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„Effects of Emotion Regulation on Wound Healing, and its Mediation by Stress"

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Abstract

The following master thesis examines the relationship between emotion regulation, stress and wound healing. With regard to emotion regulation, two different strategies were investigated: Cognitive Reappraisal, which is considered an adaptive emotion regulation strategy, and Expressive Suppression, which is considered a maladaptive emotion regulation strategy. Cognitive Reappraisal was hypothesized to lead to faster wound healing, mediated by lower stress. Expressive Suppression was hypothesized to be related to slower wound healing, mediated by increased stress. Participants (N = 15) completed the Emotion Regulation Questionnaire (ERQ) prior to study begin, subjective stress was surveyed several times over the course of the study, and wound healing was assessed via transepidermal water loss, allowing skin barrier recovery to be calculated. The regression analyses for Cognitive Reappraisal showed a trend in the expected direction of reduced stress and faster wound healing, which did not reach significance. For Expressive Suppression, there was no significant association with stress and a significant association with faster wound healing, which was contrary to expectation. The mediation analyses were not performed since the preconditions were not met, as the corresponding regression analyses were not significant. A extreme group analysis suggests that high scores on both emotion regulation strategies are associated with lower stress and faster wound healing. Although these results should be treated with caution due to the small sample size, they suggest that maladaptive emotion regulation can potentially lead to beneficial short-term outcomes, even if it is associated with negative long-term consequences for well-being and health.

Keywords: Emotion regulation, wound healing, skin barrier recovery, stress, reappraisal, suppression, transepidermal water loss, tape stripping

Contents

Effects of Emotion Regulation on Wound Healing, and its Mediation by Stress

Our way of life today is characterized by the fact that people want to meet societal expectations in all areas of life. Societal pressure is increasing more and more to combine family, career, social life and self-optimizing hobbies such as sports, traveling and learning languages (Gnedt, 2018). Together with developments such as digitalization and globalization this has resulted in a steadily increasing acceleration of everyday life. Therefore, it is only logical to assume an equally increasing level of subjectively experienced stress. While stress has always played an important role for humans and other animals in response to external threats and thus in ensuring survival (Ziegler, 2004), the nature of stress has certainly changed considerably.

In earlier times acute stress was of great relevance in relation to one's own survival, for example in the search for food, in fighting situations or in reproductive behaviour (Bear et al., 2017). Of course, humans are still confronted with acute stressors today. There is still war in several countries of the world and many in the world live under great poverty or experience severe hunger. However, for the majority of western civilization, the type of stress experiences has changed fundamentally. In everyday life, people are rarely exposed to situations in which they have to actively fight for survival. On the other hand, numerous new stressors have emerged with which they are confronted on a daily basis. These have a particularly strong influence through the constant social comparison people are exposed to. Especially through social media, there is a constant need to compare oneself with other people, see their achievements without seeing their failures, and constantly strive to optimize oneself (Gnedt, 2018; Spies Shapiro & Margolin, 2013). This relates to many different areas of life: Family, career, appearance, social life, exercise, eating habits, social engagement, self-actualization, and a wide variety of status symbols (Hur & Gupta, 2013; Rice & Klein, 2019; Spies Shapiro & Margolin, 2013).

The main problem is that some of these expectations are contrary to each other (Hur & Gupta, 2013; Rice & Klein, 2019). On the one hand, many young people today want to pursue self-fulfillment, go their own way and be independent, but on the other hand still want to start a family and become good parents. A rich social life and commitment to a good cause is also socially welcome, but people also want to be successful professionally and earn a lot of money. This balance between individualism without egoism and social integration without putting one's own self-fulfillment at risk is often very difficult to achieve. As a result, many young people regularly fear to underperform in some areas of their lives and have a constant need to improve. All these factors are not acute stressors in the sense that they concretely endanger survival, but they do lead to a constantly present sensation of stress. Many people have chronically elevated stress levels as a result (Bear et al., 2007; Hur & Gupta, 2013). As discussed in more detail below, chronic stress is a relevant health risk, both in terms of somatic and mental health.

While stress plays a major role in everyone's life, people have very different ways of coping with stress and its associated emotions (Gross & John, 2003). There are people who tend to dismiss negative experiences and avoid talking about them, while others recall them repeatedly and have an increased need to talk about and analyse them. Some people are almost like open books, one can see clearly what is on their minds, while others are rather withdrawn and difficult to read. In stressful situations, some people seem to know exactly how to react, manage to stay calm and act in a solution-oriented way. Others are so overwhelmed by the situation that they might experience a complete blackout and find it difficult to react. One possible explanation for why individuals cope with stress and feelings so differently is offered by the construct of emotion regulation (Gross & John, 2003). Described in more detail below, this construct posits that there are interindividually different strategies for how humans deal with their emotions and how they behave in stressful situations. These different emotion regulation strategies might serve as a possible explanation for why some people develop chronic stress and associated health problems under certain conditions, while others are able to function completely unaffectedly under the same conditions.

This thesis coincided with the COVID–19 pandemic. While many consequences of the pandemic are already visible, in terms of deteriorating mental and somatic health and enhanced stress symptoms (Haas, 2020; Salari et al., 2020; Skoda et al., 2021; Twenge & Joiner, 2020), the long-term consequences are yet to emerge. The COVID–19 pandemic exacerbates pre-existing problems and stressors, which might also be due to factors such as advancing digitalisation, globalisation and general acceleration in human lives (Salari et al., 2020; Skoda et al., 2021). This makes it all the more important to identify possible protective factors with the goal of promoting them in the future and develop helpful interventions to foster positive change. Emotion regulation seems to be a relevant construct here, which is worth taking a closer look at and exploring its relevance in relation to stress experience and general health (Gross & John, 2003).

Health & Illness

Health and illness play a significant role in everyone's life and improving health and preventing illness are some of the biggest challenges that people have been facing for thousands of years. Nevertheless, there are still an endless number of open questions and debates about what even can be considered as healthy and ill. Probably the most important and widely used definition of health is the one by the World Health Organization that defines *health* as “a state of complete physical, mental and social well-being and not merely the absence of disease or infirmity” (WHO, 1948).

In the English language there are multiple terms for the opposite of health. While *disease* refers primarily to a physical pathological process, *illness* focuses more on the subjective feeling of unhealth, and *sickness* focuses on the social aspect (Marinker, 1975). Whereas the definition of illness suggests an interplay of the body and the mind, the definition of disease seems to only focus on the body, omitting any influence the mind may have on the body (Boyd, 2000). In the following thesis, when referring to unhealth, the term illness will be primarily used, for easier comprehension, but also to emphasise the relevance of the subjective perspective, the *feeling* of unhealth.

Views on Health

The debate about the nature of the relationship between mind and body is often referred to as the *mind-body problem* and has played an important role in philosophy and science dating back to ancient Greece (Lovallo, 2015). While the idea of dualism traces back to ancient Greece, it was the philosopher René Descartes who divided the mind and the body in two distinct and independent categories (Descartes & Lafleur, 1950). This resulted in a view in which health or unhealth is something solely physical and has nothing to do with the mind, thoughts and emotions. For decades, this idea, called the *standard biomedical model,* has dominated people’s view on health and illness (Lovallo, 2015). Both the disease itself and the cure have been viewed as entirely physical with neither thoughts nor the emotional state of patients having an influence on them. This model simplified the relationship between pathogen and host, and did not include thoughts and emotions, although they have been shown to be able to enhance the development of diseases or to even promote their cures and thus play a significant role for human health (Boyle et al., 2017; Epel et al., 2016; Gouin & Kiecolt-Glaser, 2011; Lovallo, 2015; Rey et al., 2020; Robles et al., 2009).

The *biobehavioural model of disease and treatment* additionally included important interactions between the person and the environment, taking into account the influence of psychological processes like thoughts and emotions and the interplay between host and pathogen (Lovallo, 2015). This bidirectional relationship between host and pathogen can be observed through the influence of a variety of behaviours that have an influence on the illness: Ranging from the cellular level, i.e., the reaction of the immune system, to thoughts and feelings, and lastly, to behaviour and actions. This expanded view of health and illness is a holistic one, where the boundaries between somatic, psychosomatic, and psychological illness become blurred, revealing one single underlying process.

An example for the effect the mind can have on the body are placebos – an alleged treatment that has a real, physiological effect on the patient without any biological explanation in its original sense (Bleich et al., 1979). Psychoneuroimmunology is another field which gives attention to the influence of psychological processes on the body, more specifically on the immune system. An experiment by Ader & Cohen (1993) showed that certain stimuli can have an immunosuppressive effect merely through classical conditioning, indicating the possible effects behaviour and cognition have on health. These findings hint to the significance of personal experiences throughout the lifetime that shape the human body and personality and therefore determine the individual reaction to different stimuli, how people process information and regulate their emotions. For example, type A behaviour, a personality cluster especially characterized through hostile emotions, has been identified as a major risk factor for coronary heart disease through elevated blood pressure and stress hormone secretion (Friedman et al., 1986). The *psychosocial theories of disease and treatment* further took into account the influence of psychological and sociocultural processes on both the development and treatment of disease (Elstein & Bordage, 1979).

Stress

Definition

One stimulus often associated with having a considerable effect on health and illness is stress. The definition of stress used by Lovallo (2015, p. 32) describes it as “a bodily or mental tension resulting from factors that tend to alter an existent equilibrium”. This definition emphasizes that a stimulus event disturbs an equilibrium, the health of the body. The amount of subjective stress humans experience is determined by the severity of the stressor and the ability to compensate or eliminate it. Thus, the body and its health are at danger if the stressor is too big or resources too little to maintain the homeostatic balance.

The above stated definition also distinguishes between a bodily versus a mental tension, implying a difference between physical versus psychological stressors. While *physical stressors* like heat, cold, infections, physical pain etc. are seen as a direct threat to the body and physical well-being, *psychological stressors* like negative thoughts, emotions, interpretations etc. pose as a more indirect threat to well-being through challenging the feeling of security (Lovallo, 2015). These psychological stressors nevertheless might lead to physical stress responses, influencing bodily processes like the heartbeat or breathing rate and thus affect health indirectly, especially with concerns to long-term developments regarding physical health. Typical psychological stressors can be traumatic events like the death of a loved one, a failed relationship or personal failure. Since these stressors are impossible to induce in an experimental setting, different tasks were developed to induce psychological stress in a laboratory (Kirschbaum et al., 1993). Most commonly mental arithmetic tasks are used, in which participants have to solve arithmetic problems, often accompanied by a social dimension in the form of an experimenter who closely monitors the participant and interrupts if answers are false. These demanding tasks lead to increased heart rates, cortisol secretion, and a sense of anxiety.

Physiological Pathways of Stress

In response to stressful situations, specific processes take place in the body. The origin of the body's most important stress responses is the hypothalamus (McEwen, 2002; Kerr et al., 1991). Together with the thalamus, the hypothalamus is part of the diencephalon, a structure of the forebrain. The hypothalamus coordinates actions of the autonomic nervous system as well as of the endocrine system (Bear et al., 2007).

Hypothalamic Pituitary-Adrenal (HPA) Axis

The hypothalamus controls a variety of different endocrine processes, as its neurosecretory neurons are directly connected to the pituitary (Bear et al., 2007). One of the most pronounced and most studied stress responses is the activation of the hypothalamic pituitary-adrenal (HPA) axis, which is responsible for the humoral stress response. When the system is faced with stress, specific neurosecretory neurons of the hypothalamus are activated and release corticotropin-releasing hormone (CRH) into the bloodstream. Subsequently, CRH causes the anterior pituitary gland to release adrenocorticotropic hormone (ACTH). In response to an elevated level of ACTH in the blood, cortisol is released from the adrenal cortex. Cortisol mobilizes energy reserves throughout the body and suppresses the immune system, preparing the body for a fight-or-flight response to stressful stimuli.

The amygdala and the hippocampus play an important role in this stress system as they regulate the secretion of CRH neurons of the hypothalamus. The amygdala is particularly known to be involved in fear and the corresponding fear response. When the amygdala receives sensory information from the thalamus and the neocortex, the central nucleus of the amygdala becomes active, leading to a respective stress response by the hypothalamus through activation of both the HPA axis as well as the activation of the sympathetic nervous system.

While the amygdala stimulates CRH release, hippocampal activation inhibits this release, serving as an important feedback regulation of the HPA axis when cortisol levels get too high. Overexposure to stress is related to various mental disorders, especially those involving chronic stress (Heuser, 1998; Mohr et al., 2014). Prolonged exposure to cortisol can lead to a degeneration of the hippocampus, resulting in a stronger stress response, which in turn leads to increased cortisol release and even greater damage to the hippocampus (Bear et al., 2007). In line with these findings, anxiety disorders have been associated with a decreased hippocampal volume and diminished activation of the hippocampus, as well as to hyperactivity of the amygdala (Liu, 1997).

Neurotransmission via the Sympathetic Nervous System

The hypothalamus also controls the autonomic nervous system and thus plays a crucial role in the process of homeostasis, which means regulating the body in response to a changing environment (Appenzeller, 1990). The autonomic nervous system is a network of interconnected neurons throughout the body and consists of two separate divisions that control the vital organs: The sympathetic and the parasympathetic division.

The activation of the sympathetic division leads to the mobilization of any available energy of the body, preparing for a fight-or-flight response (Jänig & McLachlan, 1992). The fight-or-flight response is a prototypical physical stress response and represents the most effective way of reacting to external threats, through either fighting off the potential aggressor or through fleeing the situation (Lovallo, 2015). Such a response was, and still is, evolutionarily necessary for human survival in stressful situations (Ziegler, 2004). According to Selye (1956), the stress response is a non-specific reaction, occurring in response to a variety of stressors. The stress response pattern, which Selye (1956) terms the *general adaptation syndrome*, can be divided into three different stages: The alarm reaction, the stage of resistance and lastly, the stage of exhaustion. This stress response is initiated by the activation of the sympathetic nervous system, triggering responses like increased heart rate and blood pressure, sweating, and reduced digestive functions (Appenzeller, 1990).

The parasympathetic division on the other hand, is associated with lower heart rate and blood pressure, as well as enhanced digestive functions and growth. While the sympathetic division mobilizes energy resources for a short term emergency, the parasympathetic division works on processes that keep the body healthy over the long term through immune responses and energy storage.

Those autonomic responses are triggered through the release of different neurotransmitters. The primary neurotransmitter in sympathetic fibers is norepinephrine, also known as adrenaline, which is released into the bloodstream from the adrenal medulla in response to sympathetic activation (Bear et al., 2007; Jänig & McLachlan, 1992).

Health Consequences of Stress

Ongoing exposure to stress has been linked to many health difficulties (Sapolsky, 1994). Of the many ways in which stress can affect the body, hormonal changes and effects on the immune system are probably the most well-researched.

Effects of Stress at the Endocrine Level

Stress has an overall negative influence on the body's endocrine homeostasis and thus affects the energy balance and health in many aspects. One consequence of stress is amygdala sensitisation through sustained exposure of the amygdala to cortisol, leading to an imbalance in the form of increased HPA axis activity (Lovallo, 2015). This consequently leads to increased anxiety (King et al., 2009), psychosomatic complaints characterised by gastrointestinal problems (Greenwood-Van Meerveld et al., 2001), reduced hippocampal volumes and thus weaker negative feedback signals to the HPA axis, resulting in an even greater cortisol production.

Another system affected by stress is the hypothalamic-sympatho-adrenomedullary axis, which is responsible for the release of the stress hormone epinephrine, causing physiological stress responses like increased cardiac output, respiration and muscle strength (Lovallo, 2015). This adrenocortical activity is specifically sensitive to psychological stress and has been associated with working memory impairment, resulting in a reduced ability to perform calmly and rationally under demanding conditions (al’Absi et al., 1994). Cortisol also affects frontal-limbic activity, as it was shown that high levels of cortisol are linked to cognitive and mood disturbances, which disappeared when the source of the elevated cortisol was effectively treated (Dorn et al., 1997).

Effects of Stress on the Immune System

Stress exposure is accompanied by endocrine and autonomic changes, which were shown to inhibit certain immune system functions, leading to an increased risk of infection and lower resistance to disease. Chronic psychological distress has been linked to elevated sympathetic nervous system activity, depressed immune function, as well as to elevated blood pressure, catecholamines and cortisol levels, resulting in an increased risk for heart disease and heart attack (Lovallo, 2015). Caregivers of spouses with Alzheimer’s disease, which are chronically under stress, show slower wound healing, more infectious illnesses and overall poorer health (Kicolt-Glaser et al., 1994).

In a meta-analysis on over 300 empirical papers, Segerstrom & Miller (2004) described in detail the relationship between psychological stress and the human immune system, emphasizing especially the importance of the sympathetic nervous system for the immune response to acute stressors, but also behavioural factors and endocrine pathways. Several studies on factors supporting stress reduction, mood enhancement and better psychological health also show a beneficial effect on immune system function (Glaser et al., 1985; Keller et al., 1994) linked to lower HPA axis and sympathetic nervous system activation (Lovallo, 2015).

Wound Healing

Wounds are a "disruption of normal tissue structure and function" (Cherry et al., 2000, as cited by Walburn et al., 2009) and differ in their size, severity, location, duration, and causes. The process of wound healing consists of several stages: Clot formation, inflammation, proliferation, and remodeling (Walburn et al., 2009). For wounds to heal successfully, the body needs a well-functioning immune system. As stated above, the immune system is vulnerable to stress and thus it only seems logical to assume that wound healing is also affected by stress. In fact, chronic stress experience as well as acute stress experience have been associated with slower healing of superficial wounds to the skin (Lovallo, 2015; Orion & Wolf, 2012).

Those effects of stress on wound healing are thought to be mediated by elevated cortisol activation and amygdala activation. More precisely, psychological stress seems to hinder wound healing especially by slowing down the initial inflammatory phase through increased glucocorticoid and catecholamine production (see Gouin & Kiecolt-Glaser, 2011 for a review). One of the glucocorticoids is cortisol, which is secreted increasingly during periods of stress. Prior studies suggest an association between elevated cortisol production, increased subjectively perceived stress levels and slower healing of wounds (Ebrecht et al., 2004). If the body is prevented from producing glucocorticoids, this stress-induced delay in wound healing does not occur (see Gouin & Kiecolt-Glaser, 2011 for a review). Elevated glucocorticoid levels related to psychosocial stress have been shown to suppress the production of interleukin-1 (IL-1 β) and tumor necrosis factor alpha (TNF-α), pro-inflammatory cytokines that are essential for wound healing (Hunter et al., 2015). Several protective factors have been shown to reduce the stress-induced slowdown of wound healing. Among those are behavioral stress management interventions like written emotion disclosure interventions, physical exercise, social support, and pharmacologic stress reduction (see Gouin & Kiecolt-Glaser, 2011 for a review).

One possibility to assess wound healing in a laboratory setting is through measuring skin barrier recovery after a tape-stripping procedure (Robinson et al., 2017). This involves causing minor injury to the skin through the removal of the stratum corneum, the outermost layer of the epidermis, by repeatedly applying and pulling off cellophane tape (Walburn et al., 2009). This irritation affects epidermal permeability, preventing the skin barrier from its function of regulating the movement of water in and out of the body (Gouin & Kiecolt-Glaser, 2011, Walburn et al., 2009). The recovery of this function is termed *skin barrier recovery* and is measured through transepidermal water loss (TEWL; Walburn et al., 2009). The epidermal permeability barrier function of the skin was found to be diminished under increased psychological distress in healthy individuals, leading to higher TEWL and slower skin barrier recovery (Fukuda et al., 2014; Orion & Wolf, 2012). This effect of psychosocial stress on epidermal permeability has been associated with altered glucocorticosteroid and neuropeptide levels as well as with impaired antimicrobial defence barriers (Orion & Wolf, 2012).

In their systematic review on the impact of psychological stress on wound healing in humans, Walburn et al. (2009) compared 22 studies, of which 17 found psychological stress to be related to impaired wound healing. In the subsequent meta-analysis of 11 of these studies, they reported an effect size of $r = -.42$, suggesting a moderate effect between higher levels of psychological stress and slower wound healing. This effect was constant over different types of wounds, whether chronic or acute, clinical or experimental wounds, on different bodily sites and tissues, as well as over different types of stress situations (Walburn et al., 2009). Psychological distress was shown to affect skin barrier recovery in stress situations like laboratory induced stress tasks (Altemus et al., 2001; Robles, 2009), academic examination stress (Fukuda et al., 2014; Garg et al., 2001), interpersonal stress during a divorce (Muizzuddin et al., 2003) or chronic stress in the form of caregiving for a spouse with Alzheimer's disease (see Gouin & Kiecolt-Glaser, 2011 for a review). More specifically, after the performance of the Trier Social Stress Test (TSST), a standardized laboratory stress task known to elicit moderate psychological stress (Kirschbaum et al., 1993), participants showed increased heart rate, cortisol and cytokine production, subjective anxiety responses and slower skin barrier recovery (see Gouin & Kiecolt-Glaser, 2011 for a review).

