence of a certain stimulus, the regulation of the emotions that arise during its anticipation is also of great relevance. For example, high anxiety or fear levels in the anticipation of pain has been associated with cognitive, behavioural, and psychophysiological responses that may increase the risk of a future disability (Buer & Linton, 2002; Granot & Ferber, 2005; Linton et al., 2000; Picavet et al., 2002; Vlaeyen et al., 2016; Zale et al., 2013). For example, the anticipation of pain can lead to safety-seeking behaviours associated with disability if they are maintained in the long term (Moseley et al., 2004). In addition, the expectations of future negative events can elicit similar emotional and physiological stress responses as stressful events themselves (Gramer & Reitbauer, 2010; Waugh et al., 2010). In this sense, previous studies have shown that the increased physiological arousal in response to the anticipation of pain can produce body sensations that individuals can misinterpret as pain, increasing the responses of fear to this body sensations (Nisbett & Schachter, 1966; Weisenberg et al., 1984).

A small number of studies have focused on ER strategies during the anticipation of pain (Jaén, Díaz-García, et al., 2021), and they have shown mixed results. Specifically, some studies found reduced anxiety self-reports and modulated psychophysiological responses associated with the activation of the defensive system (Niharika et al., 2018; Windich-Biermeier et al., 2007). For example, Kalisch et al. (2005) found that reappraisal reduced heart rate and electrodermal activity when participants were threatened by the possibility of receiving a pain stimulus. However, Holmes & Houston (1974), showed that reappraisal was effective in reducing electrodermal activity during the anticipation of pain, but they did not find heart rate effects. Similarly, Braams et al. (2012) showed that the use of acceptance did not modulate heart rate responses during the anticipation of the stimulus. In addition, a previous study (Jaén, Escrig, et al., 2021) revealed that brief reappraisal instructions may not necessarily be favourable to regulate emotions during the anticipation of aversive events. In fact, the use of reappraisal during the anticipation of pain was associated with increased self-reported anxiety, electrodermal activity, and startle reflex responses. Similarly, Denson et al. (2014) found that although cognitive reappraisal fosters psychological perceptions of self-efficacy and control under stress, heart rate effects were not found and an increase of the cortisol reactivity was shown, which was explained by the efforts produced by using this strategy in the short-term.

There are different methodological aspects that have been suggested to explain the inconsistencies across laboratory tasks in which participants were instructed to use a specific ER strategy. For example, the ability to reduce negative emotions by reappraisal in the laboratory has been shown to be more effective for participants with higher scores in the use of reappraisal in their daily life (Mauersberger et al., 2018; Mauss et al., 2007). Thus, it has been suggested that the use of a strategy that is not familiar to participants in the laboratory could affect the self-regulation effectivity on the emotion regulation task (Evans et al., 2014). In this line, a meta-analysis conducted by Zaehringer et al. (2020) showed that allowing participants to choose from different strategies might lead them to be more successful in regulating their emotions, which could result in larger psychophysiological effects. Also, Aldao & Nolen-Hoeksema (2013) suggest that most of the people tend to implement various strategies when presented with an emotion-eliciting stimulus. Considering these findings, it might be argued that there is a need to use more flexible experimental ER paradigms that allow participants to choose their own ER strategies to down-regulate their unpleasant emotions and leave more room for individuals' ER flexibility. In addition, the fact that participants would be able to use their free choice ER strategies to face with a negative stimulus would allow researchers identifying the which strategies or combination of strategies are more effective.

In sum, CF and ER flexibility have been associated with a more adaptive management of negative emotions (Conroy et al., 2020; Han et al., 2011; Twivy et al., 2021). However, the role of CF and ER flexibility in the management of fear produced by the anticipation of pain remains unexplored. In addition, there is a lack of laboratory studies focused on studying the effects of spontaneous ER for managing fear of pain, which enable participants to be flexible in the use of ER strategies.

The current study

In the view of the above, three aims were proposed for this study. The first aim was to examine the role of CF and ER flexibility in the management of negative emotions in a daily life context. To do so, participants were asked to complete a set of self-report questionnaires and complete a two-week daily EDS where they reported the emotion regulation strategies that they used daily to face negative events. We hypothesized that a higher CF and a wide repertoire of emotion regulation strategies will be associated with a more effective daily management of negative events (hypothesis 1).

The second aim of this study was to examine the role of CF and ER flexibility in an anticipation task where participants have to manage fear of pain. For this purpose, the same individuals participated in an experimental pain anticipation task with a discrete stressor (the possibility to receive a heat painful stimulus). Differently to previous studies (Jaén, Escrig, et al., 2021), in this case specific ER instructions were not given but participants were asked about the ER strategies they used to manage fear of pain. Additionally, anxiety self-reports, electrodermal activity, and heart rate responses were also recorded. We hypothesized that higher CF, ER repertoire (in both the EDS and the anticipation task), and perceived effectivity managing daily negative emotions will be associated with a more effective management of fear of pain during the anticipation task (hypothesis 2). Specifically, the success in the management of fear of pain during the anticipation task will be reflected by lower differences between threat and safe conditions on anxiety self-reports, electrodermal activity, and heart rate bradycardia.

Finally, the third aim of the present study was to explore if different ER profiles (or clusters) in managing the fear of pain during an anticipation task was associated with differences in certain self-reports and psychophysiological measures during the same task. To do so, we will conduct a cluster analysis to identify the ER profiles, which were determined by the use of specific ER strategies or a combination of them. We will also compare the resulting profiles in terms of CF, ER repertoire in their daily life and fear of pain, in order to obtain a better characterization of the different profiles. Finally, we will compare the self-reported and psychophysiological task outcomes between the different ER profiles.

Method

Participants

Participants were 85 healthy undergraduate students who participated in simultaneous study in our laboratory to validate the Cognitive Flexibility Inventory (CFI; Dennis & Vander Val, 2010) with a Spanish sample. These participants were recruited through printed advertisement at the Jaume I University (Spain). Their age ranged from 18 to 40 (mean= 23.81; SD=4.81) and 80% of them were females (n=68). Exclusion criteria were: (a) inability to understand or speak Spanish sufficiently to understand the task; (b) current experiencing a cardiovascular disorder or a severe medical or psychological disease; (c) current using medications that might affect psychophysiological measures; or (d) having a diagnosis of chronic pain. From the initial sample, 3 participants were excluded due to recording failure, whereas 5 participants were excluded from the electrodermal activity and 26 from the heart rate analysis due to registration failures. Therefore, statistical analyses were conducted with 82 participants for affective ratings, 77 for electrodermal activity, and 56 for heart rate.

All the participants signed the informed consent form before starting the study. This study has been carried out in accordance with the Declaration of Helsinki for experiments involving humans and received the approval by the Ethical Committee of the Jaume I University.

Measures

Questionnaires

Cognitive Flexibility: We administrated the Spanish adaptation (Jaén et al., submitted) of the *Cognitive Flexibility Inventory* (CFI; Dennis & Vander Wal, 2010). The CFI is composed of two subscales: Alternatives and Control. The Alternatives subscale evaluates the ability to find multiple explanations to a problem and to produce different solutions in front of difficult situations. The Control subscale measures the tendency to perceive situations as controllable. Items are scored using a 7-point Likert scale of, which ranges from 1 (strongly disagree) to 7 (strongly agree). Higher scores in both scales reflect greater CF ability.

Pain-related fear: We used the Spanish adaption (Solé et al., 2019) of the *Fear of Pain Questionnaire – III* (FPQ-III; (McNeil & Rainwater, 1998). The FPQ-III is composed of 30 items that describe painful experiences. Participants must rate how fearful they are or would be of experiencing the pain associated with each item using a Likert scale from 1 (Not at all) to 7 (Extreme). Three subscales can be obtained, corresponding to Severe Pain, Minor Pain, and Medical Pain. In addition, a total score can be used by summing all items. For this study, the total score was used to reduce the risk of type I errors due to multiple comparisons. In the total subscale, higher scores indicate higher fear to specific situations that can produce pain.

Electronic diary study

The participants were asked daily to report a negative event that happened to them during the day and to select the emotion regulation strategy they used to manage it from a list of 10 possibilities (see Table 5.1), based on the studies of Aldao & Nolen-Hoeksema (2012) and Garnefski et al. (2001). In this list, both the term used for strategy and their descriptions were showed to participants. The order of appearance of the emotion regulation strategies was randomized daily to minimize the order bias. A total score for the frequency of each strategy during the whole study was calculated. Because not all the participants had the same number of completed assessments (they had to complete at least 10 of the 14 days to be included into the study), the number of different strategies used by each individual was divided by the number of completed assessments to obtain a ratio for the repertoire of strategies used by each participant. This ratio is henceforth termed EDS repertoire.

Table 5.1. Emotion regulation strategies assessed through the Electronic Diary Study and the pain anticipation task.

Strategy	Definition
Acceptance	Allow or accept your feelings without fighting them
Cognitive Reappraisal	Think about the situation differently to change how you feel/ look at the problem differently
Problem solving	Propose ideas for changing the situation by creating an action plan or solving the problem
Avoidance	Rejecting your feelings or putting them out of your mind, avoiding the negative event
Rumination	Worrying or repeatedly thinking about the situation without looking for solutions
Self-blaming	Criticising yourself for your feelings or having thoughts that you are to blame for what has happened
Suppression	Hiding your feelings from others
Distraction	Think about or do something else to take your mind off the problem.
Catastrophizing	Thinking about what is going to happen, exaggerating the consequences of the negative event
Blame others	Thinking that other people are to blame for what has happened or how you feel about it

Participants were also asked to complete three 10-point numerical scales evaluating the impact of the situation (*What impact do you think the event has had on you?*), the control of the situation (*How controllable do you think this event was?),* and the effectivity of the strategy used to solve the problem or to the reduce its negative impact (henceforth EDS effectivity; *How effective do you think the strategy used was to solve the problem or to reduce the impact of the negative event?)*. The impact was defined as the extent to which the event affected their physical well-being, their psychological well-being, or their relationship with others. The degree of control was defined as the number of aspects of the event that the participants felt they could change.

