universität wien

MASTERARBEIT / MASTER'S THESIS

Titel der Masterarbeit / Title of the Master's Thesis

The Effect of Acute Stress on Emotion Recognition: An Experimental Study

verfasst von / submitted by

Leonie Esser

angestrebter akademischer Grad / in partial fulfilment of the requirements for the degree of

Master of Science (MSc)

Wien, 2023 / Vienna 2023

Studienkennzahl lt. Studienblatt / degree programme code as it appears on the student record sheet:	UA 066 840
Studienrichtung lt. Studienblatt / degree programme as it appears on the student record sheet:	Masterstudium Psychologie UG2002
Betreut von / Supervisor:	Univ. - Prof. Mag. Dr. Claus Lamm
Mitbetreut von / Co-Supervisor:	Dr. Jonas Nitschke

Abstract

How does acute stress influence the way humans recognize emotions? Acute stress is an everyday phenomenon and emotion recognition is a crucial ability for successful communication and building meaningful connections. As social animals, humans are dependent on each other but are often confronted with stressful situations. This relationship has already been investigated in previous research, however, results were inconclusive. The aim of this thesis was to investigate the interaction between acute stress and emotion recognition further by means of a stressor, which combines physical and psychosocial properties, and varying the displayed emotions in intensity to add ecological validity. In all, $N = 84$ participants underwent the Maastricht Acute Stress Test (MAST) or a control counterpart, followed by the facial emotion recognition task. In response to the MAST, participants showed higher emotion recognition performance, regardless of the intensity in which the emotion was displayed. These present results suggest that acute stress facilitates the processing of social stimuli, such as facial expressions.

Keywords: Emotion Recognition; Social Attention; Cognitive Empathy; Acute Stress; Maastricht Acute Stress Test (MAST); Saliency

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Introduction

Living in groups is beneficial for survival (De Waal & Preston, 2017), and social relationships have been shown to be protective against adversity (Nitschke et al., 2021). Through cooperation and collaboration, individuals gain access to resources like food and knowledge, but also physical and emotional support (Agashe et al., 2021; Boyd & Richerson, 2009). Social bonds have always played a crucial role not only in survival but also in overall well-being (Hawkley & Capitanio, 2015). In modern-day societies, the forms of interaction and interpersonal dependencies have evolved and grown more complex (Buskell et al., 2019; Turchin et al., 2022). Also, Globalization and technological advancements have resulted in a greater interconnectedness of humans, which has simultaneously made their relationships more abstract (Sanrı & Goodwin, 2014). Previous research has shown that the modern lifestyle can generate high levels of stress (De Vogli, 2004). Acute stress is an adaptive biological mechanism, which is crucial for survival (De Kloet et al., 2005; Joëls & Baram, 2009). However, whilst the framework of our social existence has evidently changed (e.g., globalization, digitalization), our biological foundation has stayed the same. Humans have unaltered biological prerequisites for coping with and adapting to stress, as well as interpreting social stimuli (Adolphs, 2002). In this challenging and complex world, we still remain dependent on others (Ozbay et al., 2007). Nowadays when faced with adversity, others provide resources such as psychological help to cope with these situations wherefore mutual understanding of behavior and emotional states is necessary. This delicate interplay could be influenced by stress, which in turn, could affect social interactions as well as the interpretation of social information. Thus, it is crucial to investigate whether stress impacts the way humans understand other people's emotions.

Emotion Recognition

Empathy is, according to de Waal and Preston (2017), the ability of "sharing […] emotions between individuals and the adopting of another's point of view" (p. 498). It is an umbrella term for a highly complex construct, often differentiated into two segments: affective/emotional and cognitive empathy (De Waal & Preston, 2017; Nitschke & Bartz, 2023; Singer, 2006). Emotional or affective empathy (e.g., emotion contagion) refers to the ability to directly experience the emotions of others (Singer & Lamm, 2009), whilst cognitive empathy (e.g., emotion recognition, mentalizing) is defined as the capacity to comprehend the emotional state of others and seek into their perspective (Frith & Frith, 2007). However, both of these concepts often overlap and cannot be completely separated (Singer, 2006). Social cognition is attributed to cognitive empathy. It refers to the mental processes that allow us to understand others and to perceive and interpret social cues, which is crucial for our social togetherness (Frith, 2008). Emotion recognition is an essential part of social cognition and thus cognitive empathy. It encompasses the distinction and interpretation of emotions or of emotional states displayed by others (Gillioz et al., 2023). The identification of the emotional state is not through feeling the emotion oneself but through the cognitive process of identifying and interpreting the emotion (Mitchell, 2009; Nitschke & Bartz, 2023). Emotion recognition is a multifaceted process, which involves several distinct modalities. These facets can include (i) facial expression (Chen, 2014; Holland et al., 2021), (ii) the tone of voice (De Gelder & Vroomen, 2000), (iii) body movement (Meeren et al., 2005), and (iv) gestures (Zhao et al., 2021). Additionally, contextual information such as situational cues (Barrett et al., 2011; Yamashita et al., 2016) contribute to the integrated emotion recognition process.