Stress & Emotions

Physical stressors related to exercise have been associated with positive feelings of satisfaction and freedom through the secretion of ACTH & beta-endorphin (Philipp et al., 1992). However, many physical stressors have been associated with negative emotions: The fight-or-flight response is commonly accompanied by strong negative emotions like anxiety, fear, and anger, accompanied by an elevated distribution of epinephrine, cortisol, and beta-endorphin, all of which help the body to release energy to face or avoid a physical threat (Lovallo, 2015). The autonomic nervous system suppresses parasympathetic activity and increases sympathetic activity, the latter of which is associated with energy-expending functions, muscular activity, and physical effort. In the brain, these changes involve descending activation via the frontal cortex and emotion centres like the amygdala and septohippocampal complex.

Psychological stressors like mental arithmetic tasks also induced negative emotions like anxiety without any physically existing threat (Kirschbaum et al., 1993). Merely the mental effort is able to alter physiological functions and has a direct impact on the body through the negative emotions and the concomitant activation of brain centres that affect the brainstem and the hypothalamic-pituitary axis (Lovallo, 2015). Those negative emotions, which are triggered in response to psychological stressors, often are not acted out behaviourally in social settings and may lead to negative health consequences when the stressors and the corresponding negative emotions occur chronically. While emotionally positive “stress” (eustress) leads to increased cardiovascular and catecholamine responses without activating cortisol, emotionally negative stress additionally leads to increased cortisol secretion. The more negative a stressor is perceived, the higher the amount of cortisol that is released into the bloodstream (Lovallo, 2015).

Emotions & Health

Emotion Regulation

Emotions are not just something that ”happens” to people, something they are exposed to, but something they can also control in a very concrete way (Gross & John, 2003). People do this in different ways. While some people have a more pronounced habit of repressing and suppressing their emotions, others often deal with their feelings in a more conscious way and try to re-evaluate them, for example, when they are confronted with negative feelings. Gross (1998) defines emotion regulation as “the process by which individuals influence which emotions they have, when they have them, and how they experience these emotions” (p. 275).

Emotion regulation consists of several components, such as emotional awareness, emotional acceptance, clarity (as in understanding one’s own emotions), impulse control, goals (as in goal-directed behaviour) and adaptive emotion regulation strategies (Gratz & Roemer, 2004). The last component of the adaptive emotion regulation strategy can also be referred to as emotion regulation ability. Specifically, emotion regulation ability refers to the “the general capability to autonomously and efficiently regulate negative affect and disengage from concomitant thoughts” (Radtke et al., 2020, p. 2). Thus, while emotion regulation in general refers to the way people deal with their feelings, adaptive emotion regulation strategies (or emotion regulation ability) focus on dealing with negative feelings in an effective, beneficial way.

Radtke et al. (2020) outlined that individuals with higher emotion regulation abilities showed better performance on a cognition task under stress as compared to individuals with lower emotion regulation abilities. Furthermore, under high levels of demand, high emotion regulation abilities were linked to many other positive outcomes regarding life balance, success in sports, performance on a working memory task and vulnerability for ego-depletion effects on attention (Radtke et al., 2020). These findings suggest that stressful situations might have a different effect on individuals depending on their ability to regulate their emotions.

Process Model of Emotion Regulation

Gross (2001) presents a process model of emotion regulation, describing the different approaches to dealing with emotions. According to this model, emotions begin with an evaluation of emotion cues, which in turn trigger a set of response tendencies involving experiential, behavioral, and physiological systems (Gross & John, 2003). These response tendencies, also termed *emotion regulation strategies,* are often executed automatically, but there are also different ways in which they can be actively modified. Broadly speaking, those strategies can be divided into two categories. The first, *antecedent-focused strategies,* intervene early in the process of generating emotions, involving actions exhibited before the emotion-response tendencies are activated entirely, thereby already having altered behaviour and physiological responses. The second, *response-focused strategies*, intervene late in the process of generating emotions, involving actions shown after the emotion-response tendencies have been activated and the respective emotion has thus already been initiated.

Gross (2001) identified four antecedent-focused strategies and one response-focused strategy. The former includes the selection of the situation, the modification of the situation, the deployment of attention, and the change of cognitions, while the latter focuses on the modulation of responses. Gross & John (2003) focused on two of these five strategies in their study, including one antecedent- and one response-focused strategy, which were both commonly used by people in everyday life, manipulable in a laboratory, and defined in terms of individual differences. The antecedent-focused strategy chosen is Cognitive Reappraisal as a form of cognitive change and the response-focused strategy chosen is Expressive Suppression as a form of response modulation.

Cognitive Reappraisal

This emotion regulation strategy is defined as "a form of cognitive change that involves construing a potentially emotion-eliciting situation in a way that changed its emotional impact" (Lazarus & Alfert, 1964, as cited by Gross & John, 2003, p.2). In a study by Gross (1998), participants using reappraisal as an emotion regulation strategy experienced less negative emotion than participants who suppressed their emotions or did not use any emotion regulation strategy when watching a film intended to elicit negative emotions.

In a later study, Gross and John (2003) showed that those using reappraisal strategies primarily not only experienced and expressed less negative emotion, but also experienced and behaviourally expressed more positive emotion. Furthermore, individuals who primarily reappraised their emotions were more likely to cope through reinterpretation, i.e., by looking for something good during stressful events, leading them to be more effective in repairing their moods. In terms of social life, those using reappraisal strategies primarily are more likely to share their emotions, have closer relationships, and are better liked by their peers. Moreover, they show fewer depressive symptoms and are more likely to show enhanced psychological well-being in many aspects: Higher life satisfaction, better self-esteem, a more optimistic outlook on the future, increased personal growth and self-acceptance, a clearer purpose in life, more positive relations with others, as well as a greater sense of autonomy and of being in charge of their environments. In addition, reappraising was negatively associated with Neuroticism (Gross & John, 2003), a personality factor which has been linked to reduced subjective well-being, which in part is due to low levels of mindfulness (Wenzel et al., 2015).

Overall, people using primarily reappraisal strategies have been shown to feel and express more positive emotions, while feeling and expressing less negative emotions than those not using such strategies. Cognitive Reappraisal thus is able to alter the actual emotion and has been related positively to well-being in many ways. Because of its many beneficial effects, Cognitive Reappraisal is referred to as an *adaptive emotion regulation strategy*.

Expressive Suppression

This emotion regulation strategy is defined as “a form of response modulation that involves inhibiting ongoing emotion-expressive behaviour” (Gross, 1998, as cited by Gross & John, 2003, p.2). In a study by Gross (1998), participants using suppression as an emotion regulation strategy experienced as much negative emotion as participants who did not use any emotion regulation strategy when watching a film intended to elicit negative emotions. Interestingly though, the suppression of positive emotions did in turn decrease the respective experience of these emotions (Gross & John, 2003). So, while the suppression of negative emotions merely hinders their expression and not the experience of these negative emotions, the suppression of positive emotions hinders both their expression and the experience of these positive emotions, which can clearly be seen as a significant cost of this regulatory strategy. Other adverse consequences of this emotion regulation strategy are reduced social functioning and cognitive costs, as participants showed impaired memory for social information when suppressing emotions (Richards & Gross, 2000).

While both individuals who primarily use suppression, as well as those using reappraisal strategies, perceive their strategy as successful, suppression was linked to a variety of negative implications, which in turn did not apply to reappraisal (Gross & John, 2003). One of these negative implications is that individuals who typically use suppression to regulate their emotions, scored higher on inauthenticity, the deliberate deception of others with regard to their own thoughts and feelings, resulting in intensified negative feelings about the self and felt seclusion from other people. When coping, suppressors are more likely to vent (although not necessarily about their true inner feelings) and less likely to be aware of their negative emotions and express them, leading to less clarity and awareness of their emotions, and in turn to diminished efforts to repair their moods. Suppressors tend to accept their feelings less and are more likely to ruminate about their negative mood and the self than those who use suppression less frequently, which is associated with an increased risk of depressive symptoms and persistent negative emotions (Nolen-Hoeksema et al., 1993). In respect to their social life, suppressors seem reluctant to share their emotions with others and tend to avoid close relationships, which leads to a lack of social relationships and social support, with peers not necessarily disliking people who employ suppressive emotion regulation strategies, but feeling rather neutral towards them (Gross & John, 2003). Their well-being seems to be diminished in various ways: They have fewer positive relations with others, lower self-esteem, less life satisfaction, a more pessimistic outlook on their future, are less satisfied with themselves as well as with their relationships and show more depressive symptoms.

Overall, suppressors have been shown to feel and express less positive emotions, while feeling more negative emotions than non-suppressors (Gross & John, 2003). While this association does not imply causation, it seems that Expressive Suppression is not helpful in reducing the experience of negative emotion, but only able to modify the behavioural aspect in decreasing the expression of negative emotion, while also reducing the expression and experience of positive emotion. Expressive Suppression is consequently referred to as a *maladaptive emotion regulation strategy*, as this strategy is not able to alter the actual emotion and has been related negatively to well-being in various ways.

Emotion Regulation & Health

Negative affect has been linked to adverse health outcomes in various ways. Negative emotional states are accompanied by endocrine and autonomic changes, which inhibit certain immune system functions (Lovallo, 2015). More specifically, they have been suggested to lower the ability of the immune system to respond effectively to viral challenges either through an infection or a vaccination. Immune parameters have been shown to be related to emotional states, emotional valence and emotional arousal, especially during acute stressors (Segerstrom & Miller, 2004). In a study by Cohen (1994), participants who reported more negative life events, had poorer coping responses, increased negative emotional states and were more likely to contract colds after being exposed to different cold viruses.

Positive emotional experiences, social support, and enhanced feelings of self-efficacy, on the other hand, seem to enhance immune system functions and improve health by acting as buffers on the negative effect of stress on immune functions (Kiecolt-Glaser et al., 2002). Furthermore, the expression of emotions felt, either positive or negative, was linked to various positive health outcomes, suggesting that adaptive emotion regulation is especially beneficial for one's health. Laughter, arguably the strongest expression of positive feelings, was associated with lowered epinephrine and cortisol levels (Berk et al., 1989), while expressing emotions related to traumatic events was linked to an improved psychological status, less depressive symptoms and better immune function (Keller et al., 1994).

Multiple other studies also suggest that emotions and emotion regulation play an important role when it comes to physical health outcomes. In their study on cyberbullying victimization and somatic complaints Rey et al. (2020) showed that some maladaptive emotion regulation strategies partially mediated the effect of cybervictimization on somatic symptoms. These findings suggest that the way people react to stressors plays a major role in whether they experience somatic problems as a result. Regulating negative feelings one experiences in response to stressful situations is a complicated process and individuals have specific tendencies on how to regulate them. Thus, emotion regulation ability has been shown to have an influence on physical health.

A number of studies have been able to link various calming techniques to an improved immune system. In a study with elderly people from a nursing home, the application of a passive relaxation technique was found to enhance immune parameters and psychological well-being, more specifically it led to decreased negative affect, psychological discomfort, symptom perception and increased quality of life over a period of three months (Reig-Ferrer et al., 2014). Moreover, mindfulness meditation was found to improve immune system response to vaccination (Davidson, 2003). The effects of meditation and mindfulness on stress were linked to a wide variety of health factors (Epel et al., 2016). Following meditation participants showed greater vitality, decreased distress, more sustained well-being, and clinically meaningful improvement in depressive symptoms. These positive effects were linked to a "suppression of stress-related responses and immune function related to acute-phase wound healing and inflammation" (Epel et al., 2016, p. 7). In a study on younger cancer survivors it was shown that the effect mindfulness meditation has on reducing psychological distress is mediated by emotion regulation strategies (Boyle et al., 2017). Following mindfulness meditation, the implementation of adaptive emotion regulation strategies like self-kindness was linked to reductions in depressive symptoms and in perceived stress.

Emotion Regulation & Wound Healing

With regard to wound healing, emotion and emotion regulation also seem to play a crucial role. Positive emotions were shown to have a protective effect on the negative impact of wound healing (see Gouin & Kiecolt-Glaser, 2011 for a review). More specifically, greater trait positive affect was linked to faster wound healing as measured through skin barrier recovery following a brief stressor (Robles et al., 2009). These findings provide evidence that trait positive affect can have a positive impact on objective health outcomes in general and skin barrier recovery specifically.

Another psychological factor that affects skin barrier recovery seems to be social closeness. In a study by Robinson et al. (2017), participants underwent a tape stripping procedure together with another, initially unfamiliar participant, just after completing a task inducing social closeness between them. Those participants reported significantly less subjective stress and showed faster skin barrier recovery compared to participants from the control group who underwent the procedure by themselves. The better the participants liked their assigned partner, the faster their skin barrier recovery, suggesting that social support and social closeness have a positive effect on wound healing. Furthermore, this effect could be mediated by emotion regulation ability: Social closeness and connectedness have been demonstrated to boost emotion regulation ability and have beneficial effects on neural networks involved in processing emotions, social cognition, as well as cognitive control (Morawetz et al., 2021).

Furthermore, relaxation techniques like mindfulness meditation, whose beneficial effect on stress have been suggested to be mediated by emotion regulation ability (Boyle et al., 2017), have been associated with faster healing of surgical wounds in addition to reduced stress (Broadbent et al., 2012). More specifically, such relaxation effects on wound healing were also found in regard to skin barrier recovery after experimentally induced disruption of the skin through tape stripping, regardless of whether the relaxation technique occurred before or after the tape stripping procedure (Robinson et al., 2015).

Taken together, this link between greater positive emotions, social closeness, relaxation and mindfulness on the one hand and enhanced skin barrier recovery on the other hand, suggest that effective emotion regulation is crucial for overall health in general and wound healing, as measured in skin barrier recovery, in particular.

Emotion Regulation & Stress

As stated above, beneficial effects on stress have been associated with an increased emotion regulation ability (Boyle et al., 2017). This link can already be observed in young children as their ability to regulate stress responses increases with a more developed emotion regulation ability (Stansbury & Gunnar, 1994). However, this connection is also evident in adults, especially in regard to interpersonal contexts, in which emotion regulation ability is associated with better coping with emotional stress responses (Eisenberg et al., 1993). One possible physiological explanation for this connection is the influence that emotion regulation has on HPA activity in general and cortisol secretion in particular (Stansbury & Gunnar, 1994; Zimmermann & Stansbury, 2004), both of which, as explained above, are also closely related to the experience of stress. In addition, multiple neuronal structures, such as the amygdala, the prefrontal cortex and the anterior cingulate cortex, are involved in both the process of emotion regulation and stress (see Wang & Saudino, 2011 for a review).

Summary (ER, Wound Healing & Stress)

To summarize, it has been shown that emotions play a crucial role in health in general and have a significant impact on how people cope with stressors. Figure 1 illustrates in a very simplified manner the above discussed variables that influence emotion regulation and different factors which play a role in the interaction between emotion regulation and health, such as stress and emotions.

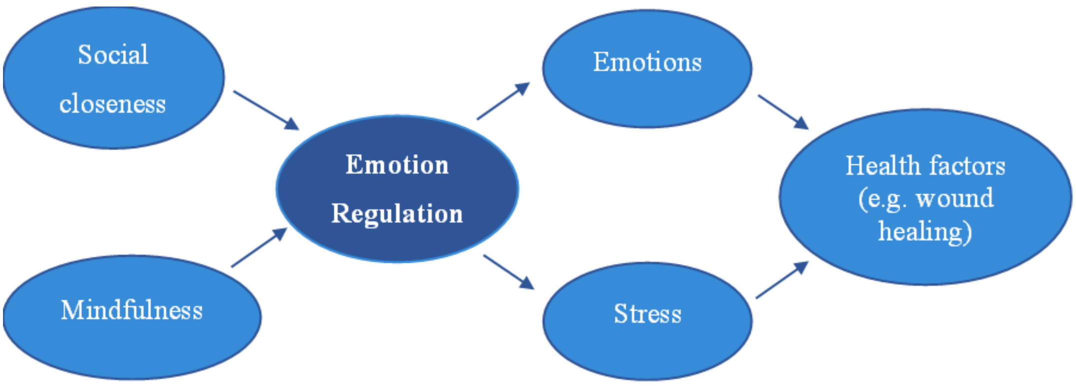

Figure 1

Simplified model of the influencing factors and consequences of emotion regulation

Individuals have different tendencies on how they deal with emotions that arise in stressful situations. These tendencies are termed emotion regulation strategies. There are a number of various strategies that seem to differ in their effectiveness and their beneficial versus adverse outcomes. This thesis concentrated on two emotion regulation strategies: Expressive Suppression on the one hand, which is seen as a maladaptive strategy as it has been connected to adverse outcomes like the enhanced experience of negative emotion and decreased well-being, and Cognitive Reappraisal on the other hand, which is seen as an adaptive strategy as it was associated with beneficial outcomes like the decreased experience of negative emotion and enhanced well-being. While maladaptive emotion regulation has been linked to increased somatic complaints, adaptive emotion regulation was associated with reduced psychological distress and depressive symptoms. Moreover, positive affect, which is experienced increasingly by individuals who reappraise as opposed to suppress their emotions (Gross and John, 2003), was linked to faster skin barrier recovery after being exposed to stressful situations (Robles et al., 2009).

In conclusion, the literature suggests that emotion regulation does not only reduce perceived stress, but also physical stress-related responses linked to wound healing and inflammation. Thus, adaptive emotion regulation strategies in general, and Cognitive Reappraisal in particular, might be connected to faster wound healing. Maladaptive emotion regulation strategies like Expressive Suppression on the contrary should be linked to slower wound healing. This effect was expected to be mediated by perceived stress, suggesting that with better emotion regulation, lower stress levels were to be reported after an acute stressor. So, while Cognitive Reappraisal was expected to lead to faster skin barrier recovery through a decrease in subjectively reported stress (see Figure 2), Expressive Suppression was expected to lead to slower skin barrier recovery through increased subjective stress (see Figure 3). The main research questions and hypotheses addressed in the paper are listed below.

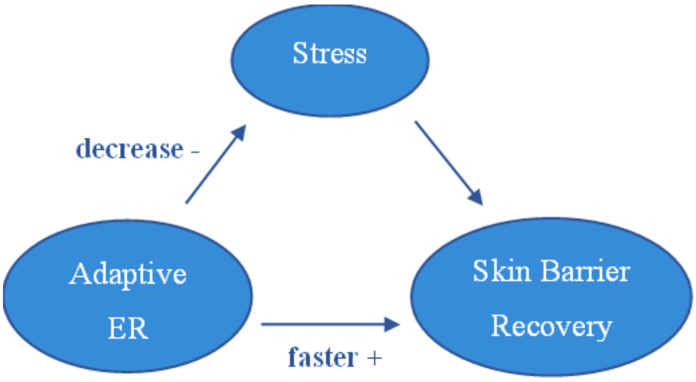

Figure 2

Expected link between adaptive emotion regulation, stress and skin barrier recovery

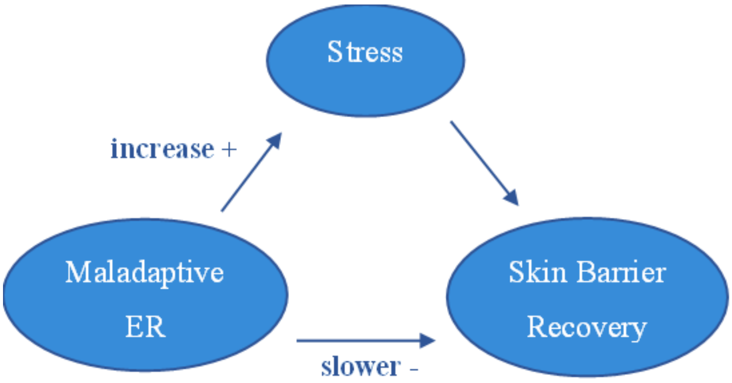

Figure 3

Expected link between adaptive emotion regulation, stress and skin barrier recovery

Research Questions & Hypotheses

Research Questions

This thesis will explore the following questions:

Q1: Do emotion regulation strategies have an effect on perceived stress after an acute stressor?

Q2: Do emotion regulation strategies have an effect on wound healing?

Q3: Is the effect of emotion regulation on wound healing mediated by perceived stress?

Hypotheses

The following hypotheses arise from the research questions presented above:

H1: Emotion regulation strategies have an effect on perceived stress.

H1.1 Maladaptive emotion regulation strategies increase perceived stress.

H1.2 Adaptive emotion regulation strategies decrease perceived stress.

H2: Emotion regulation strategies have an effect on skin barrier recovery.

H2.1 Maladaptive emotion regulation strategies are linked to slower skin barrier recovery.

H2.2 Adaptive emotion regulation strategies are linked to faster skin barrier recovery.

H3: Perceived stress mediates the effect of emotion regulation on skin barrier recovery.