Anticipation task assessment

Our experimental design consists of an anticipation task based on the threat of shock paradigm by Grillon et al. (1991). Specifically, each trial began with a 2-second fixation point followed by a coloured screen (blue/yellow) presented for 12 seconds, which signalled the possibility of receiving (or not receiving) an aversive stimulus (safe vs. threat trials). Participants were instructed about which colour was associated with the safe or threat condition. The colours indicating safety or threat trials were counterbalanced across participants to control for colour effects. The task was composed of 2 blocks with 10 trials each (5 safe, 5 threat). In addition, an extra trial was presented at the end of the task in which pain was induced to prevent participants from thinking that there was no aversive stimulus during the task. This trial was removed from the data for analyses.

After each threat trial, participants were asked about the emotion regulation strategy they used during the trial. Participants selected one from a list of 10 ER strategies (Table 1). Next, for both threat and safe trials, subjective anxiety ratings were reported using a 10-point scale from 0 (“I do not feel anxious”) to 9 (“I feel extremely anxious”). Finally, an inter-stimulus interval of 15 seconds was presented.

Self-report measures

Anxiety self-reports were collected after each trial during the anticipation task using a 10-point scale, where 0 was "I do not feel anxious" and 9 "I feel extremely anxious". After each threat trial, the participants also reported the *emotion regulation strategy* they were using to manage their emotions from the same list of strategies that they used in the EDS (Table 1). The total of different strategies was counted and named Task repertoire.

Psychophysiological measures

A Biopac MP150 system with GSR100C and ECG100C amplifiers were used to acquire electrodermal responses and cardiac responses, respectively. An Acqknowledge 4.2 software was used to collect, rectify, integrate, and smooth the physiological data. To reduce the psychophysiological data and obtain the parameters of interest for each measure for subsequent statistical analysis we used Matlab R2018a.

Electrodermal activity (EDA) was recorded through two Lead110S-R electrode leads with disposable snap electrodes placed on the left palm hand, previously cleaned with distilled water. The signal was recorded using a sampling rate of 2000 Hz with a low-pass filter (10Hz) and DC recording (high-pass). EDA amplitude was calculated at the maximum change score with respect to a baseline of 1 sec prior to the picture onset. To analyse the time course of the electrodermal responses, the data was also reduced offline for each trial by averaging the EDA corresponding to half-second bin periods across the 12s of trial duration. Change scores were calculated as the difference between baseline (1-s prior to cue onset) and each half-second bin.

An *electrocardiogram* was recorded using Ag/AgCl electrodes (6-mm diameter) filled with electrolyte paste and positioned according to the Lead-II configuration. A band-pass filtered (0.5–35 Hz) and a sampling rate of 2000 Hz was used. HR was obtained online from the ECG-signal, which measured the time interval between consecutive R waves (cardiac period). R waves were detected and interbeat intervals were obtained using the Acqknowledge 4.2 software and complemented with visual inspection. Correction of artifacts was performed by hand. For the statistical analyses, HR amplitude was calculated at the maximum deceleration from the 5 second to the end of the trial. In addition, to analyse the time course of HR responses, the data was reduced to half-second bins periods across the 12s of each trial. Finally, change scores were calculated as the difference between baseline (1s prior to cue onset) and each half-second bin.

Thermal pain stimulation

Thermal pain was induced to the participants by using a thermal stimulator TSA-II (Medoc, Ramat Yishai, Israel) with a 3x3 cm2 surface thermode. Prior to the task, a work-up procedure was conducted to determine their pain tolerance, based on three trials in which the sensor heated at a rate of 1.0º C per second from a baseline of 32º, and increased to a maximum temperature of 50º (Hampton et al., 2015; Jaén, Escrig, et al., 2021). Participants were instructed to press a button to stop the increase of heat when they reached a level of thermal sensation that went from hot to just painful. Next, the highest reached temperature was presented once to the participants, and it was adjusted when the participants reported that the stimulus was below their tolerance level. The last temperature presented was the one used in the last trial of the anticipation task.

Procedure

The study was advertised using printed posters at the Jaume I University (Spain). Once the participants contacted the researchers by email, they received more information about the study and were invited to sign the informed consent and complete CFI and FPQ questionnaires online using the Qualtrics Survey tool. Once the participants completed all the questionaries, they received a link during the following 14 days to complete the EDS assessment. The link was sent to the participants every day at 18:00h and it had to be completed the same day before 23:59h. Participants were informed that they had to complete at least 10 days to obtain the financial compensation to participate into the study.

After checking that the participants had completed at least 10 days of the EDS assessment, they were invited to the laboratory to complete the anticipation task. Upon arrival to the laboratory, the participants were asked to sit on an armchair in a dimly lit room, where the sensors were attached. Next, the threshold and tolerance levels were assessed.

The participants were then informed about the trial structure and the assessment during the task. They were informed that the last stimulus they had felt during the tolerance test would appear in the threat trials of the anticipation task from 1 to 3 times. Afterwards, we waited for 3 minutes to stabilize the signals before the anticipation task started, which had a duration of approximately 15-20 min. At the end of the study, the participants were thanked, and received a remuneration of 20 euros for the whole study participation.

Data analysis

Descriptives were obtained for the questionnaires, EDS reports, and Task outcomes. Bivariate Pearson correlations were conducted to explore the bivariate associations between cognitive flexibility, the EDS and the anticipation task outcomes.

In addition, a series of multiple linear regressions were conducted to test the contribution of cognitive flexibility and ER repertoire on study outcomes, controlling for sex and age. In total, four regressions were planned, one for each dependent variable in the study, that is, one for the EDS (efficacy in the management of negative events) and three for the anticipation task outcomes (anxiety self-reports, EDA, and HR).

To test condition effects on the pain anticipation task, the difference between the threat and safe conditions in terms of self-reported anxiety, EDA and HR were tested by means of paired-sample *t-tests.* Specifically, the maximum change score on threat and safe conditions with respect to a baseline of 1 sec prior to the picture onset was used for EDA analyses, whereas the maximum deceleration from the 5 second to the end of the trial was used for HR. Next, three new variables termed self-reported anxiety difference, EDA difference, and HR difference were calculated by subtracting the value obtained in the safe condition from the value obtained in the threat condition. These variables indicate the magnitude of the differences between safe and threat conditions, where smaller values for self-reported anxiety difference, and EDA differences, and larger values for HR-difference can be interpreted as indicating higher effectivity of the ER strategy.

As a final step, participants were classified using a hierarchical cluster analysis according to the pattern of their frequencies in the use of emotion regulation strategies during the anticipation task. A squared Euclidian distance metric and Ward's agglomeration schedule were used. Also, an ANOVA was performed with the cluster profile as factor and CFI, FPQ, and EDS repertoire and EDS effiectivity as dependent variables, to characterize the groups derived from the cluster analyses. Finally, in order to compare the effects of emotion regulation profile in the anticipation task, three ANCOVAs were performed separately for each dependent measure (self-reported anxiety, EDA and HR). For self-report anxiety, an ANCOVA was conducted, with the condition (safe, threat) as within-subjects factor and the clusters as between-factor variables. In addition, those variables that were significant in the previous regression analyses were included as covariables. For the psychophysiological measures, two ANCOVAs were conducted with the condition and time (EDA, or HR half-second bins) as within-subjects factors, the clusters as between-subjects, and those variables that were significant in the previous regression analyses as covariables.

Assumptions of normality, homoscedasticity, sphericity, and equality of variances were explored using the Mauchly test and the Greenhouse-Geisser correction, where appropriate. *Post-hoc* comparisons were performed with pairwise t-tests when significant differences in main effects were found. Partial eta squared (η_p^2) and Cohen's *d* were reported as measures of effect size. All statistical tests were conducted using SPSS IBM Statistics version 23.

Results

Descriptive statistics and bivariate correlations

The means and standard deviations for the CFI subscales, fear of pain (FPQ-III), EDS and task outcomes are presented in Table 5.2. Means for EDS impact and EDS control were also calculated to characterize the daily negative events, revealing means of 5.93 (SD=1.36) and 5.02 (SD=1.50), respectively. The mean pain tolerance level as determined in the calibration phase was 48.89 (SD=1.83); twenty-one participants reached the maximum level allowed (50º).

The frequency of each strategy during EDS and pain anticipation are shown in Table 5.3. During the two weeks of EDS, participants used a mean of 5.98 strategies. Specifically, acceptance and problem solving were the most frequently used ER strategies to manage negative events (≥ 20% of times). They were followed by distraction and cognitive reappraisal with a frequency of use of 13.76% and 11.99%, respectively. Avoidance, rumination, self-blaming, suppression, catastrophizing, and blame-others were less frequently used (between 4.34% and 8.27% of times). Regarding the task-repertoire, the participants used a mean of 3 strategies during the anticipation task. The most frequently used strategies were acceptance, cognitive reappraisal, avoidance, rumination, and distraction (>80%). Problem solving, self-blaming, suppression, catastrophizing, and blame-others were hardly ever used.