The importance of understanding others' emotions is underlined by the fact, that humans immediately after being born, display the intrinsic ability to detect and recognize emotional cues from their caregivers (Heck et al., 2018). This ability further develops and improves with age (Broeren et al., 2011), as the individual simultaneously becomes engrained in social groups and takes part in social interactions with growing complexities (Lienard, 2016). As inherently social animals (Nitschke & Bartz, 2023), humans are dependent on their social surroundings. Thus, emotion recognition has developed as an evolutionarily advantageous ability contributing to the survival of the individual (De Waal & Preston, 2017). It has an adaptive value for social functioning by contributing to communication, cooperation, the establishment of trust, reproduction and ultimately the ability to form social connections through successful interactions (Israelashvili & Fischer, 2022; LeDoux, 2012; Spoor & Kelly, 2004). Additionally, emotion recognition has proven as evolutionary beneficial due to the fact that individuals learn about the environment by recognizing emotions in others (Olsson et al., 2020). Those who are quicker in recognizing the emotions of fear or anger, for example, would be faster to identify potential threats and activate an adaptive response in order to survive unharmed. Today, in most circumstances, humans do not have to worry about basic physical survival in our day-to-day interactions. Nevertheless, the accurate recognition of emotions in others still informs about possible unpleasantness or conflict (Ferretti & Papaleo, 2018; Olsson et al., 2020). If, however, this process is impaired, individuals not only lose this contextually relevant source of information but also become less adept at empathy and emotional connection (Beals et al., 2022; Rump et al., 2009).

From a neuroscientific perspective, emotion recognition is a top-down process, which involves the activation of several higher-level brain areas. During emotion recognition tasks, key regions include the prefrontal cortex (PFC; Nakajima et al., 2022), the amygdala (Pera-Guardiola et al., 2016), the anterior cingulate cortex (ACC; Jehna et al., 2011), as well as other limbic regions (Menting-Henry et al., 2022). According to Ekman (1992), six primary, innate, emotions can be identified. Happiness, sadness, fear, anger, disgust, and surprise are universal expressions exceeding cultural reach (Ekman, 1992, 2005; Pietschnig et al., 2016). They are characterized by unmistakable facial expressions and physiological correlates (Posner et al., 2005). This further reinforces the notion that emotion recognition is a part of basic human functioning. An impairment of this ability is often a symptom of psychological or neurological disorders such as autism spectrum disorders (Fridenson-Hayo et al., 2016), schizophrenia (Gao et al., 2021; Seo et al., 2020), anxiety disorders (Demenescu et al., 2010), major depression (Dalili et al., 2015), and diverse forms of dementia (Ho et al., 2020; Strijkert et al., 2022), which also underlines the necessity to conduct research into the process underlying emotion recognition.

In summary, emotion recognition can be seen as a fundamental human ability, which is crucial in navigating through and interacting within a complex social environment (De Waal & Preston, 2017; Nitschke & Bartz, 2023). Correctly identifying and responding to emotions contributes to the development of social connections, but is also essential when identifying potential dangers (Olsson et al., 2020). It is therefore pertinent to investigate how emotion recognition changes under adverse circumstances, such as stress. Several studies, which investigate the relationship between stress and emotion recognition have already been conducted (e.g., Daudelin-Peltier et al., 2017; Domes & Zimmer, 2019; Graumann et al., 2021; for a review see: Nitschke & Bartz, 2023). However, this research has yielded no definite conclusions. Before diving into the previous research findings in more detail, it is necessary to first understand the concept of stress and its effect on the human organism.

The Human Stress Response

The human stress response is a complex and dynamic interplay of various physiological, psychological and behavioral factors, that recruits the help of several pathways (De Kloet et al., 2005; Godoy et al., 2018; Hermans et al., 2014). Confronted with an actual or perceived threat or challenge the organism strives to restore homeostasis and adapt to the newly demanding environment. Homeostasis can be defined as the dynamic equilibrium that encompasses constant balancing and adjustment of physiological variables within an organism (Billman, 2020; Cannon, 1939). This self-regulating process seeks to maintain the organism's internal stability. Stress or a so-called stressor respectively endangers homeostasis and necessitates an adaptation to the novel situation (Bali & Jaggi, 2015).

On a psychological level, stress elicits a series of cognitive and emotional changes (Bali & Jaggi, 2015). First, the stressor must be recognized as a potential danger or threat, which, second, the individual believes it is not immediately adequately equipped to deal with. Lazarus and Folkman (1984) formulated the transactional model of stress which states that it's the disparity between primary appraisal of the situation (perceiving the harmful situation) and the secondary appraisal (coping resources at disposal), which elicits stress. The stress response generates psychological reactions, which include heightened anxiety and fear (Juruena et al., 2020; Shin & Liberzon, 2010), depression (Park et al., 2019; Yang et al., 2015) or aggression and irritability (De Dreu et al., 2022; Kim & Haller, 2007).