H3.1 Maladaptive emotion regulation strategies lead to slower skin barrier recovery through increased perceived stress.

H3.2 Adaptive emotion regulation strategies lead to faster skin barrier recovery through decreased perceived stress.

Methods

Study Design

The research questions were addressed as part of an overarching research project by Dr. Jasminka Majdandžić and Univ. Prof. Dr. Urs Nater from the Music and Health Lab, which is part of the University of Vienna's Department of Clinical and Health Psychology. The study's focus was on the effects of music listening on stress and skin barrier recovery. The main independent variable in this study was music listening versus two control conditions (audio book or silence), to which participants were randomly assigned. Among the dependent variables were different stress measures like self-reported stress, salivary alpha-amylase and cortisol, heart rate/respiratory sinus arrhythmia and electrodermal activity. Another dependent variable was skin barrier recovery (SBR), as measured in transepidermal water loss, which served as a measurement for immune function.

In addition to these main variables, several other variables of interest were assessed by having the participants fill out some questionnaires at home before the actual testing in the laboratory. Among these variables of interest were life stress and stress reactivity, more specifically chronic stress, perceived stress, state and trait anxiety, abuse and neglect in childhood, and stress reactivity. Potential protective factors like coping, emotion regulation, self-efficacy and resilience were assessed as well as personality traits and self-esteem. To control for potential bias, several health and wellbeing factors were assessed that could serve as exclusion criteria like common mental disorders, depressivity, premenstrual syndrome (PMS) and fatigue. Lastly, music preferences, musicality, cognitive style of music listening, music-related mood-regulation strategies, and openness to absorbing and self-altering experiences were assessed. In the present thesis, the focus lied on emotion regulation as the independent variable and its influence on skin barrier recovery, while self-reported stress was examined as a mediating variable.

Sample

Participants were recruited via online portals and social media, as well as directly via the University of Vienna or via the snowball principle. Because of the COVID–19 pandemic and the lockdowns that have repeatedly occurred as a result, recruitment and the conduction of the study had to be put on hold several times. Consequently, of the intended 120 participants, complete data was only available from 15 participants at the time of writing. Participants received a small monetary compensation of € 45 for their time.

In order to participate in the study, several inclusion criteria had to be met. Included were healthy female participants between 18 and 35 years with a Body Mass Index (BMI) between 18 and 25. Participants had to be fluent in German and were required to be non-smokers. Potential factors that influence hormone balance, like pregnancy, breastfeeding, the intake of hormonal contraceptives or current menopause were set as exclusion criteria. Participants had to be tested in a specific phase of their menstrual cycle, namely in the follicular phase. In addition, reduced somatic health, as in the case of chronic or severe medical conditions, surgery in the last eight weeks, vaccination in the last two weeks, visual impairments or other health-related anomalies, were formulated as exclusion criteria. Furthermore, participants with a current mental disorder or a psychiatric illness were excluded as well as participants who reported excessive alcohol use, drug intake in the last year or psychopharmaca intake in the last 14 days. Hearing impairment, a music related profession and an absolute hearing were further exclusion criteria to ensure that all participants had comparable prior experience of listening to music and that there was no corresponding bias in the results.

In order for the TSST to actually induce stress, it was important that the participants did not have prior experience with it, otherwise they might have known it was not a real committee and the intended effect of inducing stress might not have been achieved. Additionally, a personal relationship with study team members was an exclusion criterion to avoid effects of social support, since it had been shown that social closeness influences skin barrier recovery (Robinson et al., 2017). Due to the COVID–19 pandemic, participants were also required to provide test evidence that they were not currently infected with SARS–CoV–2, and confirm that they were not showing any symptoms of the disease and that they had not been in any risk areas in the last 14 days. After screening participants to ensure that all inclusion criteria were met and arranging suitable study dates, participants were randomly assigned to the three conditions of music, audiobook or silence.

Measures

Emotion Regulation Strategies

Emotion regulation strategies were assessed via the revised German version of the Emotion Regulation Questionnaire (ERQ) by König et al. (2018). The ERQ is among the first validated instruments for the scientific study of emotion regulation processes and allows the assessment of preferences for two frequently used strategies for emotion regulation, namely suppression and reappraisal. Participants filled out the questionnaire before study begin at home. The questionnaire consisted of ten items in the form of statements concerning emotional regulation strategies. Participants were asked to indicate their agreement with each of the statements on a scale of 1–7. The items load onto two subscales: Cognitive Reappraisal, which can be described as an adaptive emotion regulation strategy, and Expressive Suppression, which can be described as a maladaptive emotion regulation strategy.

Six of the ten items relate to the subscale Cognitive Reappraisal, with all six items loading equally on the scale, resulting in a mean score between 1-7. An exemplary item for this scale is “Wenn ich mehr positive Gefühle empfinden möchte, versuche ich über die Situation anders zu denken“ (König et al., 2018, p. 1), which in the original English version translates to „When I want to feel more positive emotion, I change the way I'm thinking about the situation” (Gross & John, 2003, p. 351).

Four of the ten items relate to the subscale Expressive Suppression, with all six items loading equally on the scale, resulting in a mean score between 1-7. An exemplary item for this scale is “Ich behalte meine Gefühle für mich“ (König et al., 2018, p. 1), which in the original English version translates to „I keep my emotions to myself” (Gross & John, 2003, p. 351). The instructions in the beginning of the questionnaire make it clear that both the emotional experience, i.e. what is felt internally, and the emotional expression, i.e., how the respective feelings are shown verbally, gesturally or in behaviour externally, should be considered.

Abler & Kessler (2009) translated the English original version of the ERQ by Gross & John (2003) into German language and reported mean standard values of $M = 4.21$ ($SD = 1.02$) for Cognitive Reappraisal and $M = 3.14$ ($SD = 1.18$) for Expressive Suppression in a sample of female German participants. In the revised German version of the ERQ by König, Tran, & Gross (2018), which was used in the present study, three items were revised, namely the Cognitive Reappraisal items 1, 3 and 8 in order to ensure that the items were more applicable to the general population and more closely based on the original English version. For item 1, for example, the following wording was used in the original English version: “When I want to feel more positive emotion (such as joy or amusement), I change what I’m thinking about” (Gross & John, 2003, p. 351). This was translated to “Wenn ich mehr positive Gefühle (wie Freude oder Heiterkeit) empfinden möchte, ändere ich, woran ich denke“ by Abler & Kessler (2009, p. 29). Since this wording also hints at distraction, the wording in the revised version has been adjusted as follows: “Wenn ich mehr positive Gefühle (wie z.B. Freude oder Heiterkeit) empfinden möchte, ändere ich, was ich darüber denke“ (König et al., 2018, p. 1). This formulation focuses more on the *way* something is thought about, as opposed to *what* is thought about, as the latter could also merely indicate distraction.

The manuscript for the revised German version of the ERQ by König et al. (2018), which was used in the present study, is still in preparation and therefore no accurate standard values were available at the time of writing this thesis. Consequently, the norm values of Abler & Kessler (2009) were considered reference values, although these should only be used with caution here, as they are based on a version with partially different items and may therefore not be completely valid for the version used in the study.

Based on the Abler & Kessler (2009) version, satisfactory psychometric quality of the questionnaire can be reported. Cronbach Alpha values were .74 for Cognitive Reappraisal and .76 for Expressive Suppression, suggesting satisfactory internal consistency and thus good reliability. The factor structure with the two factors of Expressive Suppression and Cognitive Reappraisal was also able to explain 50% of the total variance. The maximum cross-loadings on the other factor were .098 and there was no indication that the total variance could be adequately explained by only one component, clearly indicating a 2–factor solution overall. Expressive Suppression was significantly correlated with expressive inhibition due to ambivalence, as well as with depressiveness, while Cognitive Reappraisal was not significantly correlated with either of these factors. This supports convergent and discriminant validity, although based on these findings one cannot yet explicitly speak of external validity.

Self-Reported Stress

Perceived stress was assessed via a Visual Analogue Scale (VAS; Cline et al., 1992). Participants answered the question “Wie sehr fühlen Sie sich gestresst?“, which translates to „How stressed are you feeling?” by marking the analogue scale with a line. The value 0 represents the minimum of perceived stress and 100 the maximum. The VAS was completed eight times throughout the study while the focus for the present research questions lied on the third assessment, just after completing the TSST. The perceived stress variable represents the delta between the third assessment and the baseline assessment.

Skin Barrier Recovery

Skin barrier recovery, as a form of wound healing, was assessed via transepidermal water loss (TEWL) using the Tewameter® TM 300 by the company Courage Khazaka (Cologne, Germany). Participants first underwent a *tape stripping procedure*: A painless procedure whereby the skin on the inner forearm is slightly irritated by repeatedly applying and pulling off tape. Through this method, the stratum corneum, the outermost layer of the epidermis, is removed.

Subsequently the skin's water loss was determined with a probe that measures the evaporation rate directly on the skin's surface. Transepidermal water loss is an indicator of skin barrier disruption, with an elevated TEWL pointing to lower skin barrier function and thus higher disruption of the skin barrier. To measure wound healing, more specifically here to see how quickly the irritated skin recovers, the percentage of skin barrier recovery (SBR) was calculated with the delta between the TEWL values at disruption and at recovery in respect to the delta between TEWL values at disruption and at baseline. The formula has been used in several studies and looks as follows: $SBR = (TEWL_{elevated} - TEWL_{recovery})/(TEWL_{elevated} - TEWL_{baseline}) \times 100\%$ (Robinson et al., 2017). TEWL was measured six times throughout the study, namely just before the tape stripping procedure to assess a baseline value, just after the tape stripping to assess the value with the maximum of disruption, as well as at 55, 85, 115, and 145 minutes after disruption. Prior studies on skin barrier recovery indicated that the steepest rise in the wound healing process took place in the first hour after the disruption (Robinson et al., 2017), thus this thesis focused on the third assessment of SBR, which took place 55 minutes after disruption.

Before the tape stripping procedure, the Tewameter® probe was placed in a probe heater, where it was heated to 34°C, to ensure it being close to skin temperature. Room temperature was set to a standardized temperature between 22.5–23.5°C using heating or air conditioning. The participant placed her non-dominant arm on a cushion on the table in front of the TEWL operator and was instructed not to move during the measurements. The inner arm was marked 1 cm below the elbow crease using a stamp that consists of four 1–cm^2 squares: three test sites and one control site. During the baseline TEWL measurement, each site was measured until 20 consecutive measurements with a $SD < 0.5$ were reached or alternatively if a maximum of 90s had passed.

In preparation for the tape stripping, the three test sites were shaved with a disposable razor to prevent hair from being ripped out during the procedure. The tape strips, each approximately 5 cm x 1.5 cm big, were applied one at a time across the three test sites and immediately peeled off again. To ensure all three sites were equally impaired, the strips were stripped off from alternating directions. After the first 20 strips, the top test area was tested for 40 seconds. If the TEWL value had increased by a minimum of 15 g/hr/m² from baseline, sufficient impairment had occurred and all four sites were measured. If the TEWL value was not elevated by 15 g/hr/m² from baseline, 10 more strips were applied. If the elevation still had not reached the minimum of 15 g/hr/m², another 10 strips were applied, with a total of 40 strips being the maximum of strips and thus the end of the tape stripping procedure. Participants were instructed not to cover or touch the site in any way during the rest of the experiment. The following TEWL measurements were taken exactly 55 minutes, 85 minutes, 115 minutes, and 145 minutes after the disruption.

To prepare for the analysis, the TEWL and SBR values were examined to screen for any invalid data. Three participants had negative SBR values, meaning that their TEWL values increased after the impairment. Since the $TEWL_{impaired}$ value was considered to represent the maximum of impairment and thus should be the highest TEWL value, these participants were excluded from the analysis. Another three participants had invalid $TEWL_{impaired}$ values, because the individual TEWL values of the three different test sides were too far apart (>10) to calculate a mean $TEWL_{impaired}$ value. These three participants also had to be removed from the analysis, leaving a total of nine participants (N = 9) with valid SBR values.

Tasks

Trier Social Stress Task

The Trier Social Stress Task (TSST; Kirschbaum et al., 1993) consists of a three minute preparation period in which the participant was allowed to take notes (although these notes may not be used during the following speech) and a ten minute test period in front of an audience. The TSST test period is further subdivided into five minutes of free speech, in which the participant was instructed to talk about her personal characteristics pretending to apply for a job she is eager to have, and a mental arithmetic task, in which the participant was asked to count down from the number 2043 in steps of 17. To increase the stress induction, the participant was told that her performance is being videotaped and that the audience was trained in behavioural observation. The audience consisted of one female passive stressor and one male active stressor, who were instructed to keep neutral facial expressions and to avoid any interaction with the participant to eliminate any sense of social support. While the passive stressor merely silently observed the participant and took notes, the active stressor gave instructions to the participant and interrupted if the participant deviated from the topic in the free speech or made mistakes in the arithmetic task, requiring the participant to start counting anew.

The TSST has been found to induce moderate psychological stress and physiological responses of stress in a laboratory setting and has thus been widely used as a tool for psychobiological research (Kirschbaum et al., 1993; Nater et al., 2006). Compared to a rest condition, significantly more psychological stress and state anxiety has been reported by subjects undergoing the TSST (Nater et al., 2006). Distressing psychological stimuli have been associated with increases in heart rate, increases in the concentration of hormones like adrenocorticotropic hormone (ACTH), cortisol (serum & saliva), vasopressin, β-endorphin, epinephrine, growth hormone (GH), as well as decreases in the concentration of luteinizing hormone (LH) and testosterone (Kirschbaum et al., 1993). Among the physiological responses detected specifically in response to the TSST, were significant increases in heart rate and a significant increase in the concentration of ACTH, serum and salivary cortisol, GH, prolactin (Kirschbaum et al., 1993), and alpha-amylase (Nater et al., 2006). Salivary cortisol responses to the TSST were assessed in five different studies, revealing that in each study, over 70% of participants showed a considerable increase (2– to 4–fold increase in respect to baseline) and thus a high reproducibility and consistency of salivary cortisol responses has been demonstrated across studies (Kirschbaum et al., 1993). These results indicate that the TSST leads to an activation of the hypothalamus-pituitary adrenal (HPA) axis, triggering a characteristic psychological and physiological stress response.

Procedure

Before the actual study begin at the laboratory, participants filled out a number of questionnaires at home. These questionnaires surveyed a number of variables. Life stress and stress reactivity were assessed via the Trierer-Inventar zum chronischen Stress (TICS; Schulz & Schlotz, 1999) for chronic stress, via the Perceived Stress Scale (PSS; Cohen et al., 1983) for perceived stress, via the Childhood Trauma Questionnaire (CTQ; Bernstein et al., 2003) for abuse and neglect in childhood, and via the Perceived Stress Reactivity Scale (PSRS; Schlotz et al., 2011) for stress reactivity. Coping, emotion regulation, and self-efficacy were assessed via the Brief-Cope (Carver, 1997) for coping and via the Emotion Regulation Questionnaire (ERQ; König et al., 2018) for emotion regulation. Resilience and protective factors were assessed via the Resilienz-Kurzskala (RS-11; Leppert et al., 2008). Personality traits were assessed via the NEO-Fünf-Faktoren-Inventar (NEO-FFI; Borkenau & Ostendorf, 1993) for the Big Five and via the Rosenberg Self-Esteem (RSES; Rosenberg et al., 1989) for self-esteem. Health and wellbeing were assessed via the Prime MD Patient Health Questionnaire

(PHQ-D; Spitzer et al., 2000) for most common mental disorders and via the Becks Depression Inventory (BDI II; Beck et al., 1996) for depressivity. Functional somatic symptoms and PMS were assessed via the Multidimensional Fatigue Inventory (MFI-20; Smets et al., 1995). Music variables were assessed via the Music Preference Questionnaire (MPQ; Nater et al., 2005) for music preferences and via the Gold-MSI (G-MSI; Müllensiefen et al., 2014) for musical sophistication and musicality.

Since the majority of testing took place during the COVID–19 pandemic, some additional safety precautions were implemented during the testing period. These precautions included wearing face masks, disinfecting hands and any surfaces or objects that participants or test administrators came into contact with, and measuring the body temperature of all persons involved to rule out the presence of a fever. Participants and all study team members were also required to fill out a specific COVID–19 questionnaire to rule out current COVID –19 symptoms or a visit to a risk country in the last 14 days, as well as to provide a negative COVID –19 test result before study begin. Because of varying regulations over the testing period, not all of these precautions had to be taken for all participants.

If all safety requirements had been met, participants gave their informed consent and filled out an entry questionnaire. Subsequently, the EcgMove 4 sensor by the company movisens (Karlsruhe, Germany) was attached to the lower part of the sternum using a chest strap, in order to monitor the heart rate. The EdaMove 4 movisens sensor was attached to the non-dominant hand by a wrist strap, recording the electrodermal activity. Participants in the music listening condition were asked to listen to five different playlist samples in order to choose the playlist they would like to hear in the following music listening session. Participants in the audio book condition were asked about their preference for an audio book on the topic of either biology, history, cosmology, philosophy or physics.

After these preparations, the first measurements were taken, which included a saliva sample as well as electrocardiography (ECG) and electrodermal activity (EDA) measurements, which were both measured continuously throughout the study with markers being set during each saliva sample. The measurements also included the completion of a set of questionnaires assessing the stress response and affective state. More specifically, this set consisted of the constructed The Types of Positive Affect Scale (TTPAS) which assesses a number of positive affect on a 7–point Likert Scale, the Mehrdimensionaler Befindlichkeitsfragebogen (MDBF; Steyer et al., 1997) assessing mood, fatigue, and nervosity versus calmness on a 7–point Likert Scale, and the Visual Analogue Scale (VAS; Cline et al., 1992) stress repeated assessing stress, controllability, anxiety, urge to leave, and tension on a visual analogue scale. This set of measurements (salivary sample, ECG/EDA measurements, and TTPAS/MBDF/VAS questionnaires) is assessed eight times in total throughout the study. During the first measurement, primary and secondary appraisal is also surveyed via the Primary Appraisal Secondary Appraisal questionnaire (PANAS; Gaab, 2009).

Following the first measurements, participants were led into a different room where the TSST was performed in order to induce stress. Instructions were given to the participant by the instructor who then left the room. After the three-minute preparation period, the second measurements (salivary sample, ECG/EDA, TTPAS/MBDF/VAS, PASA) were carried out, followed by the 10–minute TSST test period. Immediately after the TSST, the third measurements (salivary sample, ECG/EDA, TTPAS/MBDF/VAS) were taken before the participant was led back into the test room. Here, TEWL baseline measurements, tape stripping procedure, and TEWL impaired measurements were performed by the TEWL operator before the fourth measurements (salivary sample, ECG/EDA, TTPAS/MBDF/VAS) were conducted by the instructor.

The music listening session then started, in which the participant listened to the previously selected playlist. In the control conditions, participants either listened to the previously selected audio book or waited in silence. In all three conditions, the participant lied on a stretcher alone in the room for 30 minutes with the lights dimmed. After 30 minutes the instructor re-entered the room, turned on the lights and conducted the fifth measurements (salivary sample, ECG/EDA, TTPAS/MBDF/VAS) and participants filled out a questionnaire including specific questions about the music/audiobook that had been played (Bewertung Musikstimulus; BMS). Directly after this, the first of the four follow-up TEWL measurements was conducted, exactly 55 minutes after the TEWL impaired measurement.

Subsequently, there was a 30 minutes waiting interval, followed by the sixth measurements and the second follow-up TEWL measurement, exactly 85 minutes after the TEWL impaired measurement. To prevent boredom, participants were offered a number of different magazines to read during the waiting period. After another waiting period of 30 minutes, the seventh measurements and the third follow-up TEWL measurement, exactly 115 minutes after TEWL impaired, was conducted. A final waiting period of 30 minutes followed with the subsequent eight measurements (salivary sample, ECG/EDA, TTPAS/MBDF/VAS) and the fourth TEWL measurement, exactly 145 minutes after the TEWL impaired measurement. With this, data collection was completed and the participant was debriefed in detail about the goal of the study and informed about the deception during the TSST.

Statistical Analysis

Descriptive statistics were conducted to describe the demographic characteristics of the cohort. Metric parameters used here were mean value (*M*), standard deviation (*SD*), and standard error of the mean value (*SE*). To test Hypothesis 1, two regression analyses were conducted. For Hypothesis 1.1, the mean score on Expressive Suppression as an indicator for maladaptive emotion regulation was set as the independent variable and perceived stress as the dependent outcome variable. For Hypothesis 1.2, the mean score on Cognitive Reappraisal as an indicator for adaptive emotion regulation was set as the independent variable and the delta value of perceived stress, measured just after an acute stressor in respect to baseline, as the dependent outcome variable. To test Hypothesis 2, again two regression analyses were conducted to address the influence of both adaptive and maladaptive emotion regulation on wound healing. For Hypothesis 1.1, the mean score on Expressive Suppression as an indicator for maladaptive emotion regulation was set as the independent variable and skin barrier recovery (SBR) after 55 minutes as the dependent outcome variable. For Hypothesis 1.2, the mean score on Cognitive Reappraisal as an indicator for adaptive emotion regulation was set as the independent variable and SBR after 55 minutes as the dependent outcome variable.