Next, Pearson correlations were calculated for the CFI, FPQ, and EDS and Task outcomes (Table 5.2). The Alternatives subscale of the CFI was not associated with any of the ESD or task outcomes. However, individuals who scored higher on the Control subscale of the CFI perceived themselves as more effective reducing (r=.24, p<.05), showed less fear of pain (r=-.22, p<.05), and used a smaller Task repertoire (r=-.22, p<.05). Also, higher fear of pain was associated with larger EDS and task repertories (r=.38; p<.01; r=.35; p<.01, respectively).

EDS efficacy was negatively associated with self-reported anxiety differences (r= -.18, p < .05), indicating that individuals who reported more EDS effectivity are also more effective managing threat of pain. Also, both EDS effectivity and the anxiety self-reports differences were associated with a smaller EDS repertoire (r=-.41, p<001; r=.24, p<.05, respectively). EDA and HR responses were not significantly related to any other outcome.

Table 5.2. Means (M), standard deviations (SD), ranges and Bivariate correlations for the questionnaires scores, the Electronic Diary Study outcomes, and the anxiety self-reports, and emotion reactivity during the anticipation task.

	Study range	Mean (*SD)*	1	2	3	4	5	6	7	8
1. CFI alternatives	49, 88	73.10 (8.88)	1							
2. CFI control	6, 25	25.92 (8.11)	.33**	1						
3. Fear of Pain	38, 102	68,58 (14.64)	.03	-.22*	1					
4. EDS efficacy	2.43, 8.29	5.56 (1.29)	.09	.24*	-.001	1				
5. EDS repertoire	1, 9	5.98 (1,49)	-.07	-.17	.28**	-.41***	1			
6. Anxiety differences	-2.6, 6.10	1.84 (1.59)	-.08	-.14	.20	-.18*	.25*	1		
7. EDA differences	-1.23, 2.65	0.51 (0.81)	.04	-.05	.05	-.05	.08	-.02	1	
8. HR differences	-16.86, 4.68	-2.08 (3.92)	.02	.12	.02	.08	-.07	-.13	.01	1
9. Task repertorie	0, 7	3.21 (1,38)	-.18	-.22*	.35**	-.20	.27*	.18	-.08	.03

Note: CFI= Cognitive Flexibility Inventory; *EDS*= Electronic Study Diary; *EDA*= Electrodermal Activity; *HR*= Heart Rate; Anxiety differences: Anxiety self-report differences.
**p*<.05; ***p*<.01; ****p*.001

Table 5.3. Means (M), Standard Deviations (SD) and Ranges for the repertoire and the use of the different emotion regulation strategies during the electronic diary assessment and the anticipation task

	Electronic Diary Study		**Anticipation Task**	
	Range	***M* (*SD*)**	**Range**	***M (SD)***
Acceptance	0-72%	20.37% (16.78)	0-100%	48% (0.32)
Cognitive reappraisal	0-100%	11.99% (13.90)	0-100%	15.1% (0,22)
Problem Solving	0-58%	20.48% (12.97)	0-10%	0.7% (0,03)
Avoidance	0-35%	5.34% (7.49)	0-50%	6.1% (0,10)
Rumination	0-38%	8.27% (9.18)	0-60%	9.8% (0,15)
Self-blaming	0-35%	5.67% (7.14)	0-10%	0.1% (0,01)
Suppression	0-31%	4.34% (7.14)	0-10%	0.2% (0,02)
Distraction	0-62%	13.76% (12.67)	0-10%	18.1% (0,23)
Catastrophizing	0-25%	4.76% (6,35)	0-20%	1.6% (0,05)
Blame others	0-23%	4.90% (6.67)	0-10%	0.2% (0,02)
Repertoire	1-9	5.98 (1,49)	0-7	3.21 (1,38)

Table 5.4. Means and Standard Deviations (SD) for safe and threat conditions for subjective anxiety ratings and psychophysiological measures.

	All clusters	**Acceptance regulators**	**Distraction regulators**	**Mixed regulators**
Anxiety ratings				
Safe	0.98 (1.32)	0.64 (1.20)	1.47 (1.45)	1.09 (1.40)
Threat	2.83 (2.02)	1.69 (1.56)	4.67 (1.64)	3.19 (1.92)
EDA				
Safe	9.10 (5.11)	10.37 (3.97)	9.80 (7.87)	8.22 (5.17)
Threat	9.61 (5.43)	10.97 (4.27)	10.42 (8.45)	8.67 (5.44)
HR				
Safe	73.42 (10.25)	73.79 (12.40)	77.16 (3.43)	73.79 (9.63)
Threat	71.35 (9.17)	71.56 (10.93)	74.42 (1.78)	71.57 (8.76)

Note: *EDA*= Electrodermal Activity; *HR*= Heart Rate.

Associations between flexibility CF, ER repertoire and the effectivity in the management of daily negative events

Results of the multivariate linear regression analysis using the EDS effectivity as the dependent variable are shown in Table 5.5 (Model 1). The analyses showed that the Model was significant (R^2= .15, F(5, 79)= 3.94, p <.01). Specifically, a larger EDS repertoire predicted less EDS effectivity (β =-.34, p<.001), controlled for sex and age. However, CF measured by the two subscales of the CFI were no associated with the effectivity in the management of negative events.

Table 5.5. Multivariate regression analyses predicting perceived efficacy in the management of negative events (Model 1) or anxiety differences (Model 2) from cognitive flexibility and the repertoire of emotion regulation strategies

	β	***t***	***p***
Model 1			
Sex	-.25	-.75	.46
Age	-.01	-.25	.81
CFI alternatives	<.001	.01	.99
CFI control	.03	1.57	.12
EDS repertoire	-.34	-3.73	<.001
Model 2			
Sex	-.14	-.32	.75
Age	-.03	-.72	.48
Fear of pain	.03	2.00	.05
CFI alternatives	.00	.04	.897
CFI control	.01	.53	.60
EDS repertoire	.12	.94	.35
EDS effectivity	-.17	-1.20	.24
Task repertoire	.23	1.66	.10

Note: *CFI*= Cognitive Flexibility Inventory; *EDS*= Electronic Diary Study.

Associations between CF, ER repertoire factors and subjective and psychophysiological outcomes during the management of fear of pain

Three multiple linear regression analyses were performed to predict anxiety difference, EDA and HR differences with CF, EDS repertoire, EDS efficacy, and fear of pain as the independent variables. For anxiety self-reports (Table 5.5. Model 2), a significant regression model was found ($F(5,74)=2{,}99$, $p<.05$), with an R^2 adjusted of .11. The results revealed that self-reported anxiety difference was marginally predicted by fear of pain ($\beta=.03$, $p=.05$), but not by EDS effectivity or the EDS repertoire.

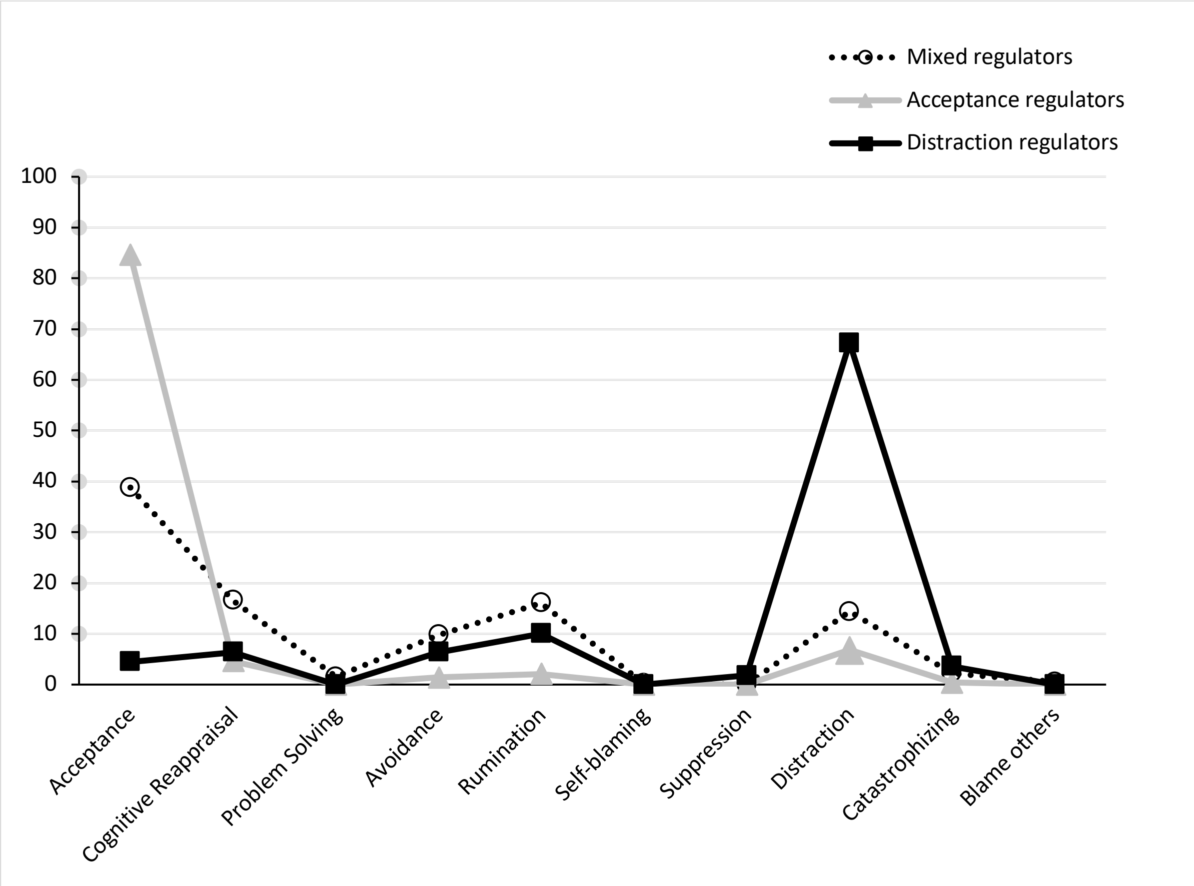
The planned multivariate linear regressions analyses for EDA and HR differences did not yield significant models (p's= .97 and .99, respectively).