On a biological level, the initiation of the stress response starts with a translation of incoming sensory information into an evaluation of the stressor followed by a situational appraisal. The PFC and limbic brain regions such as the amygdala and the hippocampus (De Kloet et al., 2005; Dickerson & Kemeny, 2004; McEwen et al., 2015) play an essential role in this sensory translation process and simultaneously enable the triggering of the intertwined neurochemical and endocrinological stress response pathways. These enlist the assistance of several modulator types including neuropeptides, neurotransmitters and steroid hormones to generate a calibrated response (Joëls & Baram, 2009). The stress response pathways constitute two main branches: a faster-acting branch (seconds to minutes) and a slower-acting branch (minutes to hours), which work together (Hermans et al., 2014). The activation of the sympathetic nervous system (SNS), including the sympathetic adreno-medullary (SAM) axis, triggers the release of several monoamines immediately after stress exposure (Joëls & Baram, 2009). This prepares the body to either fight or flee from danger: the so-called fight-or-flight response (Cannon, 1915). The SNS activation involves the release of adrenaline from the adrenal medulla (Hermans et al., 2014), the release of noradrenaline primarily from the locus coeruleus (LC) (Valentino & Van Bockstaele, 2008) and the release of serotonin (Maier & Watkins, 2005) as well as dopamine (Baik, 2020). The SAM-axis activation results in immediate physiological adjustments such as cardiovascular changes (e.g., hypertension and tachycardia), an increase in sweat production and muscle tension (Graff et al., 2019; Tank & Wong, 2014). In response to these neurochemical changes the slower-acting pathway, the hypothalamic-pituitary-adrenal (HPA) axis, is stimulated. After this, the paraventricular nucleus of the hypothalamus releases the neuropeptides vasopressin (AVP) and corticotropin-releasing hormone (CRH). Both peptides interact to stimulate the secretion of adrenocorticotropin hormone (ACTH) from the pituitary gland, which then causes the adrenal cortex to discharge the vital steroid hormone cortisol (Herman et al., 2016; Russell & Lightman, 2019; Smith & Vale, 2006). Cortisol is essential for energy mobilization resulting in metabolic adjustments (Dickerson & Kemeny, 2004). Additionally, the steroid hormone regulates the immune function and has anti-inflammatory properties. All of these physiological modifications help the organism adapt to and cope with stress (Bali & Jaggi, 2015). The cortisol secretion is terminated via a negative feedback loop, evoked by the modulation of gene transcription through specialized receptors (De Kloet et al., 2005; Hermans et al., 2014). Finally, the accumulation of cortisol is discontinued, and recovery can be facilitated by the activation of the parasympathetic nervous system (PNS). If, however, this delicate mechanism is impaired (Gjerstad et al., 2018) or the stress exposure is inadequate, excessive, or prolonged (De Kloet et al., 2005), the generally adaptive response turns maladaptive resulting in a continued activation of the stress pathways and allostatic load (Dickerson & Kemeny, 2004; Guidi et al., 2021). The stress response is influenced not only by the duration of the stressor but also by the stressor type (Joëls & Baram, 2009). On the one hand, physical stressors including physical pain, injury or illness activate distinct neuronal populations such as the brainstem as well as the hypothalamus (Ulrich-Lai & Herman, 2009) and primarily activate the SNS (Kogler et al., 2015). On the other hand, psychological or psychosocial stressors, which include social evaluation components, embarrassment, or threats to social identity recruit the help of PFC, amygdala or hippocampus (Joëls & Baram, 2009; McEwen, 2007) and usually facilitate HPA axis activation (Kogler et al., 2015). Both, however, are intertwined systems, that work in coordination and stressors often combine both properties. In addition to the stressor type, the individual's characteristics such as age (Lupien et al., 2005), gender (Kudielka et al., 2009) and genetic factors (Joëls & Baram, 2009) contribute to stress response complexity and diverse activation patterns.

These alterations in neural functioning also enable consequences on a behavioral level (Hermans et al., 2014). In order to adequately cope with potentially threatening situations, the capability of redirecting attention towards the stressor is crucial. Thus, in stressful situations, the individual becomes more vigilant, alert, and focused (De Kloet et al., 2005; Hermans et al., 2014). This state of hypervigilance includes a shift in processing towards more salient aspects of the environment and is accompanied by a more mechanical, habitual, and inflexible processing mode (Nitschke & Bartz, 2023; Wirz et al., 2018), which includes impaired core executive functions such as cognitive flexibility (Alexander et al., 2007) and a diminished working memory capacity (Devilbiss et al., 2012; Shields et al., 2016). Additionally, stress decreases the ability in task switching (Steinhauser et al., 2007). The transference towards a more effortless and straightforward processing could prove helpful when confronted with a stressor. This could be due to an increase in the availability of cognitive and computational resources for perceiving environmental stimuli and subsequently handling these quickly (Hermans et al., 2014; Schwabe & Wolf, 2009). However, it might impair the capability to manage more cognitively demanding tasks (Bogdanov et al., 2021).

Accordingly, stress alters functioning on a biological, psychological and behavioral level. It can be suggested, that during stressful encounters the biologically induced survival mode acts on psychological appraisal, as well as behavioral engagement. This circumstance makes it particularly intriguing to study emotion recognition under acute stress as it not only unveils how the multifaceted effects of stress impact our emotion recognition abilities but might also provide insights into the underlying mechanisms of emotion recognition.

Relationship between Emotion Recognition and Acute Stress

When encountering another individual, the identification of emotions in others is a process that seems to happen automatically. For example, standing at a highly frequented place (e.g., an airport) shifting one's attention towards people, one cannot help to start making inferences about the emotional state of people waiting and leaving. Although emotion recognition can be a more elaborate process, which relies on the interplay of several brain regions (Adolphs, 2002), it is an innate part of basic human cognition (De Waal & Preston, 2017). Acute stress severely alters physiological and psychological functioning causing a modification of information processing (De Kloet et al., 2005; Joëls & Baram, 2009). Brain regions that are often associated with social cognition such as the Amygdala, the ACC or prefrontal regions (Fusar-Poli et al., 2009), are also affected during the acute stress response (Dedovic et al., 2009; Ulrich-Lai & Herman, 2009). This neuroanatomical overlap has become, additional to the psychological reasonings, an area of research into the relationship between acute stress and emotion recognition.