To test Hypothesis 3, two mediation analyses, one for each emotion regulation strategy, were planned to be conducted via the SPSS macro PROCESS by Hayes (2018). To perform such a mediation analysis with emotion regulation as the independent variable, SBR as the dependent outcome variable and stress as the mediator, however, the individual path coefficients of the moderation model must be significant. Path coefficient *a* would be represented by Hypothesis 1, while path coefficient *c* would be represented by Hypothesis 2. However, since both regression analyses on Hypothesis 1 and 2 were overall not significant, the requirements for a mediation analysis were not met and thus it did not make sense to perform the analysis.

A number of statistical analyses were carried out to verify the prerequisites for the regression analyses (Field, 2018) for Hypotheses 1 and 2. The independent variable must be either interval scaled or dichotomic. The items of both emotion regulation strategies load on Likert scales between 1 and 7. These scores are subsequently averaged and thus it can be assumed that the resulting value is an interval-scaled variable. The same is the case for the dependent variable which must be interval scaled. This is the case both for stress, which was an outcome variable with a value between 0 and 100, as well as for SBR, which was an outcome variable with a value between 0 and 100%. The linearity of the correlations and homoscedasticity were tested using scatter plots of standardised predicted values (*ZPRED) and residuals (*ZRESID), as well as partial regression plots. Following the visual assessment of the partial regression diagrams of the individual variables, the prerequisite of linearity can be assumed to be met. In the scatter plots of *ZPRED and *ZRESID, no obvious pattern could be detected and thus homoscedasticity can be expected assumed. The requirement of normal distribution can also be assumed, since the residual statistics are all between –2.5 and +2.5 and the Probability-Probability (P–P) plot of the standardised residuals also indicates normally distributed residuals. Due to the study design, it can be assumed that the observations can be considered to be independent from each other, as the test persons were randomly assigned to only one condition and only one test session was performed per person. Since the prerequisites could thus be considered to be largely fulfilled, the respective regression analyses were carried out with a predefined alpha level of $p > .05$.

In addition to the regression analysis, an analysis of extreme groups was carried out to detect possible trends in the data despite the very small sample and to compare extreme values. For this purpose, the participants with the highest scores in Expressive Suppression and Cognitive Reappraisal were compared with the participants with the lowest scores on these scales. The relationship between high versus low scores on the one hand and stress and SBR on the other hand was illustrated.

Results

Sample

The final sample consisted of $N = 15$ ($N = 9$ for SBR values) healthy females between 20 and 32 years, with a mean age of 25.73 ($SD = 3.73$). This low sample number is due to the COVID–19 pandemic, as no testing could be carried out over longer periods due to the repeatedly declared lockdowns. The cohort appeared to be quite homogenic regarding nationality, education level, vocational training and employment status. In terms of housing situation and relationship status, the cohort was more heterogeneous and reported answers were relatively evenly distributed. All participants reached a Body Mass Index (BMI) in the normal range (set between 18–25) with a mean value of 21.47 ($SD = 0.41$). For a detailed list of all descriptive characteristics of the cohort, see Table 1 and Table 2.

Table 1

Descriptive Statistics of Sample I

Sociodemographic Characteristics	*M*	*SD*	Range
Age	25.73	3.73	20–32
BMI	21.47	0.41	19.15–24.49
Persons in household	2.2	0.86	1–4

Table 2

Descriptive Statistics of Sample II

Sociodemographic Characteristics	Total amount (n)	Estimate (%)
Nationality		
Austria	10	66.7%
Germany	4	26.7%
Chile	1	6.7%
Sex		
Female	15	100%
Relationship Status		
In partnership	7	46.7%
Single	7	46.7%
Other	1	6.7%
Employment		
Full-time	2	13.3%
At least part-time	4	26.7%
Less than part-time	1	6.7%
In training	6	40.0%
Unemployed	2	13.3%
Housing		
Alone	2	13.3%
Shared apartment	9	60.0%
With partner	3	20.0%
Other	1	6.7%
School Education		
A-levels	14	93.3%
Secondary school	1	6.7%
Vocational Training		
University	14	93.3%
Apprenticeship	1	6.7%

Descriptive Statistics

Mean scores of the sample on Expressive Suppression were between 1.50 and 5.75, with a mean value of 3.30 (*SD* = 1.27). Mean scores on Cognitive Reappraisal were between 4.00 and 6.67, with a mean value of 5.11 (*SD* = 0.91). Figure 4 illustrates the distribution of Expressive Suppression scores in the sample. The red line marks the reported mean standard value of *M* = 3.14, 95% CI [1.96 ; 4.32] for Expressive Suppression by Abler & Kessler (2009), suggesting that our sample scored similarly to the relevant norm on this scale. Figure 5 shows the distribution of Cognitive Reappraisal scores in our sample. Again, the red line marks the reported mean standard value of *M* = 4.21, 95% CI [3.19 ; 5.23] for Cognitive Reappraisal by Abler & Kessler (2009), which indicates that our cohort scored higher on this scale than the corresponding norm group. This is further emphasised by the fact that the maximum of the normal distribution curve based on our data is further to the right than the given standard mean value of 4.21.

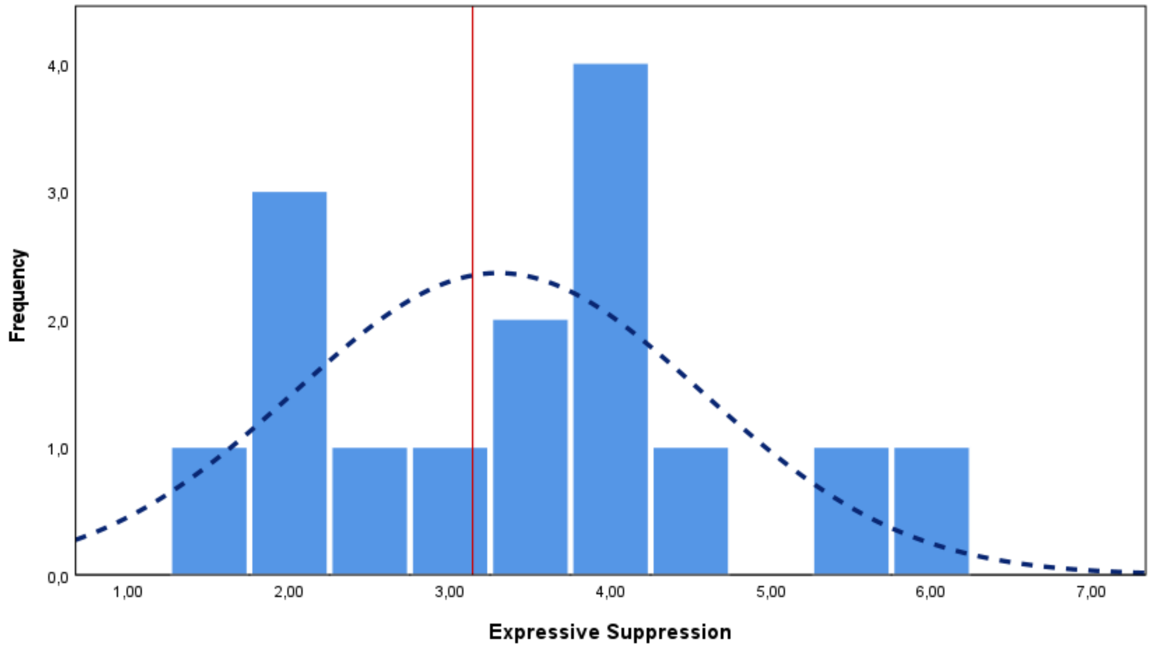

Figure 4

Distribution of Expressive Suppression Scores

Note. Blue bars indicate the distribution of scores on the Expressive Suppression scale. The dashed blue line illustrates the normal distribution curve based on the sample's scores. The vertical red line marks the mean value of the norm group as a reference point.

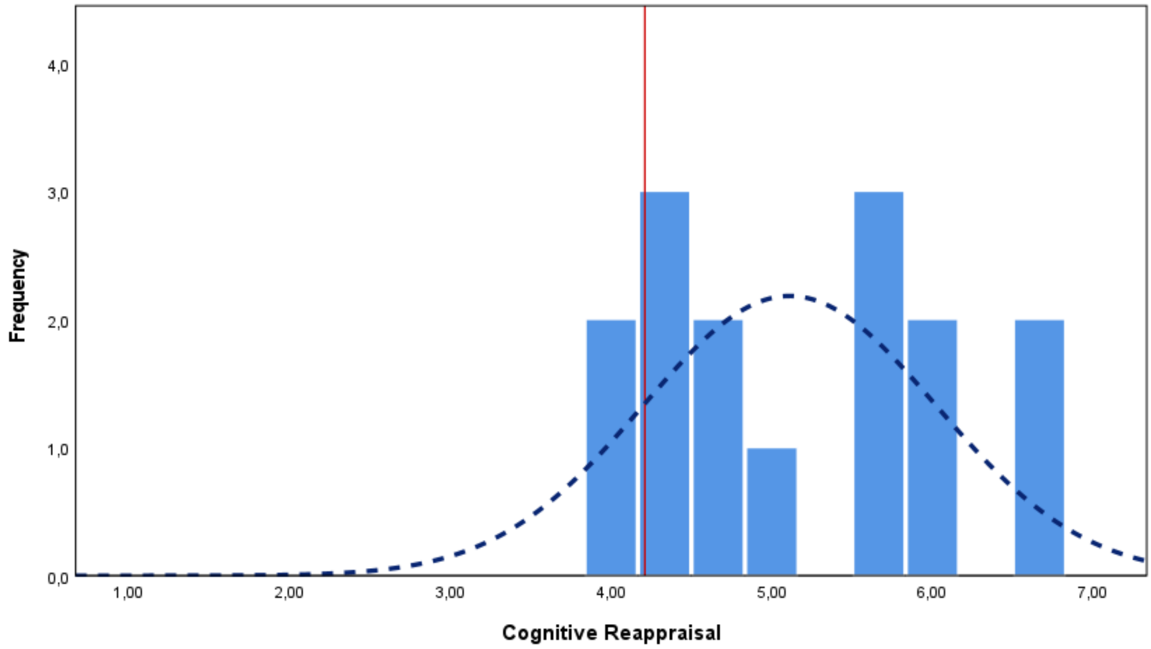

Figure 5

Distribution of Cognitive Reappraisal Scores

Note. Blue bars indicate the distribution of scores on the Cognitive Reappraisal scale. The dashed blue line illustrates the normal distribution curve based on the sample's scores. The vertical red line marks the mean value of the norm group as a reference point.

Perceived stress represents the third assessment of subjective stress, just after completion of the TSST, on a Visual Analogue Scale (VAS) with respect to the baseline assessment. Values for this delta variable of perceived stress were between 14 and 98, with a mean value of 47.80 (*SD* = 29.23). Stress levels at the third assessment were comprised of values between 31 and 99, with a mean value of 59.13 (*SD* = 23.68), and stress levels at baseline were comprised of values between 0 and 35, with a mean value of 11.33 (*SD* = 10.72). A detailed description of the characteristics of the variables with the respective statistical parameters is given in Table 3.

Table 3

Descriptive Statistics of Main Variables

Variables	*M*	*SE*	*SD*	Variance	Range	N
ES	3.30	0.32	1.27	1.61	1.50–5.75	15
CR	5.11	0.24	0.91	0.84	4.00–6.67	15
Stress_1	11.33	2.77	10.72	114.95	0–35	15
Stress_3	59.13	6.11	23.68	560.70	31–99	15
Delta Stress	47.80	7.55	29.27	854.17	14–98	15
SBR	26.78	3.48	10.45	109.11	13.79–45.20	9

Note. ES = Expressive Suppression; CR = Cognitive Reappraisal ; Stress_1 = VAS stress at baseline ; Stress_3 = VAS stress at third measurement; Stress = delta stress variable of third VAS measurement with respect to baseline; SBR = skin barrier recovery

As can be seen in Table 3, valid data was available from $N = 15$ participants for the two emotion regulation strategies, Expressive Suppression (ES) and Cognitive Reappraisal (CR), as well as for the subjective stress measures. For skin barrier recovery measures, valid data was only available for $N = 9$ participants, after $N = 6$ participants had to be excluded for reasons stated above (negative SBR values or no valid mean value).

Expressive Suppression

According to Hypothesis 1.1, Expressive Suppression was expected to be associated with an increase in perceived stress. According to Hypothesis 2.1, Expressive Suppression was expected to be associated with slower wound healing as measured in skin barrier recovery. A respective regression analysis was performed for each of these hypotheses.

Expressive Suppression and Stress

The performed Regression Analysis showed no significant correlation between maladaptive emotion regulation and perceived stress ($p = .416$). The model summary shows that 5.2% of the variance in the data could be explained by the corresponding model ($R^2 = .052$). These findings contradict the expectations of Hypothesis 1.1, according to which maladaptive emotion regulation (Expressive Suppression) is related to an increase in stress levels. While a positive correlation between maladaptive emotion regulation and stress was expected, the correlation was not only not significant, but as illustrated in the scatter plot in

Figure 6, the regression coefficient was also negative, with a value of B = –5.23. The standardised coefficient indicates a small effect with a value of $\beta = 0.23$.

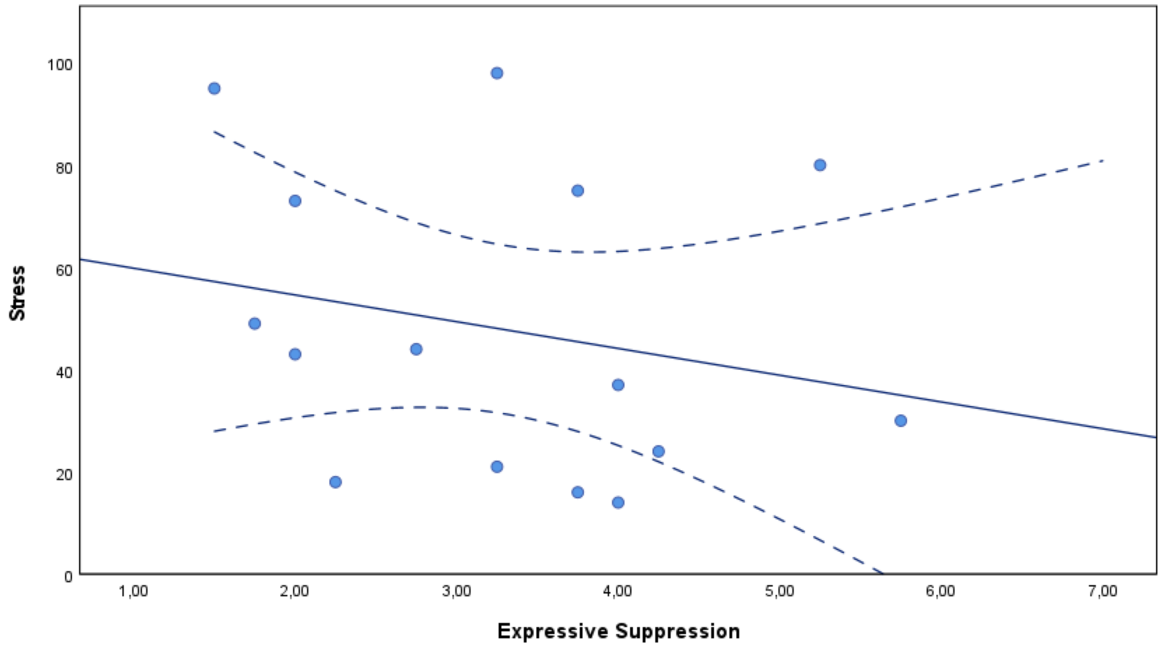

Figure 6

Correlation between Expressive Suppression and Stress

Note. The graph above represents the correlation between Expressive Suppression and stress. Each dot conveys one participant's score on Expressive Suppression and stress. The solid line represents the correlation of the mean values and the dashed edges represent its 95% CI.

Expressive Suppression and Skin Barrier Recovery

A significant association was found between maladaptive emotion regulation and SBR ($p = .006$), with 67.8% of the variance in the data being explained through the model (R^2 = .678). However, while maladaptive emotion regulation was thought to be linked to slower SBR and thus a negative correlation was expected, as illustrated in Figure 7, the correlation found was positive, with a regression coefficient of B = 8.78. The corresponding standardised coefficient beta indicates a large effect with a value of $\beta = 0.82$. Thus, despite the significant effect, the data does not support Hypothesis 2.1, as the effect goes in the opposite direction of what was expected.

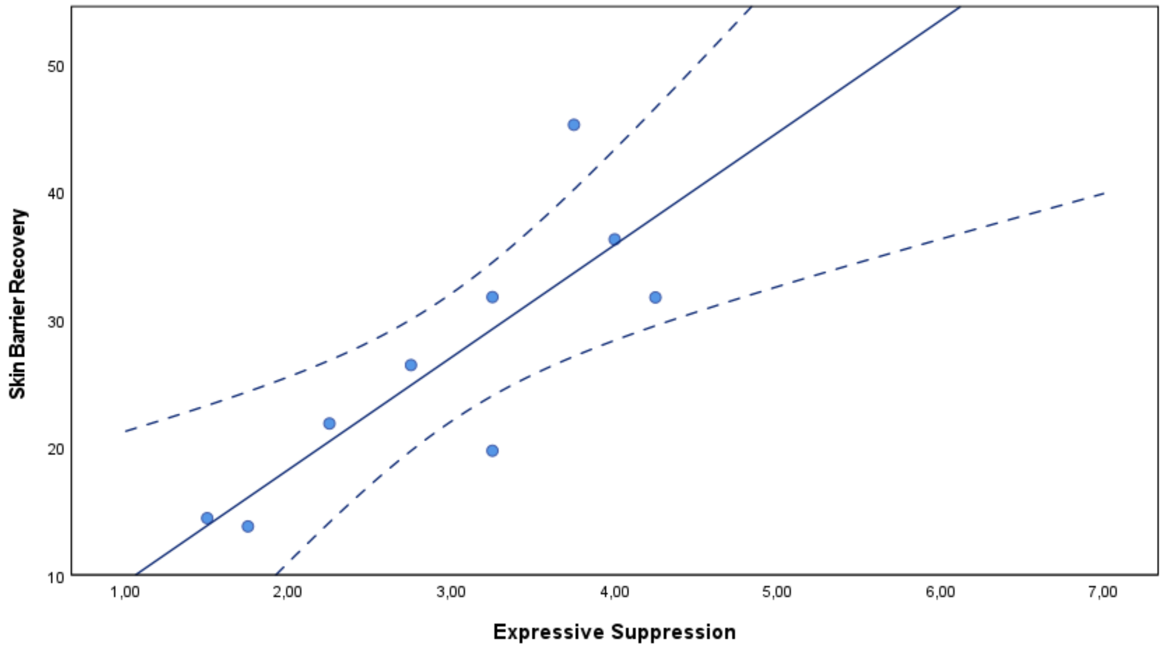

Figure 7

Correlation between Expressive Suppression and Skin Barrier Recovery

Note. The graph above represents the correlation between Expressive Suppression and SBR. Each dot conveys one participant's score on Expressive Suppression and SBR. The solid line represents the correlation of the mean values and the dashed edges represent its 95% CI.

Cognitive Reappraisal

According to Hypothesis 1.2, Cognitive Reappraisal was expected to be associated with a decrease in perceived stress. According to Hypothesis 2.2, Cognitive Reappraisal was expected to be associated with faster wound healing as measured in skin barrier recovery. A respective regression analysis was performed for each of these hypotheses.

Cognitive Reappraisal and Stress

A significant correlation could not be found between adaptive emotion regulation and perceived stress ($p = .065$), but due to the closeness of the p-value to the set alpha level of >.05, one can speak of a trend in the data. The respective model was able to explain 23.8% of the variance observed in the data ($R^2 = .238$). The correlation between stress and adaptive emotion regulation was negative with a regression coefficient of $B = -15.58$ (see Figure 8). The standardised coefficient beta indicates a medium to large effect with a value of $\beta = -0.49$.