Characterization of the different Emotion Regulation profiles (clusters)

Participants with similar emotion regulatory patterns during the pain anticipation task were identified by means of cluster analysis. The optimal number of clusters was determined by examining the agglomeration coefficients and the dendrogram, resulting in a four substantive cluster solution of emotion regulatory patterns.

The ER frequencies scores for each profile are shown in Figure 5.1. Cluster 1 (n=42) consisted of participants who reported high levels of acceptance (40%), but they also used other emotion regulation strategies during the task, mainly cognitive reappraisal, avoidance, rumination, or distraction. This group is termed henceforth *mixed regulators*. Cluster 2 (n=27) consisted of participants who mainly used acceptance (85%), so they are termed *acceptance regulators*. Cluster 3 (n=11) consisted of participants who reported to use mainly distraction (64%), and a small frequency of use for the other emotion regulation strategies (<10%), so they are termed *distraction regulators*. Finally, Cluster 4 (N=5) consisted of participants who mainly used reappraisal. Due to the small number of participants in this group, this group will not be used for further analyses.

Figure 5.1. Frequencies on each emotion regulation strategies by cluster membership



Differences in CF, Fear of pain, EDS repertoire, and EDS effectivity were analysed to explore the differences between the three clusters (mixed-regulators, acceptance-regulators, and distraction regulators). The results of this analyses revealed that clusters differed in Fear of pain scores (Table 5.6). Specifically, distraction regulators showed higher scores on Fear of pain, compared with the acceptance-regulators. However, clusters did not differ on cognitive flexibility, EDS repertoire and effectivity managing negative events in daily life (EDS effectivity).

Table 5.6. Cognitive and emotion regulation flexibility and fear of pain differences between clusters

Variable	Mixed-regulators	Acceptance-regulators	Distraction-regulators	*F*	*p*
CFI-Alternatives	70.86 (8.39)	75.93 (9.14)	72.91 (8.57)	2.80	.07
CFI-Control	26.00 (8.35)	27.63 (7.40)	22.18 (1.42)	1.75	.18
Fear of Pain	70.54 (14.96)	63.63 (12.79) [a]	76.91(13.90) [b]	9.92	.02
EDS Repertoire	6.02 (1.33)	6.04 (1.45)	6.18 (1.54)	.06	.96

Note: Means in the same row that do not share the same subscripts differ at p<.05.

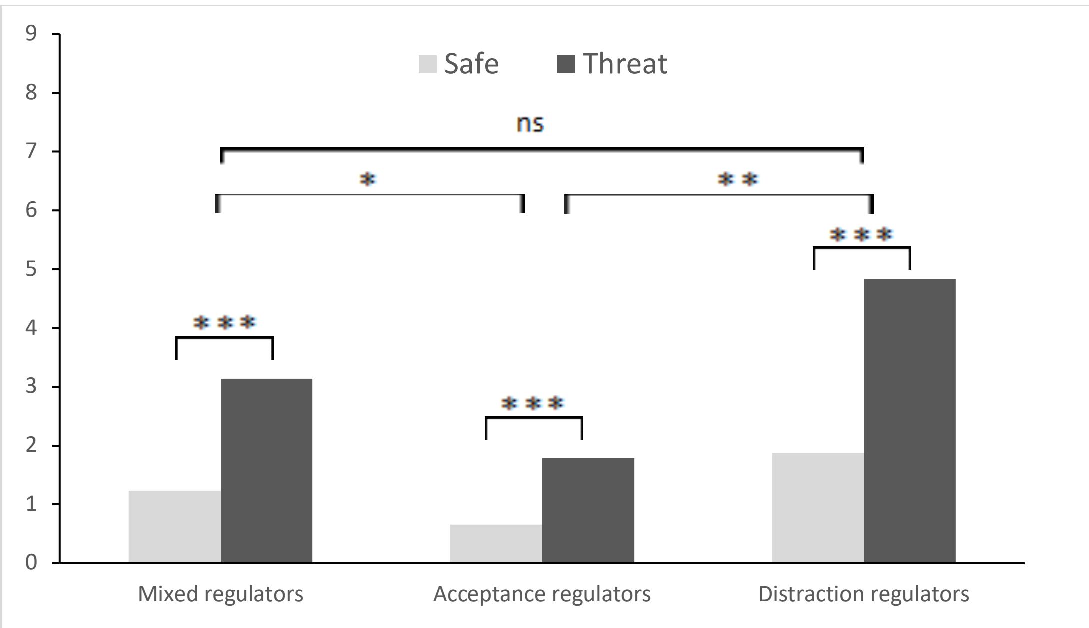
Differences in anxiety self-reports and psychophysiological responses based on the Emotion Regulation profiles

Means of self-reported anxiety for each cluster and condition are shown in Table 5.5. An ANCOVA with cluster as between subject factor, condition as within subject factor, and FPQ-III scores as covariate, showed a significant main effect of Condition (F(1, 73)= 121.03; p < .0001; $\eta_p^2 = .62$), confirming the results of the paired-samples t-test (Figure 5.2). In addition, the main effect of the cluster was significant (F(2, 73)= 7.31; p<.01; $\eta_p^2 = .17$). Post-hoc comparisons revealed that acceptance-regulators showed lower anxiety self-reports than mixed-regulators (p<.05) and distraction-regulators (p<.01). The difference between mixed-regulators and distraction-regulators were not significant (p=.19). The interaction Condition x Cluster was also significant (F(2, 73)= 6.11, p<.01, η_p^2= .14) indicating that the difference in anxiety self-report between threat and safe condition varied in function of the cluster. Post-hoc comparisons showed differences between the pattern in self-reported anxiety for Acceptance- and Mixed-regulators (F(1, 64)= 7.96, p<.001, η_p^2= .11), as well as for Acceptance- and Distraction- regulators (F(1, 34) = 14.80, p<.001, η_p^2= .30). Specifically, Acceptance-regulators (t(26)=5.43; p<.001; d=-.75) showed smaller differences in self-reported anxiety compared to Mixed- (t(40)=-8.34; p<.001; d=-1.25) and Distraction-regulators (t(10)=-5.64; p<.001; d=-2.07), as revealed by Cohen's d effect sizes. However, differences in the pattern of anxiety self-reports between Mixed-regulators and distraction-regulators were not found (F(1, 47)= 2.99, p=.09, η_p^2= .06).

Regarding the covariate effects, the result for the interaction Condition x Fear of pain (F<1) was not significant, revealing that the effects on the self-reported anxiety difference were not influenced by the fear of pain scores on the FPQ-III.

Regarding the psychophysiological responses, the ANCOVA for EDA responses, revealed a significant main effect of Condition (F(1, 73) = 19.33; p < .0001; $\eta_p^2 = .21$) and Time (F(23, 1679) = 10.49; p < .0001; $\eta_p^2 = .13$). This indicates that there was a modulation of EDA along the 12 s of the cue presentation (safe/threat), and significant higher EDA on the threat condition, compared to the safe condition. However, neither the main effect of Cluster (F(1,73)= 1,07, p=.36, $\eta_p^2 = .04$) nor the interactions were significant (Fs<1). In terms of HR, the ANCOVA revealed that there was not a main effect neither for Condition (p=.22) nor for Time (p=.19), nor for Cluster (F<1). Also, none of the interactions were significant (Fs<1).

Figure 5.2. Self-reported anxiety for safe and threat conditions by emotion regulation profile



*p<.05; **p<.01; ***p.001

Discussion

The aim of this study was to examine the role of CF and the repertoire of ER strategies in relation to the management of negative events and, in particular, anticipatory fear of pain. This aim was approached in two ways: i) a diary study where participants reported information regarding daily encounter and management of negative events; and ii) a laboratory study where a concrete negative event (i.e., pain stimulus) was shown to induce fear of pain during an anticipation task.

We hypothesized that a higher CF and a larger repertoire of emotion regulation strategies would be associated with a higher effectivity in the management of daily negative events and fear of pain. In line with our hypothesis, our results revealed that individuals who perceive themselves with less ability to control negative events were less effective in the management of their daily negative events. In other words, people with rigid thoughts about their inabilities to change the negative events might be using ineffective strategies to manage their daily difficulties. However, the scale of alternatives was not associated with the management of daily negative events. As Johnco et al., (2014) suggested, the alternatives scale of the CFI is related with the consideration of multiple solutions, which is more associated with the concept of CF. Conversely, the same authors suggested that the control subscale seems to assess the self-efficacy-based beliefs (e.g., "*I am capable of overcoming difficulties in life*"), rather than CF. In this sense, we suggest that, in our study, individuals with lower perceived self-efficacy on the CFI were more effective managing their daily emotions.