In one of the first studies investigating how stress affects emotion recognition, Smeets et al. (2009) subjected participants (n = 64) to the Trier Social Stress Test (TSST) (Kirschbaum et al., 1993). The TSST is a psychosocial stressor, which integrates free speech with mental arithmetic elements in front of an audience. Afterwards, the Reading the Mind in the Eyes Task (RMET) (Baron-Cohen et al., 2001) was conducted, which uses information inferred just from the eyes to deduct underlying mental states. Results showed no differences between stressed individuals and their control group counterparts in RMET performance. Thus, stress did not alter the recognition performance of mental states. Another study focused on how psychosocial stress affects empathy, more specifically cognitive and affective empathy (Wolf et al., 2015). The participants *(n* = 99) underwent the TSST and subsequently the Multifaceted Empathy Test (MET) (Dziobek et al., 2008), which portrays people in emotional states during day-to-day scenes where emotional states have to be assessed. No group differences were reported in cognitive empathy, indicating that stress did not influence the ability to understand and interpret affective states. However, higher emotional empathy was reported for stressed participants, capturing a higher emotional response to an emotional state in this condition. Further studies took a more nuanced approach when looking at emotion recognition and investigated if stress alters the ability to differentiate between different emotions. Deckers et al. (2015) investigated whether female participants (*n* = 69) were able to better identify the six basic emotions before vs. after the TSST. The researchers also included one group of patients diagnosed with borderline personality disorder (BPD) and one group diagnosed with cluster C personality disorder. To assess emotion recognition video clips were created that depicted faces displaying emotions (anger, fear, disgust, surprise, sadness, and happiness) each morphed with neutral faces at different intensities (from neutral to emotional). Higher emotion intensity, therefore, reflects a lower task difficulty, because the respective affect is displayed with greater vigor. There were no group differences reported in accuracy, however, in all groups, there was a higher emotion recognition performance after stress induction. Nevertheless, owning to the task design the reported effect could also be attributed to learning effects. To prevent this Graumann et al. (2021), who also looked at group differences involving BPD patients and healthy controls (*n* = 89), presented the emotion recognition task only once immediately after stress exposure. The emotions displayed were anger and sadness each at low and high intensity. In this study, there was no significant difference reported in emotion recognition performance for the stressed vs. non-stressed group and for the BPD group vs. the healthy controls. High-intensity emotions were better recognized in all groups. These findings would imply that stress does not affect emotion recognition accuracy at least for negative emotions (anger and sadness).

Studies including only healthy subjects were also conducted looking specifically at facial emotion recognition. Using all six basic emotions morphed together pairwise Daudelin-Peltier et al. (2017) induced stress with the TSST for groups (TSST-G) in healthy men (*n* = 42) and revealed an increased threshold for the emotion disgust in the stress condition and a decreased threshold for the emotion surprise. When stressed the individuals were less able to identify disgust, whereas the recognition of surprise in this condition was facilitated. The authors concluded that both emotions may have distinct opposing properties resulting from evolutionary adaptations. Implementing a virtual-reality version of the TSST in another study (Domes & Zimmer, 2019) the male participants (n = 43) viewed happy and angry facial expressions in three intensity (low, medium, high) increments. Following the stress condition, the participants showed an increased recognition performance for both emotions independent of the displayed intensity. Stress additionally led to reduced response times for angry emotions, meaning there was higher attention towards negatively valenced emotions. Von Dawans et al. (2020) subjected the male participants (n = 54) to the TSST-G subsequently also using happy and angry faces for the emotion recognition task displayed in low, middle, and high intensity. In this study, however, the stressed group (compared to the control condition) exhibited a higher sensitivity to happy faces at low intensity and diminished sensitivity to angry faces at high intensity, indicating a higher recognition rate for positive facial stimuli under acute psychosocial stress.

As becomes evident there are mixed findings concerning the relationship between emotion recognition and acute stress. This could be attributable to methodological heterogeneities. A high number of studies are only looking at men and others additionally include clinical populations; thus, the sample constitution differs. Secondly, there are differences in stimulus and task attributes concerning how emotion recognition is operationalized, and how life-like emotions are depicted also relating to variations of emotion intensity (Bek et al., 2022). Emotion recognition is a multifaceted process, which may not be fully captured when solely looking at facial images conveying unaltered information. The differences in task characteristics may recruit the help of different underlying mechanisms, partly explaining discrepant results.

These mixed results reveal a necessity to investigate the relationship between stress and emotion recognition further, also considering the complexity of the human stress response. The interaction is no doubt determined by various factors, which have still not been fully understood. Especially, keeping the heterogeneous etiology of stress in mind, it is of further interest to investigate if the experience of acute stress shows more varieties in the reaction to mind and body than has already been established. Previous research has nevertheless utilized only psychosocial stressors.

Present Study

The aim of this thesis is to test the effect of experimentally induced stress on the ability to understand and recognize emotions. In this study, a stressor is chosen, that combines physiological elements, directly targeting autonomous activation, with psychosocial elements, aiming at cortisol secretion. The use of the Maastricht Acute Stress Test (MAST; Smeets et al., 2012) is employed to specifically yield robust activations in both the HPA-axis and the SAM-axis to evoke the full force of the human stress response. In addition to that, emotion recognition is conceptualized with five emotions in varying intensities, which is an approach to alternate the information conveyed by the facial images and thus aims to capture the complexity of human emotional expression.