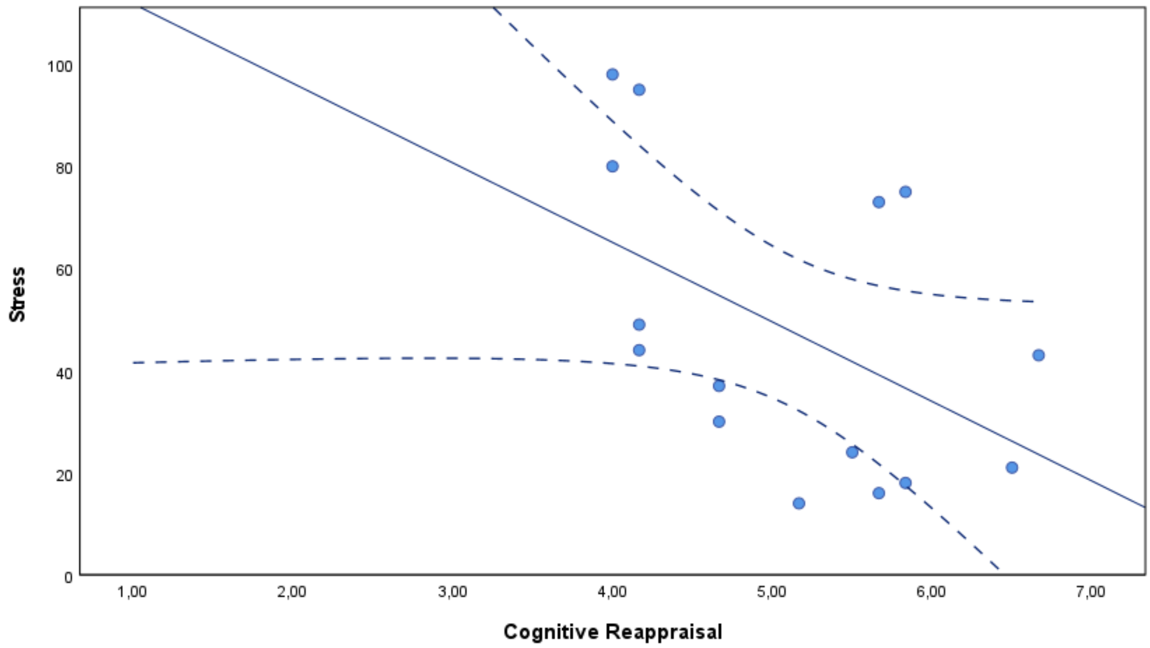

Figure 8

Correlation between Cognitive Reappraisal and Stress

Note. The graph above represents the correlation between Cognitive Reappraisal and stress. Each dot conveys one participant's score on Cognitive Reappraisal and stress. The solid line represents the correlation of the mean values and the dashed edges represent its 95% CI.

Cognitive Reappraisal and Skin Barrier Recovery

No significant correlation could be found between adaptive emotion regulation and SBR (p = .094), but due to the closeness of the p-value to the set alpha level of >.05, one can again speak of a trend in the data. The respective model was able to explain 34.9% of the variance observed in the data (R^2 = .349). Figure 9 indicates a positive link between adaptive emotion regulation and SBR, with a regression coefficient of B = 6.56. The standardised coefficient beta indicates a large effect with a value of β = .59.

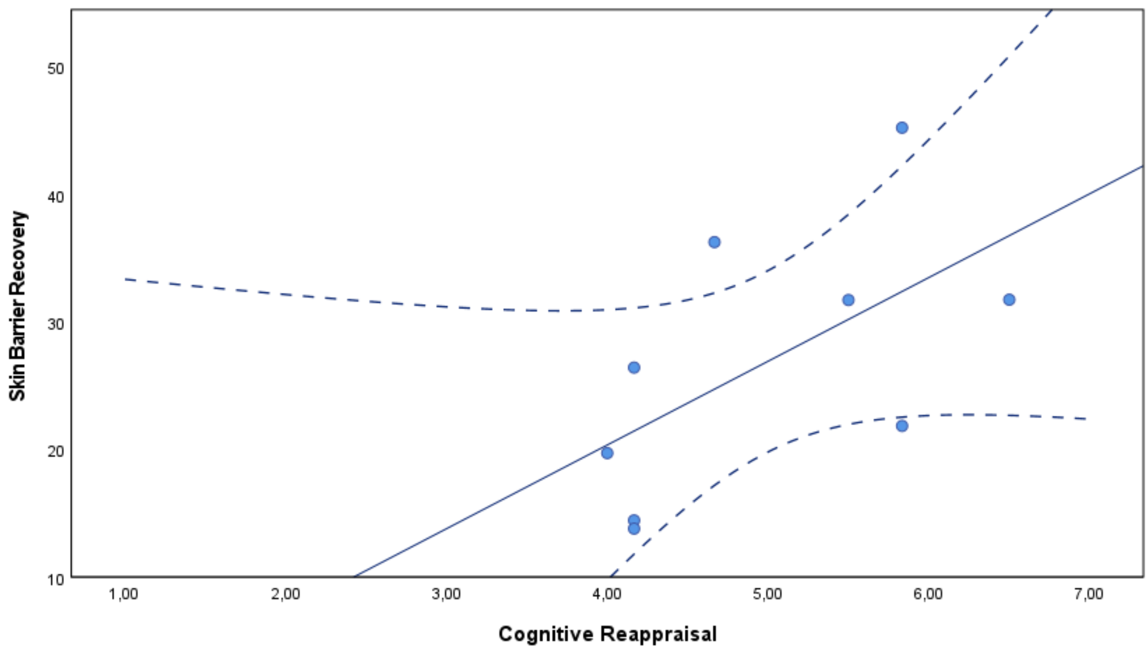

Figure 9

Correlation between Cognitive Reappraisal and Skin Barrier Recovery

Note. The graph above represents the correlation between Cognitive Reappraisal and SBR. Each dot conveys one participant's score on Cognitive Reappraisal and SBR. The solid line represents the correlation of the mean values and the dashed edges represent its 95% CI.

Extreme Group Analysis

Expressive Suppression

In order to more clearly illustrate the difference between participants scoring high on Expressive Suppression, in other words people who frequently use this emotion regulation strategy, versus participants scoring low on Expressive Suppression, not primarily using this strategy, two groups were formed. Those participants with the highest scores were grouped together and those with the lowest scores were grouped together. The group with the highest scores consisted of N = 5 participants with scores of 5.75 (one participant), 5.25 (one participant), 4.25 (one participant), and 4.0 (two participants). Of those five participants, N = 2 participants had valid SBR values. The group with the lowest scores consisted of N = 4 participants with scores of 1.5 (one participant), 1.75 (one participant) and 2.0 (two participants). Of those four participants, N = 2 participants had valid SBR values.

Expressive Suppression and Stress. The group of participants with the lowest scores on Expressive Suppression (N = 4) reported a mean stress value of 65.00 (SD = 23.8) with VAS delta scores between 43 and 95. The group of participants with the highest scores on Expressive

Suppression ($N = 5$) reported a mean stress value of 37.00 ($SD = 25.48$) with VAS delta scores between 14 and 80. This comparison, which is illustrated in form of a bar chart in Figure 10, shows that the group of participants with higher maladaptive emotion regulation scored lower on perceived stress ($M = 37.00$) than the group of participants with lower maladaptive emotion regulation ($M = 65.00$), although it must be noted that the confidence intervals overlap.

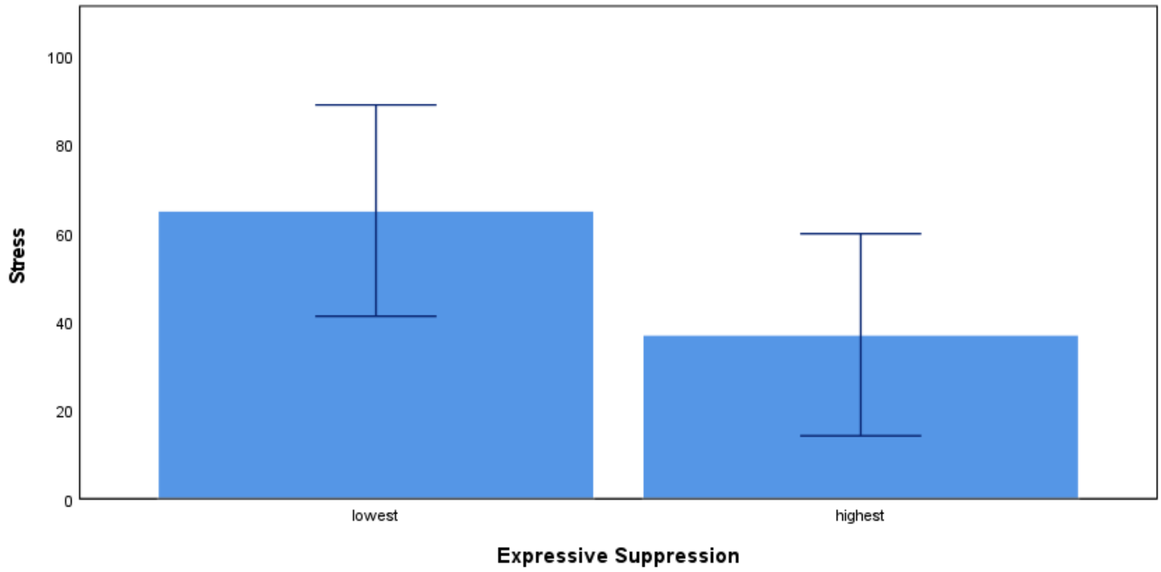

Figure 10

Stress in Expressive Suppression

Note. Bars represent mean values of stress in the group of participants with lowest scores vs. the group of participants with highest scores on Expressive Suppression. Error bars indicate Standard Error (*ER*) of the mean values.

Expressive Suppression and Skin Barrier Recovery. The group of participants with the lowest scores on Expressive Suppression ($N = 2$) reported a mean SBR value of 14.12 ($SD = 0.47$) with values between 13.79 and 14.44. The group of participants with the highest scores on Expressive Suppression ($N = 2$) reported a mean SBR value of 33.97 ($SD = 3.21$) with values between 31.7 and 36.24. Figure 11 illustrates the difference between the two groups, indicating that participants with higher maladaptive emotion regulation showed faster wound healing as measured in SBR ($M = 33.97$) than the group of participants with lower maladaptive emotion regulation ($M = 14.12$).

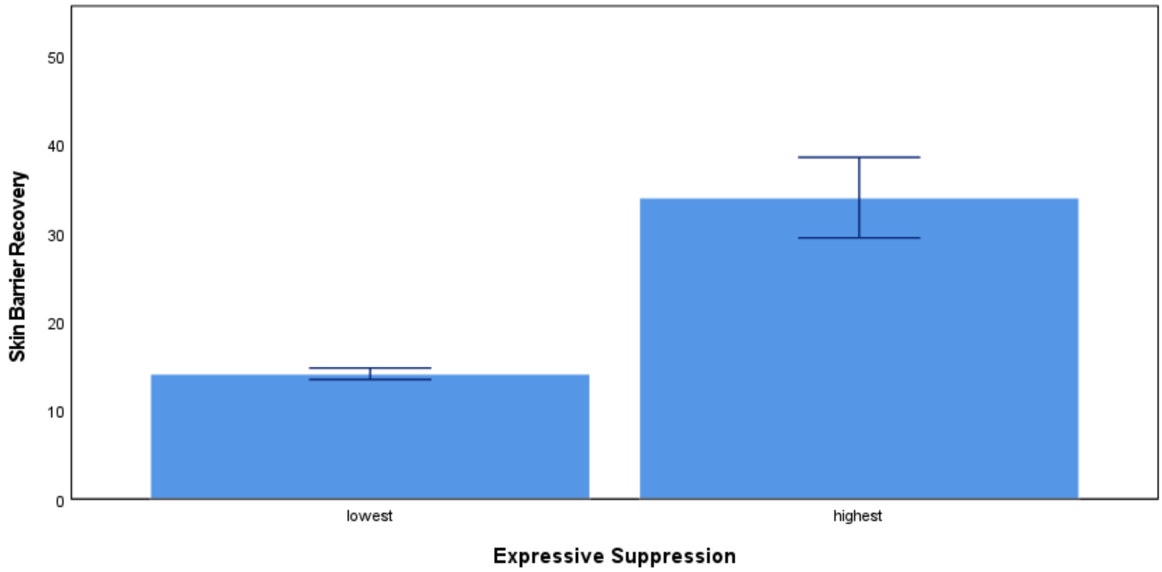

Figure 11

Skin Barrier Recovery in Expressive Suppression

Note. Bars represent mean values of SBR in the group of participants with lowest scores vs. the group of participants with highest scores on Expressive Suppression. Error bars indicate Standard Error (*ER*) of the mean values.

Cognitive Reappraisal

In order to more clearly illustrate the differences between high versus low scores on the Cognitive Reappraisal scale, those participants with the highest scores were grouped together and those with the lowest scores were grouped together. The group with the highest scores consisted of $N = 4$ participants with scores of 6.67 (one participant), 6.5 (one participant), and 5.83 (two participants). Of those four participants, $N = 3$ participants had valid SBR values. The group with the lowest scores consisted of $N = 5$ participants with scores of 4.0 (two participants) and 4.17 (three participants). Of those five participants, $N = 4$ participants had valid SBR values.

Cognitive Reappraisal and Stress. The group of participants with the lowest scores on Cognitive Reappraisal ($N = 5$) reported a mean stress value of 73.20 ($SD = 25.37$) with VAS delta scores between 44 and 98. The group of participants with the highest scores on Cognitive Reappraisal ($N = 4$) reported a mean stress value of 39.25 ($SD = 26.31$) with VAS delta scores between 18 and 75. This contrast between the two groups, illustrated in Figure 12, suggests that the group of participants with higher adaptive emotion regulation experienced less stress

($M = 39.25$) than the group of participants with lower adaptive emotion regulation ($M = 73.20$), whereby it must also be taken into account here that the confidence intervals overlap.

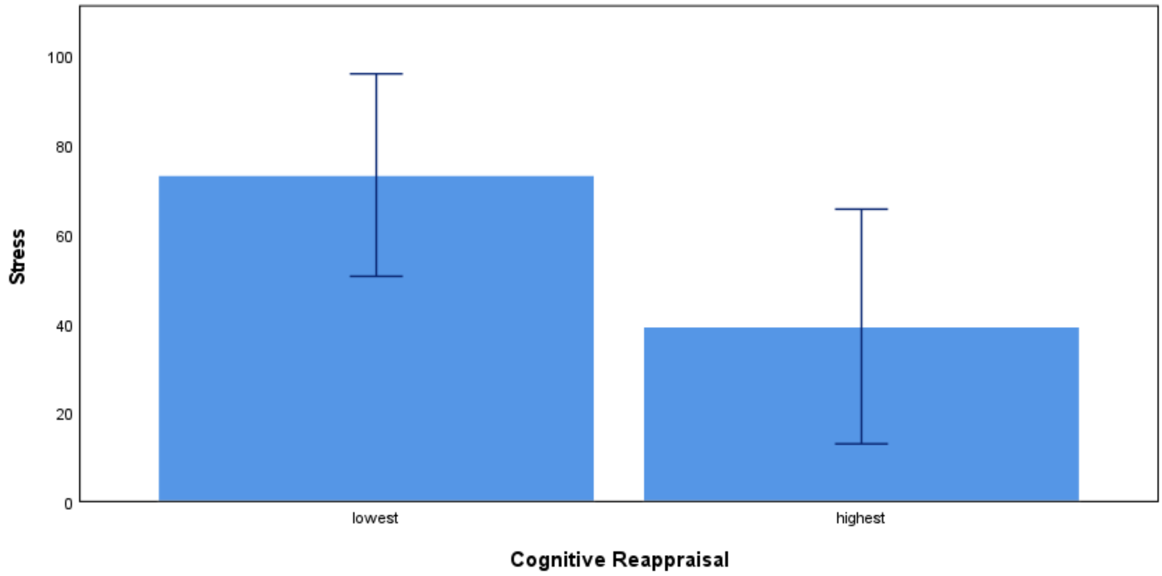

Figure 12

Stress in Cognitive Reappraisal

Note. Bars represent mean values of stress in the group of participants with lowest scores vs. the group of participants with highest scores on Cognitive Reappraisal. Error bars indicate Standard Error (*ER*) of the mean values.

Cognitive Reappraisal and Skin Barrier Recovery. The group of participants with the lowest scores on Cognitive Reappraisal ($N = 4$) reported a mean SBR value of 18.59 ($SD = 5.85$) with values between 13.79 and 26.41. The group of participants with the highest scores on Cognitive Reappraisal ($N = 3$) reported a mean SBR value of 32.92 ($SD = 11.73$) with values between 21.84 and 45.20. The bar chart in Figure 13 illustrates this comparison graphically and indicates that the group of participants with higher adaptive emotion regulation showed faster wound healing as measured in SBR ($M = 32.92$) than the group of participants with lower adaptive emotion regulation ($M = 18.59$). However, it must be noted once again that the confidence intervals overlap.

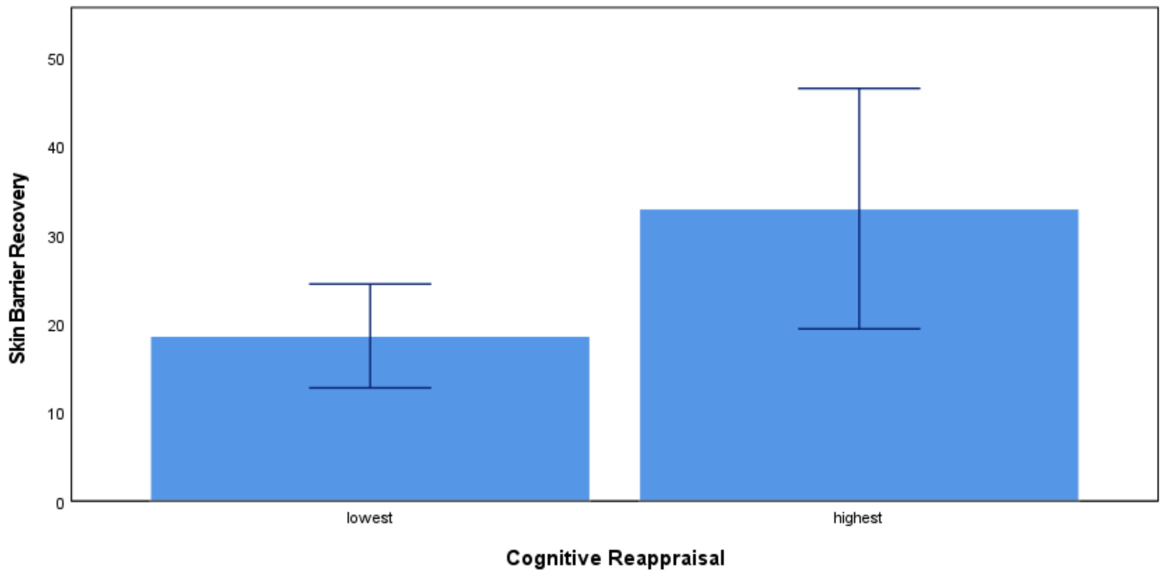

Figure 13

Skin Barrier Recovery in Cognitive Reappraisal

Note. Bars represent mean values of SBR in the group of participants with lowest scores vs. the group of participants with highest scores on Cognitive Reappraisal. Error bars indicate Standard Error (*ER*) of the mean values.

Summary of Results

With regard to maladaptive emotion regulation, the regression analysis between maladaptive emotion regulation and stress was not significant. In a second regression analysis, a significant positive correlation was found between maladaptive emotion regulation and SBR, indicating that maladaptive emotion regulation is associated with faster wound healing. The extreme group analysis further supports these findings, as it seems that those participants with higher scores on the Expressive Suppression scale showed faster SBR than those with lower scores.

While the regression analysis found no evidence of a significant correlation between maladaptive emotion regulation and stress, the extreme group analysis indicated that those participants with higher scores on the Expressive Suppression scale experienced less stress than those with lower scores. Since the extreme group analyses are only descriptive and graphical representations of the data and no inferential statistical calculations were carried out, they have no statistical significance and should therefore be treated with caution. Nevertheless, it can be observed that these analyses point to the conclusion that a higher level of maladaptive emotion regulation is associated with lower stress and faster SBR. With regard to SBR, this is also supported by the corresponding regression analysis. The regression analysis for stress could not detect any significant correlation here, but it is worth noting that the regression coefficient was negative (although not even close to significant) and thus at least the direction of the correlation in the regression analysis is the same as that of the extreme group analysis.

With regard to adaptive emotion regulation, it can be stated that the observed negative correlation between adaptive emotion regulation and stress did not reach significance. However, the corresponding values were very close to the set significance threshold and thus a trend can at least be assumed, which indicates that adaptive emotion regulation is associated with decreased stress. In the regression analysis of adaptive emotion regulation and SBR, the observed positive correlation did not reach significance either. Once again, however, the values were very close to the predefined threshold of significance. Hence, a trend can be assumed here too, suggesting that adaptive emotion regulation is associated with faster SBR.