In terms of ER repertoire, unexpectedly, a larger repertoire of ER strategies predicted less effectivity in the management of both daily negative events and fear of pain. ER repertoire has been defined as the variation of ER strategies across a number of situations (e.g., Aldao & Nolen-Hoeksema, 2013; Bonanno & Burton, 2013; Grommisch et al., 2020). Thus, previous studies suggested that the ability to use a larger repertoire of emotion regulation strategies is associated with a flexibly implement of adaptive strategies in response to contextual demands (Bonanno & Burton, 2013). In the same way, our repertoire variable was indicative of the variability on the use of ER strategies to manage negative events. However, the variability in the use of ER strategies is necessary, but not sufficient for the adaptiveness of the strategy to the situation (Aldao et al., 2015a). For example, a person can use a wide range of strategies but do not use it in a context-sensitivity manner, leading to a poor management of their emotions. Specifically for the task findings, it is also worth mentioning that the use of a large repertoire of strategies during a laboratory task, where only one type of stimuli is presented might be also indicative of haphazard and misguided attempts at regulation (Aldao & Nolen-Hoeksema, 2013). Thus, our findings suggest that using a reduced number of strategies to manage one situation (i.e., using acceptance) could be indicative of the individual effectivity on the ER selection process.

Additionally, in this study, a larger ER repertory on the EDS was associated with the use of maladaptive strategies such as catastrophizing, rumination, avoidance or self-blaming, catastrophizing, and blame-others for managing daily negative emotions (Supplemental 5.1). Although previous literature suggests that some of these emotions are not intrinsically "bad" (Aldao et al., 2015a; Bonanno & Burton, 2013), it should not overlook previous research that have demonstrated the association of this strategies with poor outcomes and psychopathology (Aldao et al., 2010). Therefore, a larger ER repertoire in our study might be indicative of a higher use of maladaptive strategies to manage daily negative events.

The results of this study also revealed an association between effectively managing negative daily life events and the effective management of anticipatory fear of pain in the laboratory task. However, the ER efficacy in daily life (EDS) did not predict the self-reported anxiety and psychophysiological responses to fear of pain in the anticipation task. Therefore, it can be argued that although the two variables are associated, a better management of fear of pain in the laboratory context is not determined by the ER repertoire or the effectivity of managing daily negative events. These findings suggest that managing a specific situation such as the anticipation of a possible future pain might be different of managing daily negative situations.

Additionally, the current study aimed to identify if different ER profiles in the management of fear of pain were associated with differences in anxiety self-reports, EDA and HR responses in the same task. To do so, we conducted a pain anticipation task composed of safe and threat conditions. Our results revealed that threat was successfully induced, since participants reported higher anxiety self-reports and psychophysiological responses in the threat condition. In addition, three profiles of ER were found: acceptance-, distraction-, and mixed-regulators. Overall, our results revealed that individuals who used acceptance showed less fear of pain on the FPQ-III, as well as in the anticipation task. Specifically, acceptance-regulators showed less fear of pain on the FPQ-III than distraction-regulators. In the same way, self-reported anxiety on the pain anticipation task revealed that the group of acceptance-regulators showed overall lower self-report anxiety than the mixed and distraction-regulators. In terms the effectivity of the ER profiles in the management of fear of pain, our results revealed that acceptance-regulators showed less differences between threat and safe conditions, compared with distraction- or mixed regulators. Therefore, it might be argued that the use of acceptance, even when controlled by FPQ-III scores, was more effective than the ustilization of distraction or using a mix of strategies for the management of fear of pain under laboratory contexts. However, it remains unclear if the selection of strategy was an antecedent or a consequence of the anxiety responses. It is possible that using acceptance results in better management of fear of pain, but it is also possible that people with less anxiety in the task use acceptance since it is a strategy that implies less cognitive costs than other strategies as, for example, reappraisal (Troy et al., 2018).

This study has several strengths. For example, we measured ER strategies in two contexts (i.e., real life and laboratory settings), exploring the cross-associations between them. In addition, this study increases the understanding of relative new concepts as cognitive flexibility and the repertoire of ER strategies using a laboratory environment where spontaneous ER was assessed, leaving room to the ER flexibility and allowing the study of different ER profiles. Moreover, the fact that participants use their free choice ER strategies to face with a negative stimulus would allow researchers identifying the which strategies or combination of strategies are more effective. In addition, the pain anticipation task was successful in inducing fear of pain, as it is indexed by the self-reports and psychophysiological measures (electrodermal and cardiac changes).

However, this study also has some limitations. The first limitation was the low emotional intensity prompted during the pain anticipation task. In this sense, using stimuli more unpleasant or arousing for the participants, such as electric shocks (Rainville et al., 1992), might lead to enhanced anticipatory fear of pain that needs to be regulated. Thus, it is possible that more unpleasant and arousing events lead participants to show larger ER repertoires across the laboratory tasks to facilitate their ER process. Hence, we suggested to further explore the effects of the ER repertoire using more unpleasant contexts that allows to generalize the current findings to populations with high fear of pain who may benefit from ER strategies to manage, for example, medical procedures. Another limitation of the current study was that the sample size was not large enough to obtain a sufficient number of individuals who used reappraisal during the pain anticipation task. Therefore, we encourage researchers to conduct further studies with larger sample sizes that allows comparing the effects between different ER profiles.

Finally, previous research has demonstrated that the perception of the context (e.g., perceived controllability of the situation, type of emotion) can be a determinant of the subsequent emotion regulation (Chen & Bonanno, 2021). Therefore, we encourage further research to explore the role of CF and the repertoire of ER strategies in different contexts. Similarly, we also recommend including goals as a marker of the emotion regulation success. To date, some studies have incorporated short-term goals (e.g., to feel better) in the ER assessment through Experience Sampling Methods (Wilms et al., 2020). However, in pursuing further research, the short- and long-term efficacy of ER strategies should be taken into account. For example, while avoidance is perceived as an adaptive strategy in the short term to deal with fear of pain (as it prevents pain from occurring), this same strategy will contribute to exacerbation and maintenance of the pain problem, and thus of associated negative emotions in the long term (Vlaeyen et al., 2016). In this sense, research has shown that individuals who strongly endorsed either achievement or pain-avoidance goals reported higher pain and disability (Karsdorp et al., 2013). Thus, we highlight the relevance of studying ER flexibility in relation with long-term goals, to facilitate the generalization of the results to populations with high fear of pain or at risk to develop chronic pain.

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CHAPTER 6

General discussion

Over the years, many works have focused on the modulation of pain-related outcomes during the induction of pain. As a matter of fact, emotion regulation strategies have found to be effective for reducing pain and anxiety self-reports, modulating autonomic responses to painful stimulation, as well as for increasing pain tolerance level in response to induced pain (Hampton et al., 2015; Lapate et al., 2012). However, the study of these emotion regulation strategies for anticipation phases has been less explored. Moreover, those studies focused on the effects of emotion regulation strategies on subjective and psychophysiological correlates have often used specific emotion regulation instructions that can influence the participants' self-regulatory abilities. In this sense, there have been recent claims for a paradigm change in the study of emotion regulation to more flexible and ecological approaches (Colombo et al., 2020; Jaén, Fuentes-Sánchez, et al., 2021).

In the view of the mentioned gaps in the literature, the broad aim of the present dissertation was to extend our knowledge about the effects of emotion regulation and cognitive and emotion regulation flexibility on the threat produced by the anticipation of pain. Specifically, the aims of the present thesis were as follows: (1) to synthesize the existing literature on the relationship between emotion regulation (i.e., cognitive reappraisal and acceptance strategies) and common peripheral correlates of the autonomic nervous system and facial electromyography, such as affect-modulated responses and corrugator activity, during laboratory tasks where pain was experimentally induced; (2) to compare a situational reappraisal strategy commonly used in traditional Cognitive Behavioral Therapy that is based on changing the negativity of the stimulus through decatastrophizing, with a mixed reappraisal instruction that combines acceptance (conceptualized as an antecedent-focused strategy focused on allowing private experiences as a manner to approaching to goals); (3) to test the reliability and validity of the Cognitive Flexibility Inventory in a Spanish sample; (4) to explore whether cognitive flexibility and the emotion regulation repertoire can foster the effectivity in the management of fear of pain during an anticipation task.

To address these aims, four studies were conducted. In this chapter, a general discussion of the results obtained in these studies is presented, structured as follows. First, an overview of the key findings of the present dissertation is showed. To do so, the research questions raised in the introduction will be addressed. Next, the main strengths and limitations of this research work will be discussed. Finally, the most salient directions and recommendations for future research will be pointed out.

Key findings

1) *Which are the psychophysiological correlates associated with the use of cognitive reappraisal and acceptance strategies in the pain literature?*

The study of cognitive reappraisal, acceptance, and their comparison to manage negative emotions has been widely addressed in the literature, since these emotion regulation strategies are included in current evidence-based psychological interventions for managing negative events (Beck et al.,1979; Hayes et al., 1999). Laboratory studies have shown that both reappraisal and acceptance are effective in down-regulating negative emotions, resulting in less negative self-reports and modulated psychophysiology, including the autonomic nervous system (e.g., electrodermal activity; heart rate), affect-modulated (e.g., startle reflex) and behavioral (e.g., corrugator) responses (Goldin et al., 2019; Webb et al., 2012; Wolgast et al., 2011; Zaehringer et al., 2020). In the same way, these strategies have also shown to be effective in reducing pain experience and increasing pain tolerance (Blacker et al., 2012; Kohl et al., 2014). However, the psychophysiological correlates associated to the use of emotion regulation strategies to manage pain were less clear.