Research Question and Hypothesis

The research question of this thesis is: Does acute stress influence emotion recognition performance? As described above, acute stress and the resulting heightened state of vigilance results in more selective processing of environmental stimuli. The narrowing of the cognitive focus towards salient features in the environment might therefore require less intensity of emotional expressions in order to be recognized. This could result in a lower threshold for emotion recognition under stress. Therefore, looking at previous research and taking the biological underpinnings of the human stress response into account, the hypothesis of this thesis is that under acute stress less information may be needed to understand and recognize specific emotions.

Methods

Participants

Participants aged between 18 and 40 were recruited through the distribution of flyers, the placement of online advertisements and via the paid studies platform of the University of Vienna. The objective of the study given was to examine situational decision-making behavior. Potential participants were asked to fill out a self-report online prescreening questionnaire. The exclusion criteria were any of the following conditions: neurological damages or abnormalities, cardiovascular problems, current or previous psychiatric or somatic diseases, abuse of alcohol or drugs, and (for female participants) the current use of hormonal contraceptives. Fluency in German was an additional requirement. If the participants met the inclusion criteria, they were invited to take part in the study.

A power calculation using G*power 3.1.9.4 (Faul et al., 2007) was performed leading to a proposed sample size of $N = 84$ subjects for 80% statistical power and an alpha of 0.05, to detect a moderately large-sized effect ($d = 0.25$). At the time of data analysis, 84 (age: M = 25.6 years, $SD = 4.48$) participants (men and women) had participated. Note, that the data collection is still ongoing. They were randomly assigned to either the experimental condition ($n = 41$, 30 females, 11 males) or the control condition ($n = 43$, $n = 28$ females, $n = 15$ males). All participants gave written and informed consent. The study protocol was approved by the ethics committee of the University of Vienna. The participants had the right to refrain from the experiment at any given time.

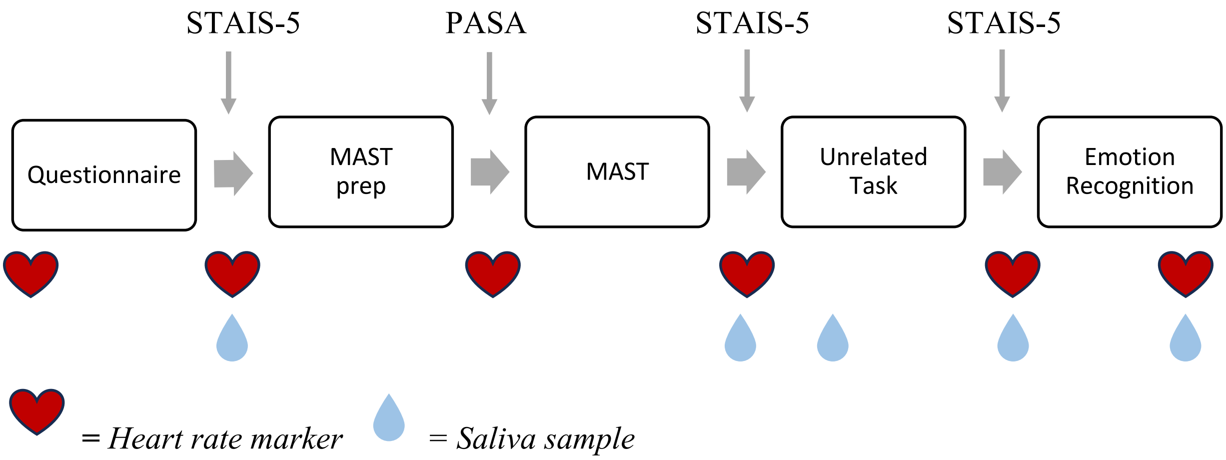
Procedure

All testing was conducted between 9:00 a.m. and 2:00 p.m. to minimize the influence of circadian fluctuations in cortisol levels (Debono et al., 2009). In this time-span participants could choose two timeslots: from 9:00 a.m. to 11:.00 a.m., or from 12:00 p.m. to 2:00 p.m. The participants were reminded to refrain from the consumption of caffeine, sugary drinks, food, or gum, and brushing teeth two hours prior to the experiment. Additionally, in the last 24 hours carrying out physical exercise, smoking, drinking alcohol as well as taking drugs had to be avoided. The experiment took place in a laboratory in the Faculty of Psychology at the University of Vienna. After arrival, the participants were handed out the consent form, which also included further information about the experiment. They were given a verbal explanation of the saliva sampling and were instructed to self-apply the electrodes of the heart rate measuring device. All subjects then completed an initial questionnaire (see supplementary material). The experimental induction of stress was performed using the Maastricht Acute Stress Test (MAST; Smeets et al., 2012) or its non-stress counterpart the control MAST. Every participant was assigned to one of the two experimental conditions. Immediately prior to the stress induction, the State-Trait Anxiety Inventory-5 (STAIS-5; Spielberger, 2012) was administered. A detailed verbal instruction of the MAST or the control MAST followed respectively. Directly before the stress induction, the Positive Appraisal Negative Appraisal (PASA; Gaab, 2009) was completed. Participants then concluded the MAST, which is described in more detail below. Immediately after the completion of the MAST, the STAIS-5 is filled out again. An unrelated task follows, which will not be explained here because it is not relevant to this study. Thereafter, participants performed the emotion recognition and perception tasks.