Both of these trends are also apparent in the extreme group analysis. In the comparison of the participants with the lowest and highest scores, it is recognisable that those participants with a higher score on the Cognitive Reappraisal scale report less stress than those participants with a lower score. Furthermore, the group of participants with higher Cognitive Reappraisal scores appeared to show faster SBR than the group with lower scores. Accordingly, it can be stated that with regard to adaptive emotion regulation, the results of the regression analysis are in line with those of the extreme group analysis. Once again, however, since the extreme group analysis has no statistical power and the results of the regression analysis are not significant effects, but merely recognisable trends, these results should also be treated with caution and can only be seen as a slight tendency of the data in one direction.

Since the extreme group analysis suggests that high levels of both emotion regulation strategies are associated with reduced stress and faster SBR, a correlation analysis was conducted to rule out the possibility that the two strategies correlate with each other and that the two effects are one and the same. As shown in the scatterplot in Figure 14, there was no significant correlation between Cognitive Reappraisal and Expressive Suppression ($r = -.15$, $p = .60$) and thus it can be assumed that the reported results are two individual effects of the respective emotion regulation strategies.

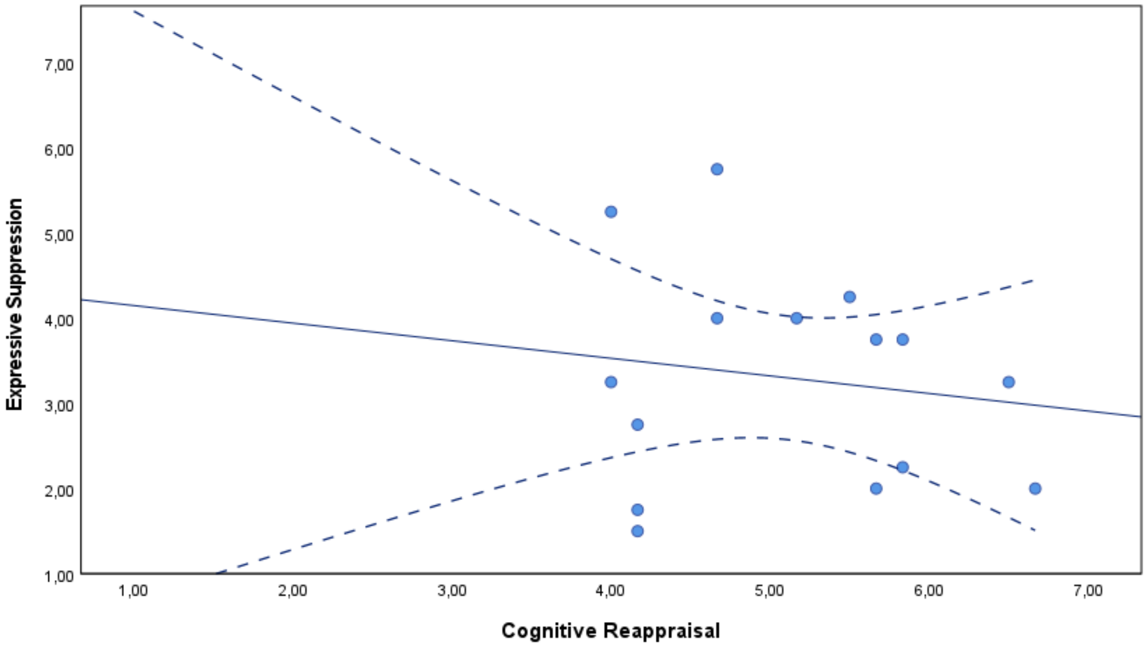

Figure 14

Correlation between Expressive Suppression and Cognitive Reappraisal

Note. The graph above represents the correlation between Cognitive Reappraisal and Expressive Suppression. Each dot conveys one participant's mean score on Cognitive Reappraisal and on Expressive Suppression. The solid line represents the correlation of the mean scores and the dashed edges represent its 95% CI.

Discussion

The present thesis explored the influence of emotion regulation on stress experience and wound healing. Based on prior research, it was assumed that, while adaptive emotion regulation would lead to positive outcomes, such as reduced stress and faster wound healing, maladaptive emotion regulation would lead to negative outcomes, such as increased stress and slower wound healing. Indeed, a trend, albeit not a significant correlation, was found in our data indicating that adaptive emotion regulation is associated with reduced stress and faster SBR. Although regression analyses on both stress and SBR did not reach significance, obtained p-values were close to set alpha levels of $p>.05$ and thus, at least a trend can be assumed. These trends are also apparent for both SBR and stress in the extreme group analyses. Since the extreme group analyses have no statistical power and the results of the regression analyses are not significant effects, but merely recognisable trends, these results should be treated with caution and can only be seen as a slight tendency of the data in one direction.

Contrary to expectations, the results of the data analysis suggest that both emotion regulation strategies may have a positive effect on stress and wound healing. At first, this seems surprising, as maladaptive emotion regulation has been negatively associated with well-being (Gross & John, 2003) and physical health (Rey et al., 2020), whereas adaptive emotion regulation has been positively related to well-being (Gross & John, 2003), a better handling of stressful situations (Radtke et al., 2020), reduced stress and depressive symptoms (Boyle et al., 2017), and positive affect has been linked to faster wound healing (Robles et al., 2009). These findings of previous literature would suggest maladaptive emotion regulation to be much less effective, if not counterproductive, in reducing perceived stress and promoting wound healing. However, the data revealed a significant effect linking maladaptive emotion regulation to faster skin barrier recovery. Furthermore, although no significant correlation between maladaptive emotion regulation and stress was found in the regression analysis, a extreme group analysis of the extreme groups suggests that maladaptive emotion regulation is associated with decreased stress.

The results raise the question of whether Expressive Suppression can actually be called a maladaptive emotion regulation strategy if it leads to positive effects such as reduced stress and improved wound healing. However, it must be borne in mind that the two outcome variables surveyed are only very short-term consequences. It is quite conceivable that maladaptive emotion regulation leads to short-term positive consequences, in the sense that suppressed emotions reduce stress levels in the short term in response to stressful stimuli. This, however, says little about how a trait emotion regulation strategy such as this will affect a person's chronic stress level in the longer term. Of the cited studies reporting a negative association of Expressive Suppression with well-being, many of the related variables could be seen as long-term consequences: Depressive symptoms, life satisfaction, self-esteem, optimism, and satisfaction with relationships (Gross & John, 2003). This would support the assumption that Expressive Suppression may have beneficial short-term effects, but significant long-term costs. However, Gross & John (2003) also report some immediate negative consequences of suppression: A decrease of experienced positive emotions, as well as cognitive and social costs, more specifically memory impairment for social information. Thus, suppression seems to have several adverse consequences also in the short term.

Possible Long-Term Effects of Maladaptive Emotion Regulation

While the data suggests that maladaptive emotion regulation might have a beneficial effect on skin barrier recovery after 55 minutes, it is possible that there are adverse health outcomes in the long run, i.e., negative effects on the immune system. It is only plausible that individuals who experience more negative emotions, as do people who primarily suppress their emotions (Gross & John, 2003), also experience increased distress, which is known to negatively influence the immune system (Bear et al., 2007; Lovallo, 2015; Segerstrom & Miller, 2004; Sapolsky, 1994).

In addition, individuals who lead stressful lives show more self-destructive behaviour and habits that again have a negative impact on their health. Segerstrom & Miller (2004) state that many adverse effects on the immune system are not direct results of stress but may have their origin in associated harmful behaviour like increased sleep disturbances, cigarette smoking, and physical activity, resulting in psychomotor retardation and increased body mass. People who have been exposed to increased stress in their lives and reported adverse childhood experiences have been suggested to show reduced stress reactivity, altered cognition and maladaptive emotion regulation in the long term (Lovallo, 2015). This has been associated with modified frontolimbic functions, which are related to executive functioning and decision making (Hanson et al., 2013). Individuals with such early life adversities are more likely to act impulsively and take risks, which in turn is related to reduced health and increased risk of addiction (Tarter et al., 2013).

Furthermore, addiction and increased risk taking are strongly related to reduced emotion regulation ability (Babaei et al., 2021). Substance abuse is often a form of self-medication and an attempt to cope with the symptoms of a mental disorder. Patients with posttraumatic stress disorder have also been found to be at increased risk of alcohol and substance abuse, associated with reduced cortisol secretion (Sinha, 2001). Thus, these adverse outcomes of increased stress and maladaptive emotion regulation are not necessarily connected to short time stress responses. In fact, participants reporting childhood abuse showed decreased cortisol responses to psychological stress induced in a laboratory (Carpenter et al., 2007) and participants reporting substance abuse showed diminished stress reactivity (Sorocco et al., 2006), cortisol (Gerra et al., 2003) and heart rate responses (Pankin et al., 2002) to stressful stimuli.

Another indication that maladaptive emotion regulation may have desirable short-term but harmful long-term consequences comes from the research field of interpersonal emotion regulation and attachment styles. Interpersonal emotion regulation describes the different strategies of how individuals use other people to regulate their own emotions (Gökdağ, 2021). In a study on the relationship between interpersonal emotion regulation, attachment style, and social support, attachment anxiety was related to regulation strategies like soothing, but also to factors such as depression, anxiety, and stress symptoms (Gökdağ, 2021). Robles et al. (2013) found that among women, greater attachment anxiety was linked to faster skin barrier recovery. This indicates that certain ways of dealing with emotions, whether self-referential or interpersonal, might be successful in the short term and even associated with faster wound healing, although they are associated with many negative health consequences and increased stress in the long term.

Observed Trends in Adaptive Emotion Regulation

The data suggests a trend, albeit not a significant effect, for the association between adaptive emotion regulation and stress, linking Cognitive Reappraisal to decreased stress. This is supported by the results of the extreme group analysis as those participants with a higher score on the Cognitive Reappraisal scale reported less subjective stress than those participants with a lower score. These findings are in line with prior literature that links Cognitive Reappraisal to improved stress coping and psychological well-being (Gross & John, 2003). Beneficial effects on stress have been associated with increased emotion regulation ability (Boyle et al., 2017). A more developed emotion regulation ability has been linked to an increase in children's ability to regulate stress (Stansbury & Gunnar, 1994) and to better coping with emotional stress in adults (Eisenberg et al., 1993). Stress and emotion regulation both seem to be regulated by HPA activity (Stansbury & Gunnar, 1994; Zimmermann & Stansbury, 2004) and are connected to similar neural structures (see Wang & Saudino, 2011 for a review).

The data further suggests a trend in the association between adaptive emotion regulation and SBR, linking Cognitive Reappraisal to faster wound healing. This trend is also supported by the results of the extreme group analysis as those participants with a higher score on the

Cognitive Reappraisal scale showed faster SBR than those with lower scores. These findings are in line with prior literature that links Cognitive Reappraisal to the decreased experience of negative emotions (Gross & John, 2003), which in turn are associated with multiple adverse health outcomes (Lovallo, 2015; Rey et al., 2020; Segerstrom & Miller, 2004). Cognitive Reappraisal further has been linked to an increased experience of positive emotions (Gross & John, 2003), which have been associated with improved health outcomes (Kiecolt-Glaser et al., 2002) in general and faster wound healing specifically (Robles et al., 2009). Cognitive Reappraisal has also been linked to an increased expression of emotions, both positive and negative, which in turn have been associated with lowered cortisol and epinephrine levels (Berk et al., 1989) as well as with improved psychological health and immune function (Keller et al., 1994). Cognitive Reappraisal has also been suggested to be linked to a better social life with closer and more meaningful relationships (Gross & John, 2003), while social closeness has been linked to decreased stress and faster skin barrier recovery (Robinson et al., 2017).

Although these observed trends in the data should be taken with caution as they are not significant effects, they are promising results that are in line with prior literature and should be further investigated in the future with a larger sample to see if there are indeed significant effects between adaptive emotion regulation on the one hand and decreased stress and faster wound healing on the other hand. If this link does exist, Cognitive Reappraisal could be a promising strategy to reduce subjective stress and adverse health outcomes. The enhancement of adaptive emotion regulation strategies could lead to significant symptom relief and improved well-being for a variety of somatic and psychological complaints.

Limitations

There are several limitations to report in respect to the particular times in which data was collected, as well as numerous critical points about the study conceptualization, data assessment and the present approach to the specific topic of this thesis.

Limited Generalisability due to the COVID –19 Pandemic

First of all, it must be emphasised that most of the data collection took place during the COVID –19 pandemic and thus during a time that deviated in many ways from the usual “normality” as people knew it before. This period was, and still is, characterised by massive uncertainty in many areas of life, such as financial instability, increased risk of unemployment, reduced social contacts and increased stress due to political turmoil and restricted rights (Haas, 2020; Salari et al., 2020).

The cohort also consisted largely of students who are arguably among those groups within society whose needs have not been adequately addressed by the government and its policies during this time of crisis. All teaching during this period took place online, which is not only incomparable to face-to-face teaching in terms of quality, but often presents a multiple burden for the students due to the constant accessibility, the insufficient separation between their workplace and home, and possible difficulties in respect to internet connection. Moreover, the positive effects of studying, especially social contacts, which are crucial for people at this age, have been largely eliminated, leading to increased feelings of loneliness.

During the pandemic there was an increase in mental health problems (Brooks et al., 2020; Haas, 2020; Salari et al., 2020; Vindegaard & Benros, 2020). Both Germany and the United States of America reported an increased prevalence of depression and anxiety disorders, a higher proportion of severe depressive symptoms, and a link between higher regional incidence of infection and more mental health problems, as well as stress symptoms (Salari et al., 2020; Skoda et al., 2021; Twenge & Joiner, 2020). There was an aggravation in existing complaints and increased psychosomatic complaints (Salari et al., 2020). One in three children showed mental health problems, with socially disadvantaged children being particularly badly affected (Arzberger, 2021). Many people, especially students, experienced an increased need for self-optimisation, perfectionism and pressure to succeed in many areas of life during the pandemic (Skoda et al., 2021), which is associated with a wide range of health problems (Rau & Buyken, 2015).

Jointly, these factors suggest that stress experience as well as somatic and mental health are strongly influenced by the impact of the pandemic. Thus, as the general stress level might already be elevated by prevailing circumstances, confrontation with an acute stressor in the experiment could entail a diminished stress response. On the other hand, it could also lead to a stronger stress reaction, especially since the TSST creates stress in a social setting and the ability to deal with social interactions is certainly influenced by the government restrictions taken during the pandemic, since the majority of people were forced to live a very secluded life and there was hardly any interaction with strangers. How exactly all these factors affect various aspects of people's lives and health remains to be seen, but it is safe to assume that they have a significant effect on the experience of stress and the somatic and mental state of health. Thus, the results found are difficult to generalize, as subjective stress experience, emotion regulation and health aspects that affect wound healing are all likely to be influenced by the specific conditions of the COVID –19 pandemic.

It should also be noted that additional safety precautions had to be taken due to the pandemic. These were not constant over the whole time of the data collection, as they were adapted to the governmental measures and restrictions in force. Precautions such as wearing a mask and having to provide a negative COVID –19 test result may have influences that were not accounted for. Especially the social aspect, which as described above plays a relevant role in the stress experience and particularly also in wound healing, may have been affected. On the one hand, this could be the case due to the wearing of a facial mask by both the participant herself as well as the experimenter and TEWL operator, which could have led to reduced social closeness, but also to reduced facial expression of emotions, as well as insecurity with regard to reading the emotions of the person opposite. On the other hand, the examination situation may also represent an unfamiliar or potentially stressful situation, even more so since most of the individuals at this time lived in relative isolation and were less accustomed to contact with different people, especially with strangers.

Study-Specific Limitations

A major point of criticism applies to the assessment of the TEWL values. Out of only 15 participants, six had to be excluded from the SBR calculations, either because the TEWL values increased after impairment or because the values of the individual measurement sites were too far apart from one another to calculate a representative average value. This raises the question of how reliable this measurement is and what factors might be responsible for so many invalid values. One speculation is that the participants increasingly touched the marked area after the tape stripping procedure, which could have led to further irritation of the skin. Although participants were instructed not to touch it, it was evident in the field that many had difficulty doing so and unconsciously kept touching the site. The fact that the individual measurement sites revealed such different TEWL values could be due to the way in which the tape stripping procedure was carried out. Although the strips are applied and pulled down alternately from above and below, it is plausible that these movements are not equivalent to each other. It is therefore quite conceivable that greater or smaller irritation is provoked at the one site than at the other sites.

Another point worth mentioning is that when emotion regulation strategies are assessed using the ERQ, only two strategies are considered, namely Expressive Suppression and Cognitive Reappraisal. However, there are numerous other types of emotion regulation, such as Situation Detection, Situation Modification, or Attentional Deployment (Gross & John, 2003). Moreover, the assumption that Expressive Suppression is generally regarded as maladaptive emotion regulation and that Cognitive Reappraisal is generally regarded as adaptive emotion regulation should be treated with caution. It can be assumed that the suppression of emotions was and still is evolutionarily meaningful in certain situations and may therefore occasionally be more adaptive than the reappraisal of emotions (Gross & John, 2003).

However, the overarching study does not focus specifically on emotion regulation strategies, but examines the effect of music listening on stress experience and wound healing. Emotion regulation is only one of many additional variables collected here, but it does not play a central role in the study itself, which explains why only a questionnaire with a limited number of assessed strategies was used here.

Thesis-Specific Limitations

SBR after 55 minutes was used as a reference for wound healing in this thesis. This was chosen based on previous research which has shown that the greatest increase in of SBR occurs within the first hour after disruption (Robinson et al., 2017). It could have been a valuable exploration to also look at the SBR at later time points in this context, especially with regard to the discussed possibility that maladaptive emotion regulation can have short-term beneficial effects but long-term detrimental consequences. The same also applies with regard to the variable of subjective stress. The focus was placed on the third assessment of perceived stress, in respect to baseline. This survey was conducted directly after the TSST, under the assumption that the highest stress values and thus the greatest deviation from baseline can be observed at this time. Again, it is quite conceivable that, for example, maladaptive emotion regulation leads to a short-term reduction in the experience of stress by suppressing the expression of emotions, but that this perceived stress may decrease less quickly in the longer term than with adaptive emotion regulation. However, these are only speculations that would have to be considered in further conceptualisations and with a larger sample in order to make more informative statements.

Another interesting point that was not dealt with in the context of this thesis, is the possible link between music and emotion regulation. Since the overarching study examines the influence of music on stress and SBR, it would have been worthwhile to take a closer look at the connection between listening to music and emotion regulation and possibly uncover some correlation here. However, this would have gone beyond the scope of this work, so that the variable of listening to music was not thoroughly taken into account. At this point, it should only be noted that in the extreme group analysis, those subjects who were assigned to the music condition as well as those assigned to the control condition (silence, audio book) were both represented in all groups. The distribution was fairly balanced here, so that in the respective groups approximately half were assigned to the music condition and the other half to the control condition. Merely in the group of low-scoring test persons regarding Expressive Suppression was there a slight imbalance with $N = 3$ subjects who listened to music and only $N = 1$ subject who was in the control condition. However, due to the small sample size, this is not very meaningful and most likely part of a random distribution. Accordingly, based on the results presented here, we cannot truly indicate a connection between emotion regulation and music listening.

Nevertheless, the literature on this topic certainly suggests that this is an interesting field worthwhile exploring. Music has been shown to activate the body in an emotion-specific way and to evoke affective processes (Panksepp & Bernatzky, 2002). Furthermore, music is used to regulate mood and arousal, as well as psychological health and well-being (Chanda & Levitin, 2013). In relation to somatic processes, music has been shown to influence heart rate variability, which in turn is related to emotion regulation (Ellis & Thayer, 2010). Specifically, individuals with poorer emotion regulation ability also appear to have reduced heart rate variability. Therefore, it would be interesting to further explore this possible relationship between emotion regulation and music with a larger sample size.

It should also be mentioned that some of the prerequisites for the regression analysis were only barely fulfilled. In addition, a extreme group analysis was carried out, which is an interesting way of examining the data and illustrating possible trends, but it must be emphasised once again that this has no statistical relevance and can only be regarded as an impetus for future research.

Limitations regarding Generalisability & Validity

Several points further limit the generalisability and validity of the reported results. Regarding validity, the small sample size has to be reported. Only 15 participants were included in the calculations, and in respect to SBR only 9 participants could be taken into account. This leads to a reduced power, which in turn makes the correct detection of an effect more difficult and less likely. Furthermore, this bears the risk of random findings and false positives. Therefore the results can only be seen as a "snapshot in time", as a brief insight into a specific group, which, however, cannot be generalised to the general population at this point in time.

Regarding the results' generalisability, the homogeneity of the test persons' play an important role. Almost all of the participants had an A-level degree, were attending university, and reported Austrian or German nationality. The participants were all young and healthy, within an age range of 20–32 years and of normal weight, with no significant somatic or mental illnesses. Furthermore, only female participants were tested and thus it is only possible to make a statement about persons who are biologically clearly assigned to the female sex. This is especially relevant as it has been shown that men and women differ in their use of emotion regulation strategies, with men showing more suppression than women (Gross & John, 2003).