In the light of the above, a systematic review was conducted that synthesized those studies focused on the relationship between emotion regulation (i.e., cognitive reappraisal and acceptance) and psychophysiological measures (Chapter 2). Results showed that cognitive reappraisal was associated with decreases in psychophysiological measures associated with valence (heart rate, corrugator activity) and arousal (electrodermal activity, pupil diameter) changes. However, acceptance was associated with reductions on valence responses (heart rate), but it was not associated with changes on arousal correlates (electrodermal activity). These findings suggest that although both cognitive reappraisal and acceptance strategies are useful for modulating self-report responses, they may be associated with differentiated psychophysiological responses. Thus, whereas cognitive reappraisal is an effective measure to modulate valence (unpleasantness of pain) and arousal affective responses, acceptance is effective for reducing the valence responses, but less effective for modulating the activation level in response to pain.

Nevertheless, it is important to note that the number of studies obtained in this systematic review were low, so the interpretation of this findings should be taken with caution. Additionally, the inconsistences found between the different studies suggest that there is a need to study emotion regulation in a deeply way. For example, comparing subtypes of emotion regulation strategies. This may be a way to help researchers understand which specific mechanisms are effective for managing pain-related outcomes, clarifying the inconsistences between previous literature.

In addition, the systematic review revealed that there was only a little number of studies focused on testing the effects of cognitive reappraisal or acceptance on the management of the anticipation phases. Therefore, it is difficult to draw conclusions regarding the effectiveness of emotional regulation strategies to manage fear of pain. However, these studies shown that different psychophysiological responses can be obtained from induction and anticipation phases. For example, some studies found effects of emotion regulation for the induction phase, but not for the anticipation phase (Braams et al., 2012; Holmes & Houston, 1974). Therefore, emotion regulation effects should not be generalized from induction to anticipation phases since effectivity might differ. Further studies are needed that focus on determining which are the psychophysiological correlates associated to the anticipation phase.

2) *Are emotion regulation strategies effective to reduce the fear produced by the anticipation of pain?*

Chapter 2 showed that there are some studies that found effects of reappraisal and acceptance downregulating negative emotions produced by the anticipation of pain (Braams et al. 2012; Houston & Holmes, 1974; Kalisch et al. 2005). However, research in this field is still scarce, and it had shown inconsistent results. To advance in this line, an anticipation task was designed to study the effect of two subtypes of reappraisal in the management of fear of pain (Chapter 3). Specifically, in this task participants were instructed to down-regulate their emotions during the anticipation of pain using one type of two cognitive reappraisal strategies: stimulus-focused or goal-based reappraisal.

The results of this study revealed that these strategies were not effective to reduce fear of pain during the anticipation of pain. Specifically, we found enhanced self-reported anxiety, electrodermal activity and eyeblink responses when participants had to use the emotion regulation strategy. Given that previous studies have shown the effectivity of these strategies in reducing anxiety self-reports and psychophysiological responses, we argue that the inconsistencies with previous literature arise from the use of an stimuli that produce low fear and/or the brevity of the emotion regulation instructions. Therefore, it could be argued that stimulus-focused or goal-based reappraisal might not be effective to reduce fear of pain when the fear intensity is low.

Importantly, research suggests that the context is very relevant for the adaptation of the strategy, and it plays a powerful impact in the selection of the emotion regulation strategy (Ullah et al., 2020). Thus, the intensity of the emotion might have a high relevance for the effectivity of the emotion regulation strategy. Previous research that investigates the spontaneous use of emotion regulation strategies have also showed that people do not choose to use reappraisal very frequently to regulate their emotions relative to the use of suppression and distraction (Brans et al., 2013; Suri et al., 2015). Indeed, the study presented in Chapter 5 shows that, when fear of pain is low and participants can choose which strategy to use to face their emotions, reappraisal was rarely used. Instead, participants engage more frequently in acceptance strategies (i.e., "*allow or accept* *your feelings without fighting them*"). Thus, the fact of using reappraisal in the context of low fear of pain might involve engaging in top-down processing (i.e., cognitive evaluations of the stimuli), that increases subjective anxiety and enhanced autonomic activity.

Thus, results showed in Chapter 3 highlighted the importance of studying the different contexts where emotion regulation strategies can be applied, as well as exploring the effects of emotion regulation strategies from theoretical approaches focused on emotion flexibility. Hence, Chapter 5 described a task where participants used spontaneous emotion regulation strategies, leaving room for the individual's context sensitivity in the emotion regulation selection process.

3) *Do acceptance (conceptualized as an antecedent-focused strategy focused on allowing private experiences as a manner to approaching to goals) and reappraisal lead to different outcomes in terms of subjective and psychophysiological responses?*

As it has been mentioned in Chapter 2, acceptance strategies appear to be associated with decreased psychophysiological responses. However, these findings are not found in all the studies. The inconsistencies found between previous studies might be explained by inconsistences in the operationalization of acceptance. As we reported, some studies used acceptance-based strategies based on ACT components such as mindfulness or cognitive defusion (Evans et al., 2014; Haspert et al., 2020), whereas other studies just instruct participants to "fully experience and accept any feelings and responses...without trying to control, avoid, resist or change them" (Braams et al., 2012). In addition, other studies as the meta-analysis conducted by Webb et al. (2012) refer to acceptance as a type of reappraisal focused on revaluating the emotional response. Therefore, we suggested that is necessary to study the different components or subtypes of strategies to better understand the mechanisms that are effective to manage negative emotions (e.g., fear of pain).

In this regard, a study in which two subtypes of reappraisal (stimulus-focused and goal-based reappraisal) were compared was presented in Chapter 3. Stimulus-focused reappraisal is a strategy based on reinterpreting the focal stimulus (the context or the cause of the emotion) in order to change the emotion and it is one of the emotion regulation strategies most instructed in laboratory context (Webb et al., 2012), since it is commonly used in traditional Cognitive Therapy to decatastrophize negative events (Beck et al., 1979). Goal-based reappraisal could be defined as a mixed reappraisal instruction that combines acceptance (conceptualized as an antecedent-focused strategy) with negative functional reappraisal based on the goals, which is closer to 3rd generation therapies as the Acceptance and Commitment Therapy. The results of this study revealed that these two types of reappraisal did not differ in effectivity in the management of fear of pain. These findings might suggest that acceptance, conceptualized as a cognitive strategy that use language to create commitment to approach to the stimuli (a subtype of reappraisal), might lead to similar subjective and psychophysiological outcomes compared to traditional reappraisal focused on change the content of the negative stimuli. In this sense, the effect differences between reappraisal and acceptance strategies found in previous literature could be derived from an operationalization of acceptance as a response-focused strategy that is mixed with other components associated with attentional deployment (e.g., defusion, mindfulness).

Despite these findings, it is noteworthy that the strategies used in this study were not effective to reduce fear of pain, so this was probably not an adequate context to compare the effects of these two strategies. Therefore, it would be advisable to compare the effectivity of these strategies in more challenging contexts where participants might show a heightened fear of pain.

4) *Is the Cognitive Flexibility Inventory a reliable measurement for a Spanish sample to be included as a predictor variable for the modulation of negative emotions?*

The study of cognitive flexibility is growing in last years, so it has been suggested as a transdiagnostic process underlying psychopathology (Morris & Mansell, 2018). In fact, this construct is a core mechanism of change in therapies such as Cognitive Behavioural Therapy (Beck et al., 1979), as well as in more modern, transdiagnostic treatments, such as the Unified Protocol (Boisseau et al., 2010). In the same vein, the study of this construct in relation to pain-related outcomes is growing interest (e.g., Meesters et al., 2019; 2021), showing association with the recovery period from pain (Meesters et al., 2019). In addition, a previous study showed a positive correlation between both cognitive flexibility and flexibility in coping with stress (Rudnik et al., 2019). Therefore, we decided to conduct a study to test the role of cognitive flexibility in the modulation of fear of pain (Chapter 5). However, the psychometric properties of the scale had not yet been examined in Spanish samples. Therefore, we investigated the psychometric properties of the online Spanish version of the Cognitive Flexibility Inventory in a Spanish sample to determine the factor structure of the scale, assess its construct validity, as well as examine the scale's internal consistency and test-retest reliability (Chapter 4).

The results of this study showed satisfactory fit indices for the two-correlated factor model of the Cognitive Flexibility Inventory. Evidence for the construct validity of the Cognitive Flexibility Inventory was obtained. Also, the Cronbach's alpha and test-retest coefficients were above of .86 and .67, respectively. Therefore, Cognitive Flexibility Inventory showed validity and reliability, facilitating access to appropriate instruments for evaluating cognitive flexibility in Spanish samples. Consequently, this inventory was incorporated as a predictor variable for the modulation of negative emotions in the study presented in Chapter 5.

5) *Do cognitive and emotion regulation flexibility predict the modulation of fear of pain in an anticipation task?*

Research has shown that cognitive flexibility and a limited number of strategies are associated with worse adjustment to stressful events (Meesters et al., 2019; Orcutt et al., 2014). However, the effects of these variables on the pain field, and specifically on fear of pain, has been hardly explored. Thus, the study presented in Chapter 4 aimed to advance knowledge of the relationship between cognitive flexibility, emotion regulation repertoriees and fear of pain.