The saliva samples were collected at five time points in total. Heart rate was constantly measured throughout the duration of the experiment. Instantly after the conclusion of the experiment, participants were given a debrief about the purpose of the study and received 21 Euros as compensation for their time and contribution. Figure 1 depicts the experimental procedure.

Figure 1

Description of the experimental procedure



Tasks and Measures

Stress Induction

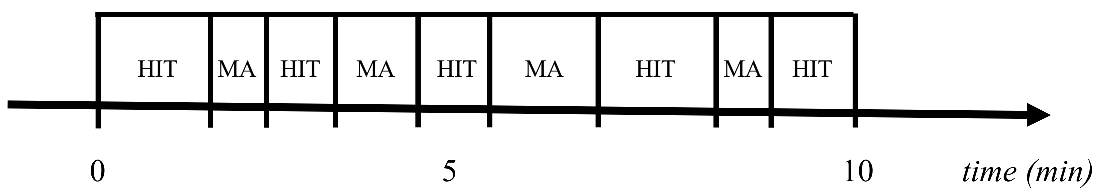
The MAST was used to experimentally induce acute stress (Smeets et al., 2012). This well-validated laboratory stressor consists of two parts. A five-minute instruction phase, where the participants received a verbal as well as a written explanation of the following task, was followed by a ten-minute acute stress phase. During the stress induction, the participants were told to immerse one hand in cold water (1-3ºC). These blocks were alternating with a socially evaluated mental arithmetic task, in which the participants counted backwards in steps of 17 as fast and as accurately as possible from a seemingly random four-digit number. Additionally, they received critical negative feedback from the experimenter wearing a white lab coat immediately directed at their performance. The trials had a maximum length of 90 seconds and a minimum length of 45 seconds. The order was fixed (see Figure 2). However, the participants were set to believe that these time windows are purely random. This is implemented with the intention of amplifying participants' perception of uncontrollability and unpredictability (Smeets et al., 2012), both elements are known to enhance HPA activity

(Dickerson & Kemeny, 2004). Adding to the socially evaluated pressure the impression of being videotaped was conveyed for a later analysis of facial expressions and body language. The camera, however, throughout the experiment remained not in use.

The control condition of the MAST has an identical sequence to its stressful equivalent, however, eliminating the stressful features. Hand immersion trials alternated with mental arithmetic in the same order and duration as in the acute stress condition. Instead, the water temperature was changed to room temperature (36ºC) and the mental arithmetic task was substituted by a simple counting task, consisting of repeated counting from 1 to 25. The participants were neither evaluated nor corrected when making mistakes. Additionally, no videotaping was announced. The social evaluative threat, amplified by uncontrollability and unpredictability, as well as a physical stressor were thus not present in this version. Figure 2 portrays the timeline of the MAST.

Figure 2

Timeline MAST



HIT = *Hand Immersion Trial* MA = *Mental Arithmetic*

Facial Emotion Recognition Task

The facial emotion recognition task was designed as a computerized task, which consisted of facial stimuli taken from the Max Planck FACES database (Ebner et al., 2010). The recognition performance of anger, fear, sadness, disgust and happiness, five basic facial emotional expressions, was assessed. Faces of two different Caucasian actors (male and female) were morphed with neutral expressions to display each emotion at different intensities: 3%, 11 %, 19%, 26%, 34%, 42%, 50% and 57%. The 80 colored pictures in total (two actors, one male one female, each for five emotions at eight different intensities) were presented in randomized order. Participants were instructed to correctly identify the facial expression visible at the time. The faces were presented on the left side of the screen on a neutral black background, whereas the six response alternatives were provided on the right side of the screen. In addition to the five emotions (anger, fear, sadness, disgust and happiness) the category “neutral“ was an option, although there was no “neutral” face (i.e., intensity 0%) present in the task. No time limit was set, and no feedback on accuracy was provided. The facial stimuli remained onscreen until the participants clicked on one of the response alternatives via a computer mouse.

Psychological Assessment

Two different scales were used to assess subjective psychological stress. First, a German version of the STAIS-5 was used. It was developed as a shorter version of the State-Trait Anxiety Inventory (STAI; Zsido et al., 2020) and consists of five items, which capture emotions associated with anxiety such as nervousness or concern. The STAI is an efficient self-assessment tool frequently implemented in research, but also in clinical settings. Responses are recorded on a 4-point Scale ranging from 1 (*not at all*) to 4 (*very much*). The STAIS-5 was applied three times (see Figure 1). One additional item asking about the current stress level was added, making it six items in total.

Additionally, the German version of the PASA (Gaab, 2009) was administered. It consists of 16 items divided into two subscales with eight items each. Primary appraisal assesses the initial evaluation of a situation as threatening or challenging, whereas secondary appraisal captures the evaluation of resources for coping in general. It was developed, based on the transactional model of stress (Lazarus & Folkman, 1984). The answers are given on a six-point Likert scale. In the current study, the PASA was administered once (see Figure 1).

Heart Rate

Heart rate was measured using a Faros 180 monitor (Bittium, Oulu, Finland) which is a portable, externally applicable electrocardiogram (ECG) recorder that continuously monitors heart rate at 1000Hz. In total three electrodes were used for measurement and placed on fixed markers on the participant's chest by themselves. For the whole duration of the experiment heart rate was marked six times (see Figure 1). An increase in heart rate is an indicator of sympathetic arousal (Schneider et al., 2021).