Another limiting factor relates to the ERQ scores. Compared to the norm values reported by Abler & Kessler (2009), participants from our cohort showed on average much higher Cognitive Reappraisal scores. As shown in Figure 4, none of the 15 participants scored below average, but 7 participants scored above average. The distribution of Expressive Suppression scores, however, is comparable to the reported norm values. As shown in Figure 5, two of the 15 participants scored below and two above average, while the remaining 11 participants scored in the normal range. As the manuscript of the revised version of the ERQ used by König et al. (2018) is still in preparation, the norm values of Abler & Kessler (2009) were used here for reference. However, these refer to an older version of the ERQ and its items. In the revised version by König et al. (2018), three of the Cognitive Reappraisal items were revised in terms of wording of the statements, so it is quite possible that this influenced the distribution of scores and could explain why our cohort scored so high on this scale. Due to the above-average level of Cognitive Reappraisal in our cohort, a certain bias in the data can be assumed as persons with lower levels of Cognitive Reappraisal are underrepresented. Therefore, no conclusive statements can be made about how low levels of this regulatory strategy affect the subjective experience of stress and wound healing. It is quite conceivable that different results would be obtained in the general population, in which lower levels of Cognitive Reappraisal are also represented.

Conclusion

In times such as these, when the stress level of many people is chronically elevated and people are confronted with stressors of various kinds every day, it is of particular relevance to investigate more closely what the consequences of these stress experiences are and how the consequences can be alleviated. Emotion regulation ability seems to be a promising resource here, which might alleviate the stress experience itself, but also the associated health consequences. The data collected suggests that high levels of both the emotion regulation strategy of suppression and the strategy of reappraisal led to lower perceived stress and faster wound healing. These results are particularly surprising in relation to suppression, as this strategy has in the past been associated with negative consequences for well-being and health. However, it is worth noting that it is certainly plausible that suppressing emotions can result in short-term positive effects, but long-term negative consequences.

Even though the trend found in the data should be taken with extreme caution due to multiple limitations, especially due to the small sample size, these are nevertheless interesting results that should be further explored. If emotion regulation ability is indeed an important resource for reducing stress and enhancing overall health, the question is whether it can be actively trained. Since individuals have different tendencies in terms of which emotion regulation strategies they display primarily, these tendencies may be so deeply embedded in the personality that it may be difficult to change them. In fact, however, the literature suggests that people can actively work on emotion regulation and subsequently also enjoy the positive health consequences. For example, emotion regulation ability has been shown to be enhanced in children after a yoga intervention (Rashedi et al., 2021). In recent decades, the dynamic nature of emotion regulation processes has been studied in more detail and it is suggested that a particularly important factor of adaptive emotion regulation is that one can adaptively apply different strategies and adjust them to the situation at hand (Bettis et al., 2021). These dynamics of emotion regulation can be trained in different ways. One promising field here are digital technologies such as social media, technology including physical activity, acoustic and visual data, smart-home technology, virtual reality, wearable and smartphone technology, and ecological momentary assessment (Bettis et al., 2021). This area is worth exploring further to examine how these technologies and other methods might help in training emotion regulation ability in order to subsequently have positive effects on stress experience and overall health.

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Tables

Table 1

Descriptive Statistics of Sample I

Sociodemographic Characteristics	*M*	*SD*	Range
Age	25.73	3.73	20–32
BMI	21.47	0.41	19.15–24.49
Persons in household	2.2	0.86	1–4

Table 2

Descriptive Statistics of Sample II

Sociodemographic Characteristics	Total amount (n)	Estimate (%)
Nationality		
Austria	10	66.7%
Germany	4	26.7%
Chile	1	6.7%
Sex		
Female	15	100%
Relationship Status		
In partnership	7	46.7%
Single	7	46.7%
Other	1	6.7%
Employment		
Full-time	2	13.3%
At least part-time	4	26.7%
Less than part-time	1	6.7%
In training	6	40.0%
Unemployed	2	13.3%
Housing		
Alone	2	13.3%
Shared apartment	9	60.0%
With partner	3	20.0%
Other	1	6.7%
School Education		
A-levels	14	93.3%
Secondary school	1	6.7%
Vocational Training		
University	14	93.3%
Apprenticeship	1	6.7%

Table 3

Descriptive Statistics of Main Variables

Variables	*M*	*SE*	*SD*	Variance	Range	N
ES	3.30	0.32	1.27	1.61	1.50–5.75	15
CR	5.11	0.24	0.91	0.84	4.00–6.67	15
Stress_1	11.33	2.77	10.72	114.95	0–35	15
Stress_3	59.13	6.11	23.68	560.70	31–99	15
Stress	47.80	7.55	29.27	854.17	14–98	15
SBR	26.78	3.48	10.45	109.11	13.79–45.20	9

Note. ES = Expressive Suppression; CR = Cognitive Reappraisal ; Stress_1 = VAS stress at baseline ; Stress_3 = VAS stress at third measurement; Stress = delta stress variable of third VAS measurement in respect to baseline; SBR = skin barrier recovery

Figures

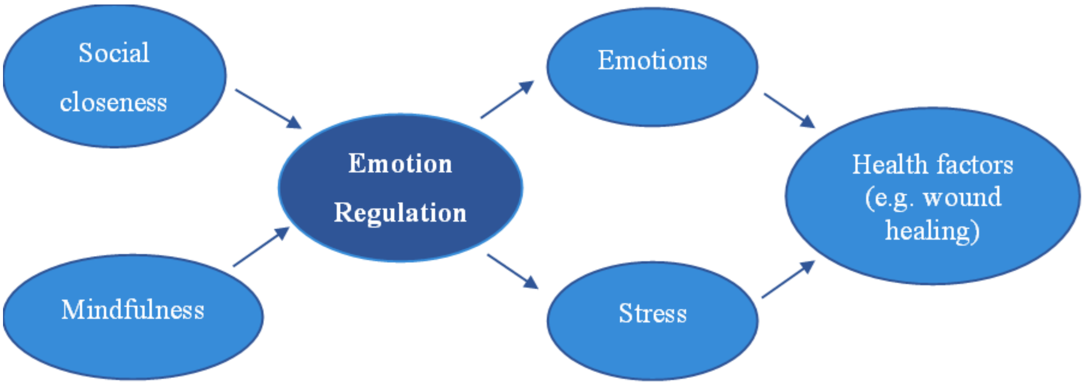

Figure 1

Simplified model of the influencing factors and consequences of emotion regulation

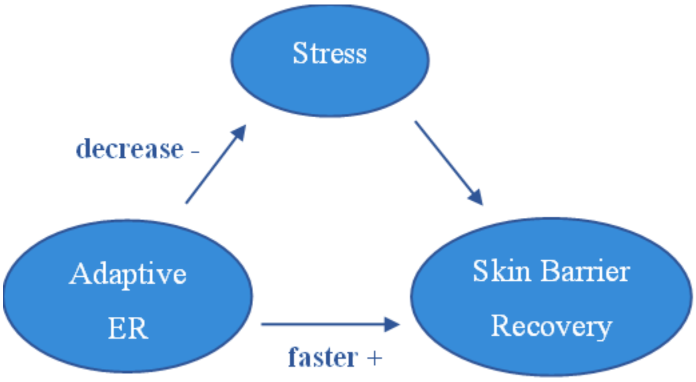

Figure 2

Expected link between adaptive emotion regulation, stress and skin barrier recovery

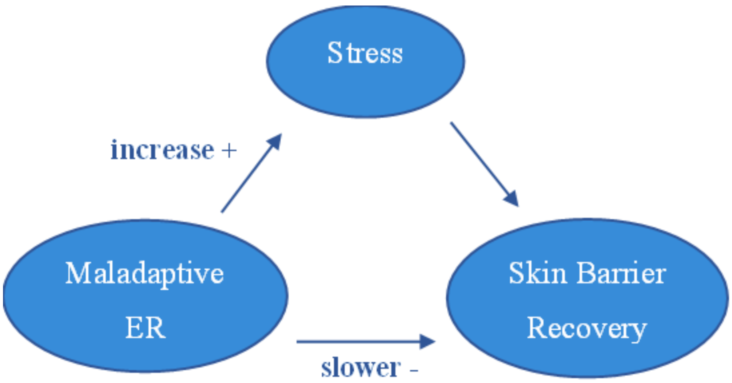

Figure 3

Expected link between adaptive emotion regulation, stress and skin barrier recovery

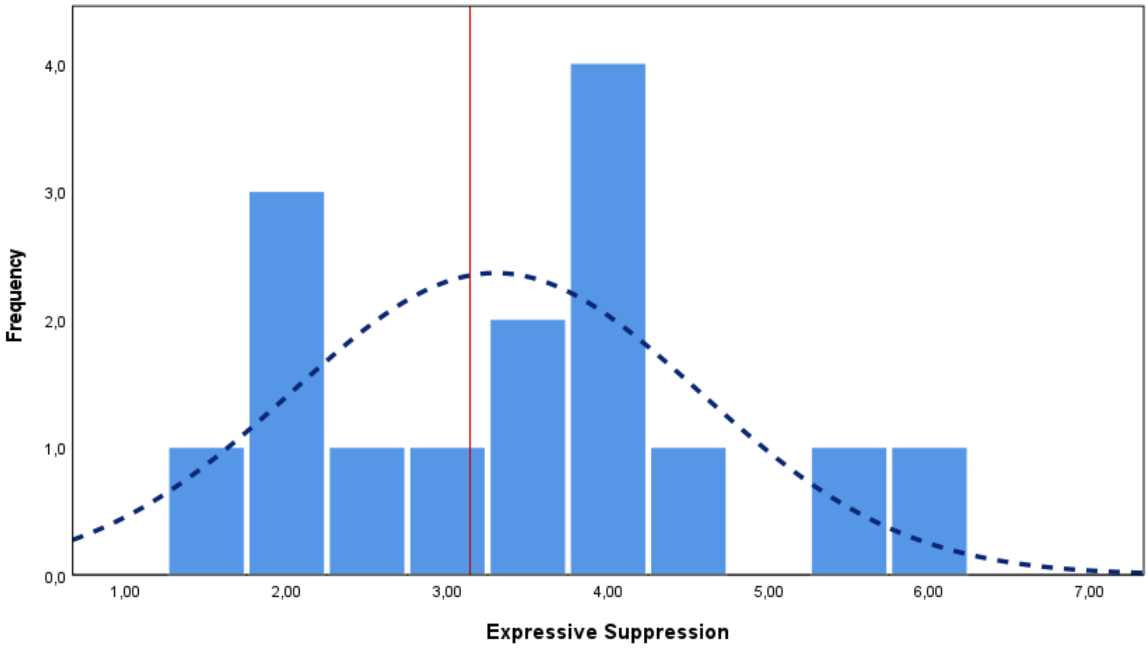

Figure 4

Distribution of Expressive Suppression Scores

Note. Blue bars indicate the distribution of scores on the Expressive Suppression scale. The dashed blue line illustrates the normal distribution curve based on the sample's scores. The vertical red line marks the mean value of the norm group as a reference point.

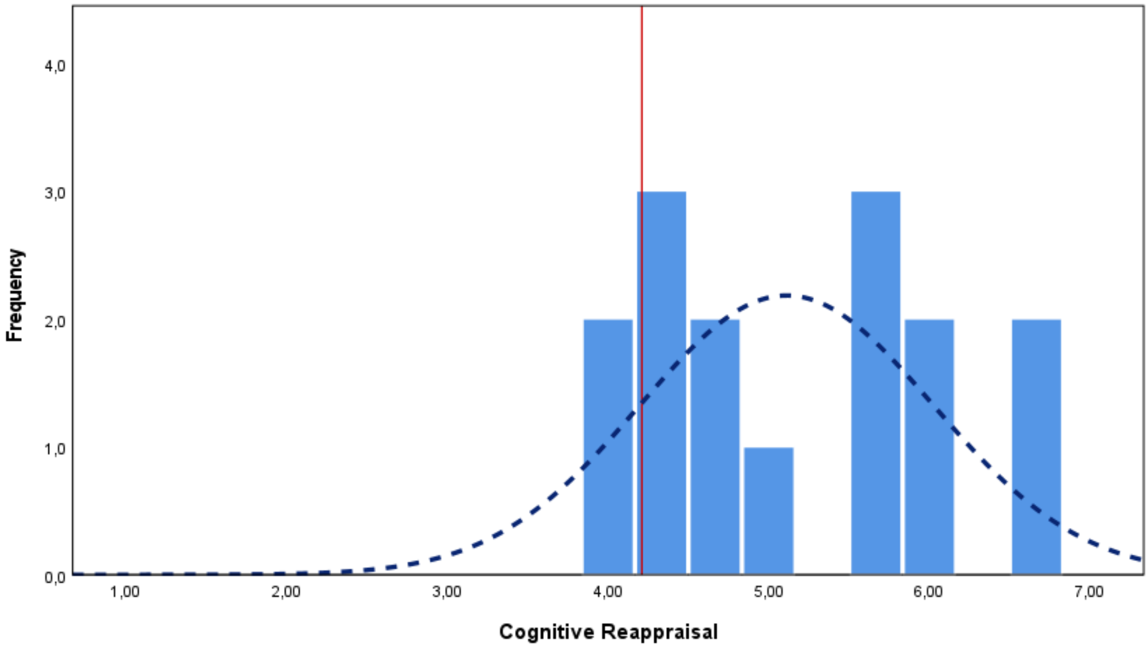

Figure 5

Distribution of Cognitive Reappraisal Scores

Note. Blue bars indicate the distribution of scores on the Cognitive Reappraisal scale. The dashed blue line illustrates the normal distribution curve based on the sample's scores. The vertical red line marks the mean value of the norm group as a reference point.

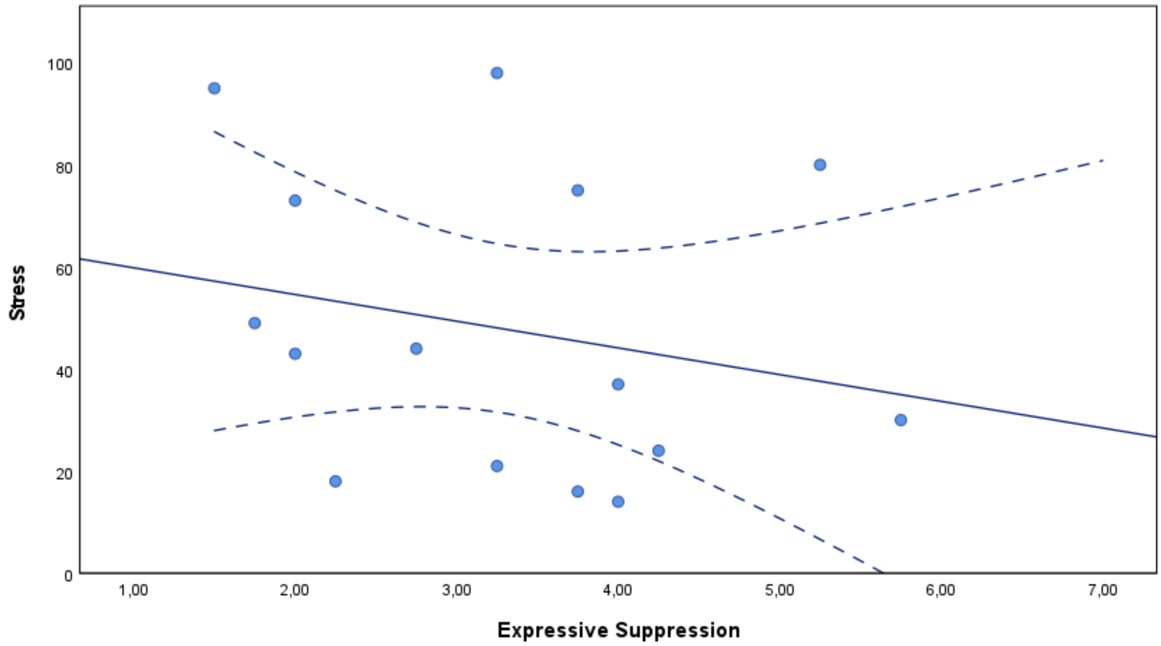

Figure 6

Correlation between Expressive Suppression and Stress

Note. The graph above represents the correlation between Expressive Suppression and stress. Each dot conveys one participant's score on Expressive Suppression and stress. The solid line represents the correlation of the mean values and the dashed edges represent its 95% CI.

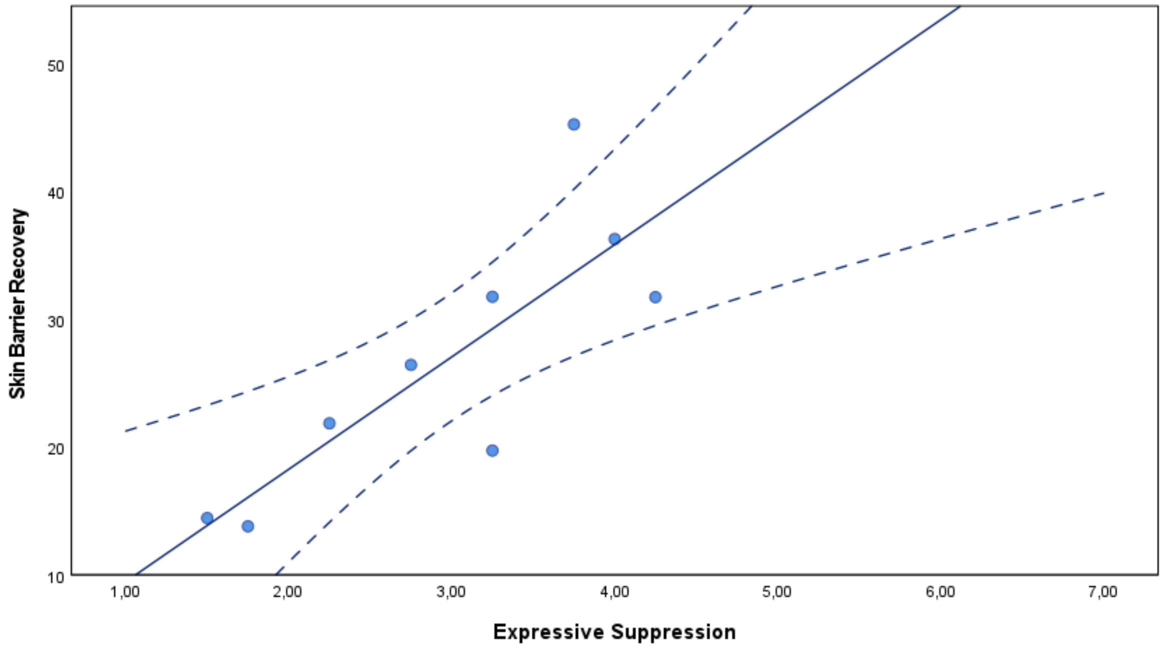

Figure 7

Correlation between Expressive Suppression and Skin Barrier Recovery

Note. The graph above represents the correlation between Expressive Suppression and SBR. Each dot conveys one participant's score on Expressive Suppression and SBR. The solid line represents the correlation of the mean values and the dashed edges represent its 95% CI.

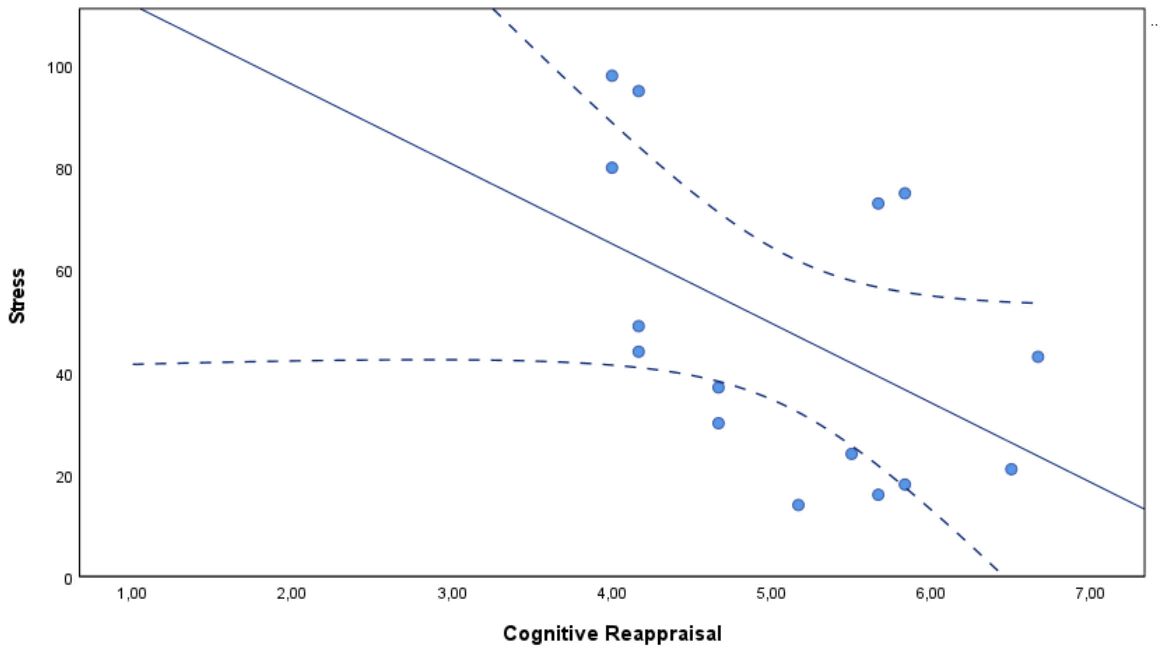

Figure 8

Correlation between Cognitive Reappraisal and Stress

Note. The graph above represents the correlation between Cognitive Reappraisal and stress. Each dot conveys one participant's score on Cognitive Reappraisal and stress. The solid line represents the correlation of the mean values and the dashed edges represent its 95% CI.