Regarding cognitive flexibility, our results revealed that none of the Cognitive Flexibility Inventory subscales were associated to the management of anticipatory fear of pain. In contrast, we found that the control subscale was associated to a better management of daily negative events on the electronic diary study. These differences might be explained by contextual aspects regarding the negative situation (e.g., diary negative event/ induced pain). We argue that perceiving the difficult situations as more controllable might be associated with a better management of negative events. In this sense, the negative events recorded by the electronic diary study could be more varied on controllability and emotion regulation repertorie. However, it is possible that, overall, the perceived control in our laboratory study might be low since participants could do nothing to prevent the pain stimuli. Also, our results revealed that the number of strategies used in the task was low compared to the electronic diary study, which might lead to lower variability in their use.

In terms of emotion regulation flexibility, our results showed that the use of a higher repertoire of strategies to manage negative events in daily life was associated with a poor management of anticipatory fear of pain in a laboratory task. This finding can be explained in terms of an increased use of maladaptive strategies, since larger repertories were associated with the use of strategies considered as maladaptive for managing daily negative emotions, such as catastrophizing, rumination, avoidance or self-blaming, and blame-others.

Importantly, this construct refers to the ability to use different emotion regulation strategies, and it is necessary for the selection process of the emotion regulation strategy, but not necessarily implies that the chosen strategy is the most adaptive one (Aldao & Nolen-Hoeksema, 2012). In other words, the fact that individuals tend to use distinct emotion regulation strategies do not imply that these strategies are adaptive to this specific context and is synchronized with the individual' goals. In this sense, electronic diary studies are useful tools to study the emotion regulation process in a more ecological way, compared to questionnaires. However, our study only assessed shown short-term emotion regulation adjustment in terms of effectivity self-reports. Therefore, a deeply study of the emotion regulation process is needed that includes the context where the emotion regulation is used, as well as both short- and long-term goals. In this way, we would be more able to draw conclusions about the adaptative function of having a larger repertoire.

Additionally, rather than the number of strategies used, it is important to analyze the specific or the combination of emotion regulation strategies that are more adaptive to the context and individual's goals. In order to advance in this field, we conducted analyses a cluster analysis to identify the different emotion regulation profiles to manage fear of pain during a pain anticipation task. Thus, our study showed that acceptance was more effective in reducing self-reported anxiety than distraction, or the implementation of a set of distinct strategies. In line with the results found for the electronic diary study, the use of a single strategy (i.e., acceptance) was more effective than the use of a mix of them, which included strategies considered as both adaptive and maladaptive. In this sense, the fact that mixed-regulators reported a higher overall anxiety might reflect a strong challenge for the emotion regulation process, being the use of several strategies indicative of misguided attempts of emotion regulation.

Strengths and Limitations

This dissertation includes the results of a series of studies that should be interpreted in the light of some strengths and limitations, which are presented below.

Strengths

There are numerous research works focused on studying the role of emotion regulation on pain, but many of them have not been conducted using controlled tasks in the laboratory (e.g., Koechlin et al., 2018). In addition, among the studies conducted using controlled laboratory tasks, not all use peripheral psychophysiological measures. Thus, identifying the studies that specifically use acceptance or reappraisal strategies to manage induced pain in addition to include psychophysiological measures can be a challenging task. In this sense, the first strength of this dissertation was to provide the first review to systematically summarize the literature on the relationship between peripheral psychophysiology and two of the most widely used emotion regulation strategies (cognitive reappraisal and acceptance) in pain management (Chapter 2).

Secondly, to date, the study of the relationship between fear of pain and emotion regulation is understudied. Thus, a strength of this dissertation is that it focused on broadening knowledge in this field, showing that specific strategies considered adaptive strategies (i.e., reappraisal) and a larger emotion regulation repertoire are not necessarily effective for managing fear of pain. Indeed, our results reveal the need of a deeply study of these strategies taking into account the context in which the negative event is presented.

The third strength of the current dissertation is the effort to include the use of an electronic diary study in addition to the laboratory tasks to examine in more detail the relation between cognitive flexibility, emotion regulation flexibility and the management of negative emotions in the anticipation of pain. Therefore, we used a measure of emotion regulation flexibility (i.e., emotion regulation repertoire) obtained in an ecological environment to study the associations between emotion regulation flexibility and fear of pain.

Fourth, we used an experimental task where spontaneous emotion regulation was assessed, leaving room to the emotion regulation flexibility and allowing the exploration of different emotion regulation profiles. The fact that participants could select and implement their free choice emotion regulation strategies to face a negative stimulus would allow researchers identifying which strategies or combination of strategies (emotion regulation profiles) are more effective.

Finally, the inclusion of the Cognitive Flexibility Inventory as part of the present dissertation should be highlighted as an additional strength of the present work, since the validity and reliability of the Spanish adaptation of the Cognitive Flexibility Inventory was demonstrated. Therefore, a cognitive flexibility measure will be available for for the broad scientific community (either researchers or clinicians) interested in assessing the ability to cognitive adapt and face adverse events, which is a core trait to predict greater therapeutic success.

Limitations

First, in the systematic review (Chapter 2), studies that did not specify that used a component of acceptance were excluded. However, acceptance might be addressed in an indirect way in some of the excluded studies. As a consequence, some of the studies using acceptance may have been left out of our systematic review. Also, our study only focuses on reappraisal and acceptance strategies, leaving out other emotion regulation strategies that may be of interest.

Second, the sample of all the studies was composed of university students. It is therefore possible that the findings obtained in the current dissertation are not fully generalizable to clinical populations. In addition, the sample size of the study presented in Chapter 5 was not large enough to compare all the emotion regulation profiles. Specifically, a very small group of participates that use reappraisal was recluted, and it could not be therefore used for the following statistical analyses.

Third, a between-group design was used in the study presented on Chapter 3, with each group being instructed with a specific reappraisal strategy. Thus, participants were instructed to use a specific emotion regulation strategy during the task. This design provides methodological accuracy but at the cost of less ecological validity. Indeed, eight participants were excluded as they responded in the post-experimental query that they spontaneously switched to another emotion regulation strategy during the task.

Fourth, a recent study revealed that emotion regulation success is associated with high levels of stress (Langer et al., 2021). However, the heat stimuli used to induce fear in both Chapter 3 and Chapter 5 produced low anxiety. This limitation was attempted to be eliminated in the study presented on Chapter 5, using the tolerance pain level instead the threshold pain level. However, the anxiety self-reports remained low. Indeed, 21 participants reached the maximum level allowed (50º), which might have affected the induction of fear of pain.

Recommendations for future studies

Besides the aforementioned key findings and limitations, the studies included in the present dissertation might potentially open the way to fascinating future directions of research.

The systematic review presented in Chapter 2 shown that there is a lack of studies that include peripheral psychophysiological correlates to the study of the role of emotion regulation strategies (i.e., reappraisal and acceptance) in the management of pain. Given that the emotion experience is composed by cognitive, behavioral, and psychophysiological responses (Mauss et al., 2005), it would be necessary that further studies include this component to be able to draw more precise conclusions regarding this relationship. Moreover, there is a lack of studies focused on comparing emotion regulation strategies, which could be very useful to determine which components of psychological interventions can be more useful in clinical contexts. Therefore, we encourage future studies to compare emotion regulation strategies, specifically, focusing on specific components or subtypes of emotion regulation strategies to advance in the knowledge regarding the relationship of each cognitive process with the psychophysiological correlates.

In addition, further research is needed to design ecological validated designs to study the emotion regulation process, such as ecological mommentary assessment. In this sense, it would be recommendable to develop validated questionnaires focused on the emotion regulation process to be used in ecological mommentary assessment designs. In addition, it would be recommendable the use of ecological environments such as virtual reality scenarios to study emotion regulation, since it may provide a contextualized situation to measure a certain emotion regulation construct in a controlled way (Colombo et al., 2019, 2020, 2021). Both ecological mommentary assessments and virtual reality may help researchers to advance in the study of cognitive flexibility and emotion regulation flexibility, since they allow to assess emotion regulation in changing ecological contexts that helps to better understand the influence of context-sensitivity on the emotion regulation process. Also, these contexts may be an important step forward for the generalization of the research findings to the life environments.

Additionally, the results shown in Chapter 3 and Chapter 5 suggest that emotion regulation can be less useful in contexts of low emotions intensity. Therefore, it would be appropiate to design tasks to study the anticipatory fear of pain that allows the comparison of different modalities (i.e., heat, shock, mechanical pain) and intensities of the pain stimulus.

Finally, further studies would be required to confirm the current structure of the Spanish version of the Cognitive Flexibility Inventory using confirmatory factor analyses in larger samples. Also, it would be recommended to test the validity and reliability of this measure in a clinical sample, including individuals suffering from affective disorders characterized by rigid thinking (e.g., depression, generalized anxiety disorder, or obsessive-compulsive disorder).

Conclusions

The main conclusions that can be drawn from the present dissertation are the following:

- Cognitive reappraisal and acceptance strategies appear to be associated with decreased physiological responses in the management of pain, although these findings are not found in all the studies.
- Reappraisal strategies might not be effective to manage fear of pain when instructions are brief and the anticipation of pain produces low anxiety levels. This finding highlights the relevance of the context for the effectiveness of the ER strategy.
- Differences between stimulus-focused and goal-based reappraisal for the management of fear of pain were not found, neither for self-reported anxiety nor psychophysiological measures.
- The Spanish version of the Cognitive Flexibility Inventory is a reliable and valid measure for assessing cognitive flexibility in Spanish adults.
- Under low anticipatory fear of pain, individuals tend to use the acceptance strategy. In addition, this strategy was the most effective to manage that context.
- A larger emotion regulation repertoire, operationalized as the total number of emotion regulation strategies used to manage negative emotions, was related to less effectivity in the management of negative emotions, including fear of pain.