Saliva Sampling

Saliva samples were collected using Salivette sampling devices (Sarstedt, Nümbrecht, Germany) at five time points (see Figure 2) during the experiment. The participants were asked to place the cotton swab in their mouths for one minute. All samples were stored at -20ºC until biochemical analysis, which was conducted to measure the concentration of free salivary cortisol. Salivary cortisol is considered a reliable biomarker of stress (Kudielka et al., 2009).

Statistical Analysis

First, manipulation checks were conducted to establish if the stress induction was successful. This was done using separate Welch independent two sample t-tests between the control group and the experimental group to test for significant differences in subjectively experienced stress, as measured in the STAI-5 and the primary scale of the PASA.

Second, a generalized linear mixed model (GLMM) with a binomial distribution fit by maximum likelihood was used to examine potential differences in emotion recognition performance between the two groups and to test the main hypothesis. The outcome variable was whether the given emotion was classified as correct (=1) or incorrect (=0). Gender (1= male, 2 = female), emotion (anger, sadness, happiness (coded as reference group), disgust, and fear), intensity (eight degrees; as continuous predictor) and condition (0 = control, 1= experimental) were included as predictors. The repeated observations by participants were controlled for by including a random effect of intensity (slope) nested within participant ID (intercept). This allows the effect of intensity on the outcome variable to vary between the different participants. Additionally, in a second model, the two-way interaction between condition and intensity was added, to assess whether the impact of intensity on the outcome variable differs between conditions. The level of significance was established at $p > 0.05$.

All statistical analyses were conducted using R V. 4.1.3 (R Core Team, 2021) in RStudio (RStudio Team, 2020), and the LME4 package (Bates et al., 2015) for mixed effects models.

Results

Manipulation Checks

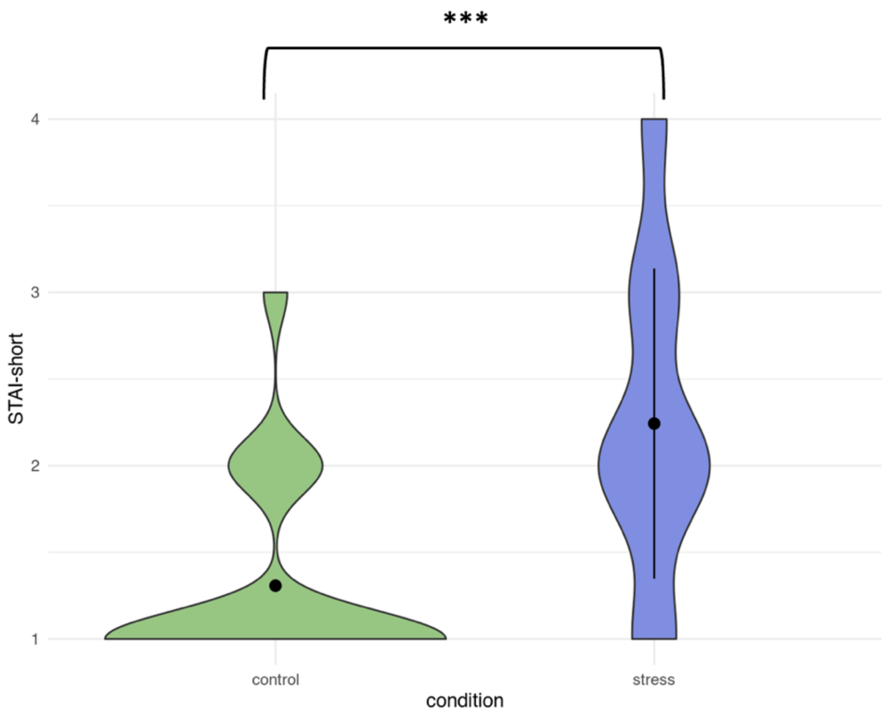
The subjective experience of acute stress was measured with the STAI-5 and the PASA (see Figure 1). STAI-5 measures administered directly after stress induction were contrasted with those of the control group at the same time point. The t-test results indicate a statistically significant difference between the means of both groups regarding their subjective experience of stress as measured in the STAI-5 (t (60.502) = -5.407, $p < 0.001$) with 95% confidence intervals (CI) between -1.282 and -0.589. The experimental group, subjected to the MAST, shows significantly higher ratings ($M = 2.243$, $SD = 0.895$) indicating a higher level of experienced stress than the control group ($M = 1.307$, $SD = 0.569$) (see Figure 3).

Additionally, results from the primary appraisal scale of the PASA indicated that both groups differed in how threatening the participants perceived the situation. The PASA was administered after the participants had received the instructions but before undergoing the MAST or the control counterpart. The Welch two-sample t-test showed significant differences between the control group (M = 2.135, SD = 0.609) and the experimental group (M = 3.226, SD = 0.785) (t (67.86) = -6.751, p < 0.001) with 95 % CI = [-1.414, -0.769]. Higher scores in the experimental group indicated a higher level of perceived potential threat from the following situation (see Figure 4).

By contrast, the secondary appraisal scale of the PASA showed no significant differences t (73.745) = 1.097, p = 0.276, 95 % CI = [-0.132, 0.456] between the control group (M = 4.442, SD = 0.68) and the experimental group (M = 4.28, SD = 0.61). Thus, both groups did not differ in how they generally perceive themselves in intimidating situations (see Figure 4). Overall, these results indicate a successful acute stress induction.