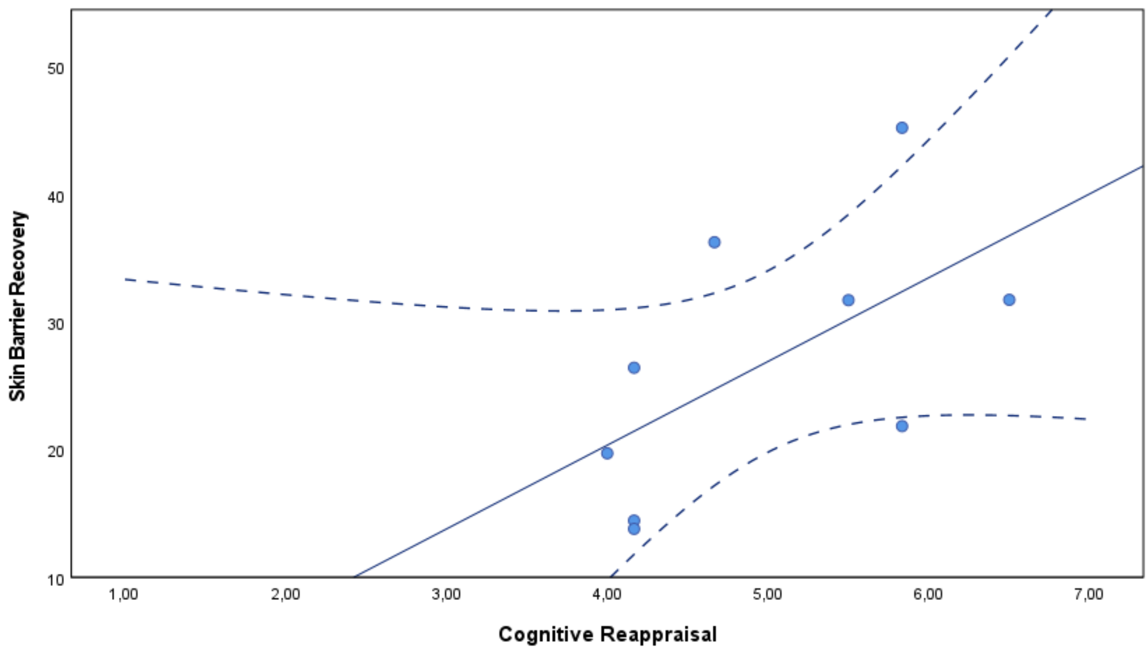

Figure 9

Correlation between Cognitive Reappraisal and Skin Barrier Recovery

Note. The graph above represents the correlation between Cognitive Reappraisal and SBR. Each dot conveys one participant's score on Cognitive Reappraisal and SBR. The solid line represents the correlation of the mean values and the dashed edges represent its 95% CI.

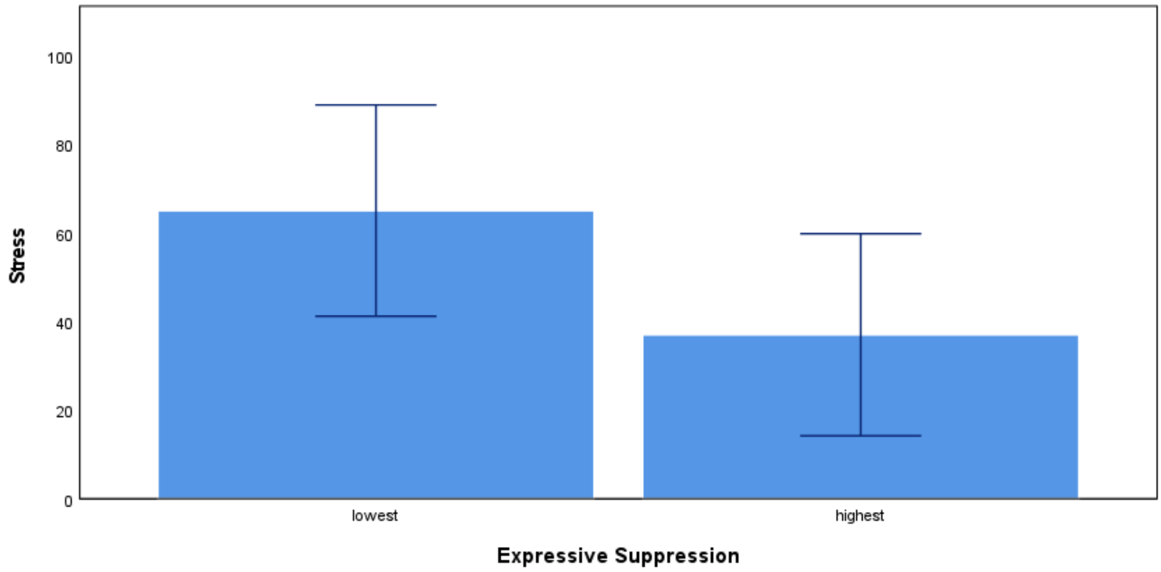

Figure 10

Stress in Expressive Suppression

Note. Bars represent mean values of Stress in the group of participants with lowest scores vs. the group of participants with highest scores on Expressive Suppression. Error bars indicate Standard Error (*ER*) of the mean values.

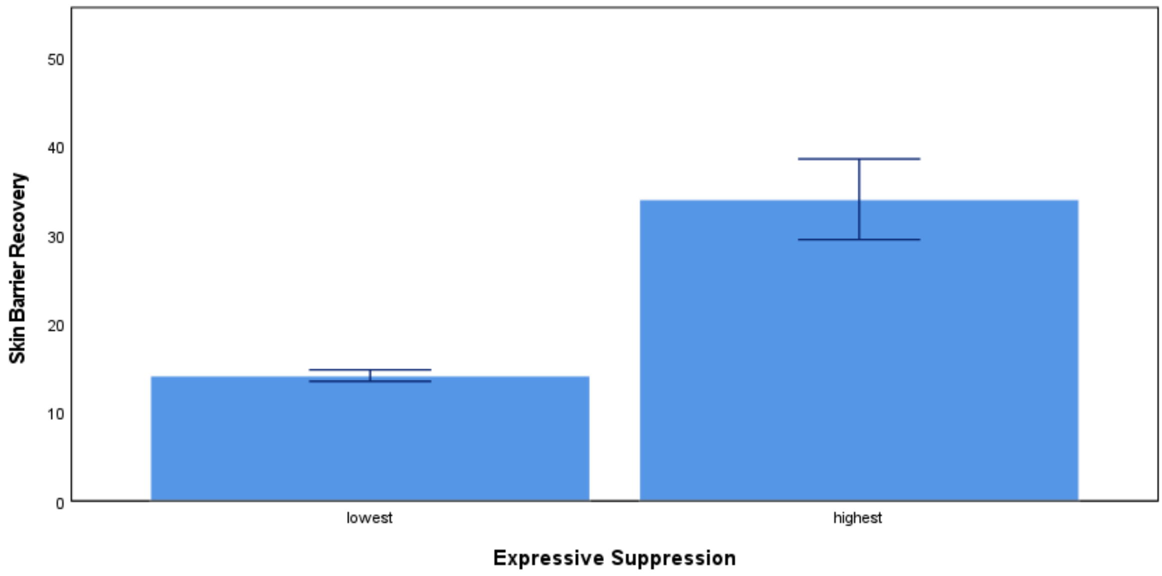

Figure 11

Skin Barrier Recovery in Expressive Suppression

Note. Bars represent mean values of SBR in the group of participants with lowest scores vs. the group of participants with highest scores on Expressive Suppression. Error bars indicate Standard Error (*ER*) of the mean values.

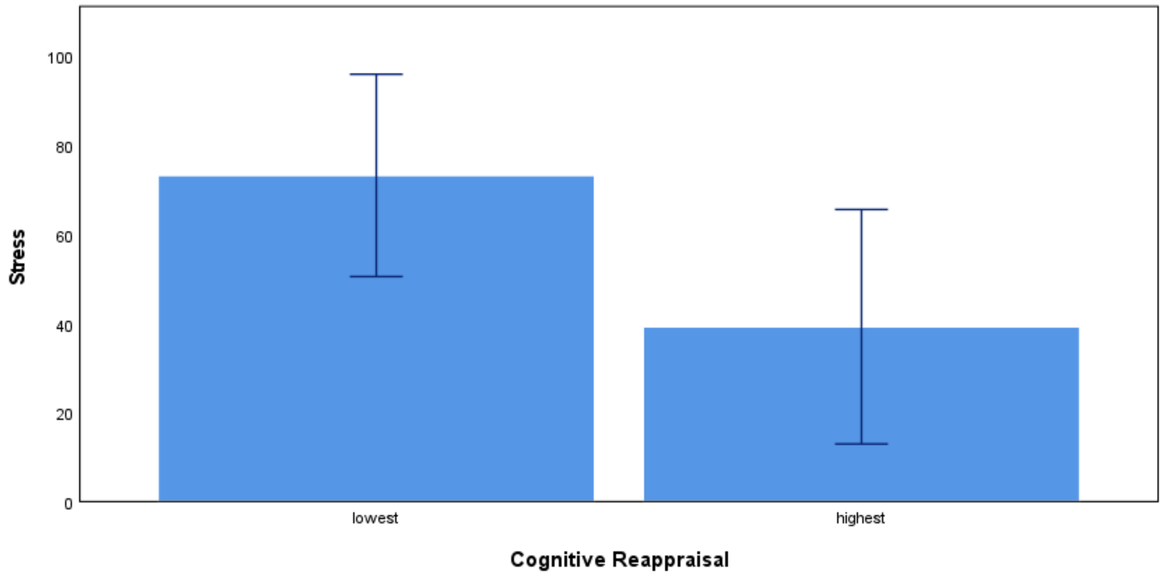

Figure 12

Stress in Cognitive Reappraisal

Note. Bars represent mean values of stress in the group of participants with lowest scores vs. the group of participants with highest scores on Cognitive Reappraisal. Error bars indicate Standard Error (*ER*) of the mean values.

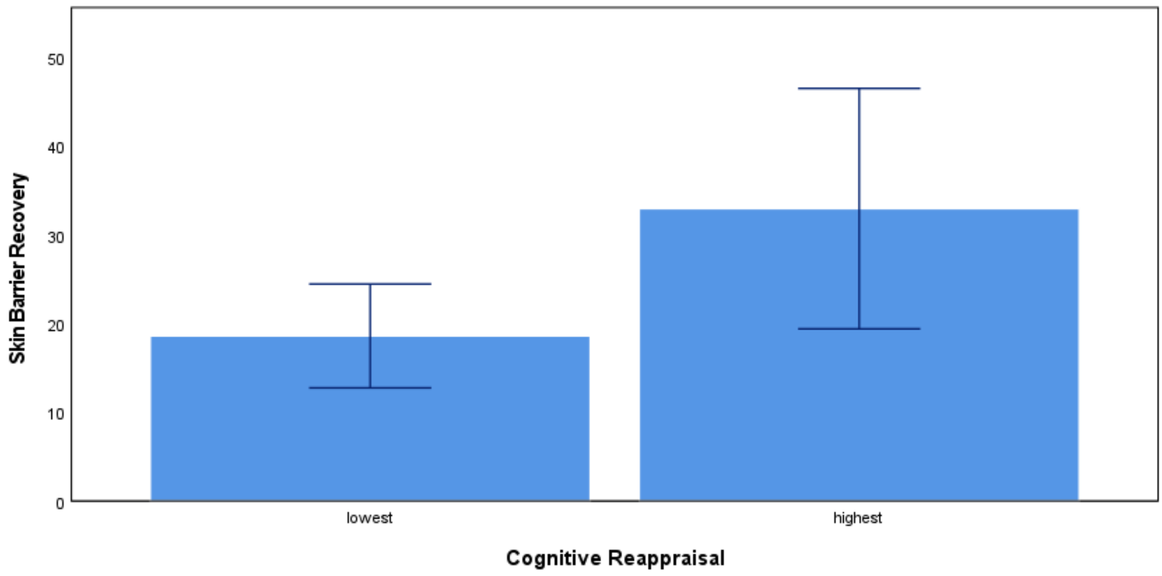

Figure 13

Skin Barrier Recovery in Cognitive Reappraisal

Note. Bars represent mean values of SBR in the group of participants with lowest scores vs. the group of participants with highest scores on Cognitive Reappraisal. Error bars indicate Standard Error (*ER*) of the mean values.

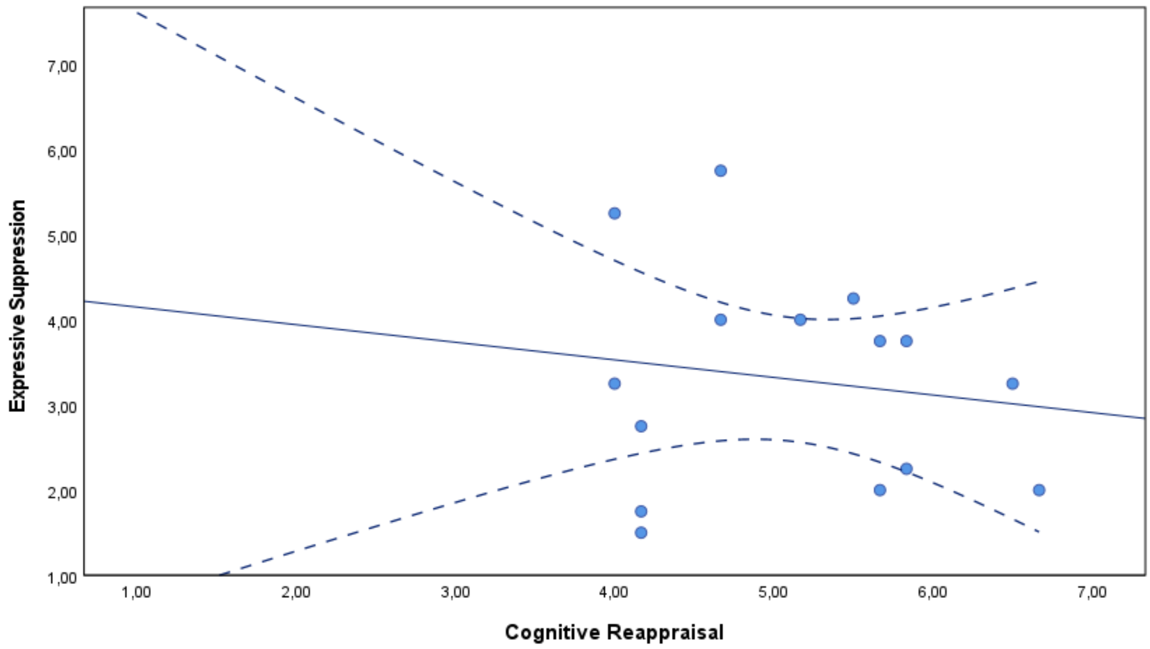

Figure 14

Correlation between Expressive Suppression and Cognitive Reappraisal

Note. The graph above represents the correlation between Cognitive Reappraisal and Expressive Suppression. Each dot conveys one participant's mean score on Cognitive Reappraisal and on Expressive Suppression. The solid line represents the correlation of the mean scores and the dashed edges represent its 95% CI.

Abbreviations

ACTH – adrenocorticotropic hormone

BMI – Body Mass Index

CR – Cognitive Reappraisal

CRH – corticotropin-releasing hormone

ECG – electrocardiography

EDA – electrodermal activity

ERQ – Emotion Regulation Questionnaire

ES – Expressive Suppression

GH – growth hormone

HPA – hypothalamic pituitary-adrenal

LH – luteinizing hormone

MDBF – Mehrdimensionaler Befindlichkeitsfragebogen

PMS – premenstrual syndrome

SBR – Skin barrier recovery

TEWL – Transepidermal water loss

TSST – Trier Social Stress Task

TTPAS – The Types of Positive Affect Scale

VAS – Visual Analogue Scale

WHO – World Health Organization

*ZPRED – standardised predicted values

* ZRESID – standardised predicted residuals

Appendix

Abstract English

The following master thesis examines the relationship between emotion regulation, stress and wound healing. With regard to emotion regulation, two different strategies were investigated: Cognitive Reappraisal, which is considered an adaptive emotion regulation strategy, and Expressive Suppression, which is considered a maladaptive emotion regulation strategy. Cognitive Reappraisal was hypothesized to lead to faster wound healing, mediated by lower stress. Expressive Suppression was hypothesized to be related to slower wound healing, mediated by increased stress. Participants (N = 15) completed the Emotion Regulation Questionnaire (ERQ) prior to study begin, subjective stress was surveyed several times over the course of the study, and wound healing was assessed via transepidermal water loss, allowing skin barrier recovery to be calculated. The regression analyses for Cognitive Reappraisal showed a trend in the expected direction of reduced stress and faster wound healing, which did not reach significance. For Expressive Suppression, there was no significant association with stress and a significant association with faster wound healing, which was contrary to expectation. The mediation analyses were not performed since the preconditions were not met, as the corresponding regression analyses were not significant. A extreme group analysis suggests that high scores on both emotion regulation strategies are associated with lower stress and faster wound healing. Although these results should be treated with caution due to the small sample size, they suggest that maladaptive emotion regulation can potentially lead to beneficial short-term outcomes, even if it is associated with negative long-term consequences for well-being and health.

Keywords: Emotion regulation, wound healing, skin barrier recovery, stress, reappraisal, suppression, transepidermal water loss, tape stripping

Abstract German

In der folgenden Masterarbeit wird der Zusammenhang zwischen Emotionsregulation, Stress und Wundheilung untersucht. In Bezug auf die Emotionsregulation wurden zwei unterschiedliche Strategien untersucht: Cognitive Reappraisal (Neubewertung) welches als adaptive Emotionsregulationsstrategie gilt, und Expressive Suppression (Unterdrückung), welches als maladaptive Emotionsregulationsstrategie gilt. Es wurde angenommen, dass Cognitive Reappraisal zu einer schnelleren Wundheilung führt, mediiert durch geringeren Stress. Bei Expressive Suppression wurde angenommen, dass diese mit einer langsameren Wundheilung verbunden ist, mediiert durch erhöhten Stress. Die Teilnehmer ($N = 15$) füllten vor Studienbeginn den Emotion Regulation Questionnaire (ERQ) aus, der subjektive Stress wurde im Verlauf der Studie mehrmals erhoben, und die Wundheilung wurde über den transepidermalen Wasserverlust (TEWL) beurteilt, wodurch die Erholung der Hautbarriere berechnet werden konnte. Die Regressionsanalysen für Cognitive Reappraisal zeigten einen Trend in der erwarteten Richtung, in Bezug auf reduzierten Stress und schnellerer Wundheilung, der jedoch keine Signifikanz erreichte. Für Expressive Suppression gab es keine signifikante Assoziation mit Stress und eine signifikante Assoziation mit schnellerer Wundheilung, was entgegen der Erwartungen war. Die Mediationsanalysen wurden nicht durchgeführt, da die Voraussetzungen nicht erfüllt waren nachdem die entsprechenden Regressionsanalysen nicht signifikant waren. Eine Einzelfallanalyse legt nahe, dass hohe Punktzahlen bei beiden Emotionsregulationsstrategien mit geringerem Stress und schnellerer Wundheilung assoziiert sind. Obwohl diese Ergebnisse aufgrund der geringen Stichprobengröße mit besonderer Vorsicht zu behandeln sind, deuten sie darauf hin, dass eine maladaptive Emotionsregulation potenziell zu kurzfristigen positiven Auswirkungen führen kann, auch wenn sie langfristig gesehen mit negativen Konsequenzen für Wohlbefinden und Gesundheit verbunden ist.

Schlagwörter: Emotionsregulation, Wundheilung, Wiederherstellung der Hautbarriere, Stress, Neubewertung, Unterdrückung, transepidermaler Wasserverlust, Klebestreifenabrissverfahren