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APPENDICES

APPENDIX 1

Supplemental material 4.1. Original and Spanish items of the Cognitive Flexibility Inventory

ORIGINAL (Dennis & Vander Wal, 2012)	SPANISH
1. I am good at ‘‘sizing up’’ situations	1. Soy bueno evaluando situaciones
2. I have a hard time making decisions when faced with difficult situations	2. Tengo dificultades para tomar decisiones cuando me enfrento a situaciones difíciles
3. I consider multiple options before making a decision	3. Considero múltiples opciones cuando tomo una decisión
4. When I encounter difficult situations, I feel like I am losing control	4. Cuando me enfrento a situaciones difíciles, me siento como si perdiera el control
5. I like to look at difficult situations from many different angles	5. Me gusta ver las situaciones difíciles desde muchos ángulos diferentes
6. I seek additional information not immediately available before attributing causes to behavior	6. Busco información adicional que no está disponible inmediatamente antes de atribuir causas al comportamiento
7. When encountering difficult situations, I become so stressed that I can not think of a way to resolve the situation	7. Cuando me encuentro ante situaciones difíciles, me estreso tanto que no puedo pensar en una manera de resolver la situación
8. I try to think about things from another person’s point of view	8. Intento pensar sobre las cosas desde el punto de vista de otra persona.
9. I find it troublesome that there are so many different ways to deal with difficult situations	9. Encuentro problemático que haya tantas formas de lidiar con situaciones difíciles
10. I am good at putting myself in others’ shoes	10.Soy bueno poniéndome en la piel de otra gente
11. When I encounter difficult situations, I just don’t know what to do	11.Cuando me enfrento a situaciones difíciles, no sé qué hacer.
12. It is important to look at difficult situations from many angles	12.Es importante ver las situaciones desde muchos ángulos.
13. When in difficult situations, I consider multiple options before deciding how to behave	13.Cuando estoy en situaciones difíciles, considero múltiples opciones antes de decidir cómo comportarme.
14. I often look at a situation from different viewpoints	14.A menudo veo una situación desde diferentes puntos de vista.
15. I am capable of overcoming the difficulties in life that I face	15.Soy capaz de superar las dificultades a las que me enfrento en la vida
16. I consider all the available facts and information when attributing causes to behavior	16.Considero todos los hechos disponibles e información cuando atribuyo causas al comportamiento.
17. I feel I have no power to change things in difficult situations	17.Siento que no tengo poder para cambiar las cosas en situaciones difíciles
18. When I encounter difficult situations, I stop and try to think of several ways to resolve it	18.Cuando me enfrento con situaciones difíciles, paro e intento pensar en diferentes formas de resolverlas.
19. I can think of more than one way to resolve a difficult situation I’m confronted with	19.Puedo pensar en más de una manera de resolver una situación difícil cuando me enfrento a ella.
20. I consider multiple options before responding to difficult situations	20.Considero múltiples opciones cuando respondo a una situación difícil.

APPENDIX 2

Supplemental material 5.1. *Bivariate correlations between the questionnaires and Electronic Diary Study outcomes*

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16
1. CFI acceptance	1															
2. CFI control	.33**	1														
3. EDS acceptance	.09	.13	1													
4. EDS reappraisal	.12	.07	-.28**	1												
5. EDS problem solving	.16	.26*	-.21	-.10	1											
6. EDS avoidance	-.17	-.05	-.17	-.06	-.32**	1										
7. EDS rumination	-.20	-.16	-.15	-.24*	.01	-.03	1									
8. EDS self-blaming	-.34***	-.23*	-.22*	-.16	-.17	.14	.18	1								
9. EDS suppression	.02	-.01	-.25*	-.05	.03	-.16	-.18	-.15	1							
10. EDS distraction	-.06	-.09	-.20	-.22*	-.15	-.03	-.27*	-.02	.07	1						
11. EDS catastrophizing	-.04	-.34***	-.15	-.11	-.31**	.15	.17	.12	-.08	-.14	1					
12. EDS blame others	.20	.07	-.11	-.05	-.11	-.01	-.08	-.15	.14	-.18	.08	1				
13. EDS repertoire	-.09	-.18	-.33**	-.30**	-.15	.30**	.23*	.25*	.28*	-.09	.39***	.36**	1			
14. EDS effectivity	.09	.24*	.27*	.28*	.22*	-.05	-.41***	-.38***	-.11	.02	-.42***	-.20	-.40***	1		
15. EDS impact	-.16	-.28**	-.16	-.05	-.27*	.10	.20	.13	.09	.13	.27*	-.09	.20	-.11	1	
16. EDS control	-.25*	-.17	-23*	.19	-.11	.22*	.14	.17	-.01	-.05	-.01	-.13	.06	.28**	.12	1
17. FPQ-III Fear of pain	.03	-.22*	-.03	-.22*	-.12	.09	.01	<-.01	-.01	.18	.32**	.02	.28**	<.01	.24*	-.01

Note: *CFI*: Cognitive FLexibiulity Inventory; *EDS*: Electronic Study Diary; *FPQ-III:* Fear of Pain Questionnaire-III; *p<.05; **p<.01; ***p<001

APPENDIX 3

Co-author’s agreements

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Azucena García Palacios, como coautora doy mi **autorización** a Irene Jaén Parrilla para la presentación de las siguientes publicaciones como parte de su tesis doctoral.

Relación de publicaciones:

- Jaén, I., Díaz-García, A., Pastor, M.C., García-Palacios, A. (2021) Emotion regulation and peripheral psychophysiological correlates in the management of induced pain: A systematic review. *PLoS ONE, 16*(6): e0253509.
- Jaén, I., Escrig-Ayuso, M.A., Wieser, M.J., García-Palacios, A., Pastor, M.C. (2021). Cognitive reappraisal is not always successful during pain anticipation: Stimulus-focused and goal-based reappraisal effects on self-reports and peripheral psychophysiology. International *Journal of Psychophysiology, 170*:210-217.
- Jaén, I., Vidal-Arenas,V., Suso-Ribera, C., Pastor, M.C., García-Palacios, A. Psychometric Properties of the Spanish Version of the Cognitive Flexibility Inventory. Submitted to Current Psychology.
- Jaén, I., Peters, M.L., Vancleef, L.M.G., Suso-Ribera, C., Pastor, M.C., García-Palacios, A. When more is worse: the role of cognitive flexibility and the repertoire of emotion regulation strategies in managing daily negative events and fear of pain. In preparation.

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Relación de publicaciones:

- Jaén, I., Díaz-García, A., Pastor, M.C., García-Palacios, A. (2021) Emotion regulation and peripheral psychophysiological correlates in the management of induced pain: A systematic review. *PLoS ONE, 16*(6): e0253509.
- Jaén, I., Escrig-Ayuso, M.A., Wieser, M.J., García-Palacios, A., Pastor, M.C. (2021). Cognitive reappraisal is not always successful during pain anticipation: Stimulus-focused and goal-based reappraisal effects on self-reports and peripheral psychophysiology. International *Journal of Psychophysiology, 170*:210-217.
- Jaén, I., Vidal-Arenas,V., Suso-Ribera, C., Pastor, M.C., García-Palacios, A. Psychometric Properties of the Spanish Version of the Cognitive Flexibility Inventory. Submitted to Current Psychology.
- Jaén, I., Peters, M.L., Vancleef, L.M.G., Suso-Ribera, C., Pastor, M.C., García-Palacios, A. When more is worse: the role of cognitive flexibility and the repertoire of emotion regulation strategies in managing daily negative events and fear of pain. In preparation.

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Relación de publicaciones:

Jaén, I., Escrig-Ayuso, M.A., Wieser, M.J., García-Palacios, A., Pastor, M.C. (2021). Cognitive reappraisal is not always successful during pain anticipation: Stimulus-focused and goal-based reappraisal effects on self-reports and peripheral psychophysiology. International *Journal of Psychophysiology, 170*:210-217.

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List of articles:

Jaén, I., Escrig-Ayuso, M.A., Wieser, M.J., García-Palacios, A., Pastor, M.C. (2021). Cognitive reappraisal is not always successful during pain anticipation: Stimulus-focused and goal-based reappraisal effects on self-reports and peripheral psychophysiology. International Journal of Psychophysiology, *170*:210-217.

Signed, Rotterdam, 10/12/2021

Prof. Dr. Matthias Wieser

In accordance with article 28 of the Regulations on doctoral studies of the Universitat Jaume I in Castelló*, regulated by RD 99/2011, at the Universitat Jaume I (*Approved by the Governing Council at its meeting no. 8/2020 held on 2 October 2020*):*
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Jaén, I., Vidal-Arenas,V., Suso-Ribera, C., Pastor, M.C., García-Palacios, A. Psychometric Properties of the Spanish Version of the Cognitive Flexibility Inventory. Submitted to Current Psychology.

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- Jaén, I., Peters, M.L., Vancleef, L.M.G., Suso-Ribera, C., Pastor, M.C., García-Palacios, A. When more is worse: the role of cognitive flexibility and the repertoire of emotion regulation strategies in managing daily negative events and fear of pain. In preparation.

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