Figure 3

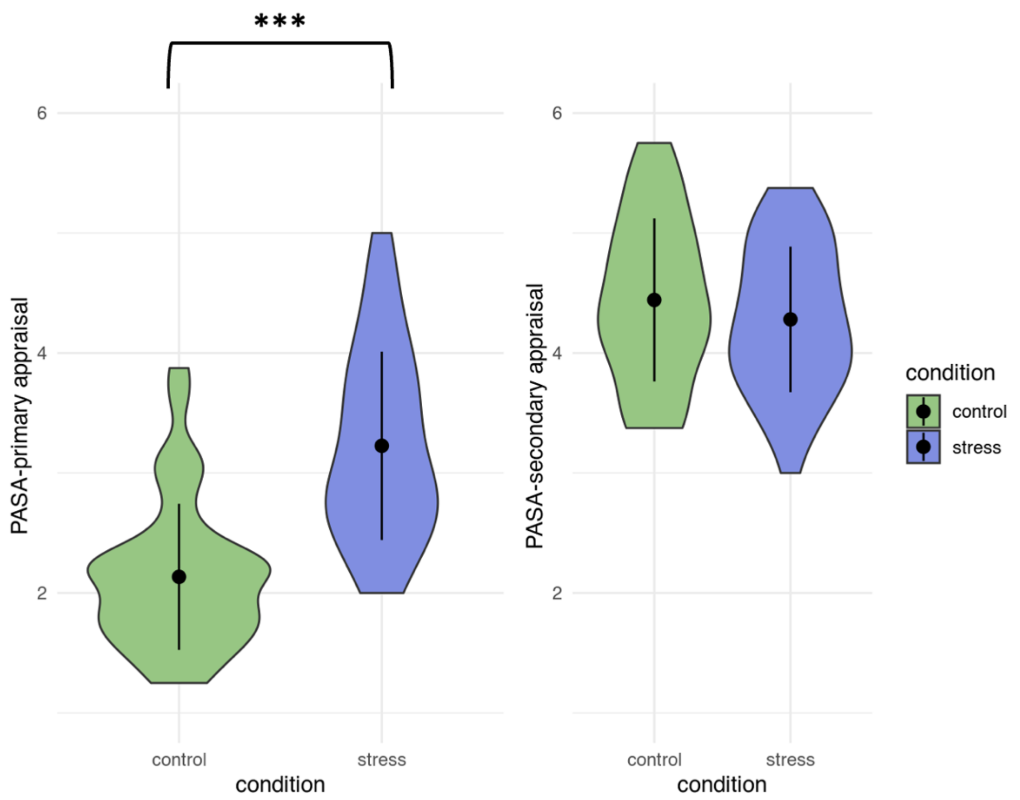
Manipulation Checks: Violin Plot of control group vs. stress STAI-5



Note. Significance code * p < 0.05; ** p < 0.01; *** p < 0.001

Figure 4

Manipulation Checks: Violin Plot of control group vs. stress PASA



Note. Significance code * p < 0.05; ** p < 0.01; *** p < 0.001

Effect of Stress Induction on Emotion Recognition

In order to assess whether stress affected the performance in facial emotion recognition a GLMM was run with emotion recognition accuracy scores as the outcome variable. A total of 84 participants completed 80 recognition trials each, resulting in a combined total of 6720 observations. Several previous studies indicated a potential gender difference between men and women in how emotions are recognized (Wingenbach et al., 2018). Thus, gender was added as a fixed effect, which was proven insignificant (z = -0.320, p = 0.749). In addition to the primary analysis, the GLMM included fixed effects for specific emotions, namely happiness, anger, disgust, sadness and fear. Happiness was chosen as the reference emotion. There was no emotion-specific hypothesis, however, as the only emotion with a positive valance, it compromised a potentially more meaningful contrast in terms of interpreting the findings. Anger (z = -3.503, p < 0.001), disgust (z = -2.707, p = 0.007) and fear (z = 3.260 p = 0.001) were significantly different from happiness (see Table 1), though sadness showed no differences (z = 1.170, p = 0.242). Whereas anger (β = -0.423, SE = 0.121) and disgust (β = -0.326, SE = 0.120) showed negative estimates indicating a lower probability of correctly identifying the emotion compared to happiness, the estimate for fear was positive (β = 0.393, SE = 0.121), suggesting a higher probability to accurately recognize fear emotions compared to happiness.

Intensity (z = 24.405, p < 0.001), as well as condition (z = 2.041, p = 0.041), were both significant predictors of emotion recognition accuracy. With increasing intensity, accuracy increased (β = 0.170, SE = 0.007). Additionally, subjects in the stress group showed a higher accuracy of correctly identifying the emotions (β = 0.278, SE = 0.136), compared to the control group.

The second model, assessing if the significant difference between both groups can be explained by the intensity of the emotion displayed (intensity x condition), did not yield a significant interaction effect (z = -0.354, p = 0.723), indicating that the main effect of "condition" explained the previous significant result thus, that the effect of "stress" on the emotion recognition accuracy does not dependent on the levels of intensity (see Figure 5). In Figure 5 a sigmoid curve was fitted to the results of both groups with an intensity threshold of 0.5, which marks the threshold of a recognition not associated to chance (above 50%).

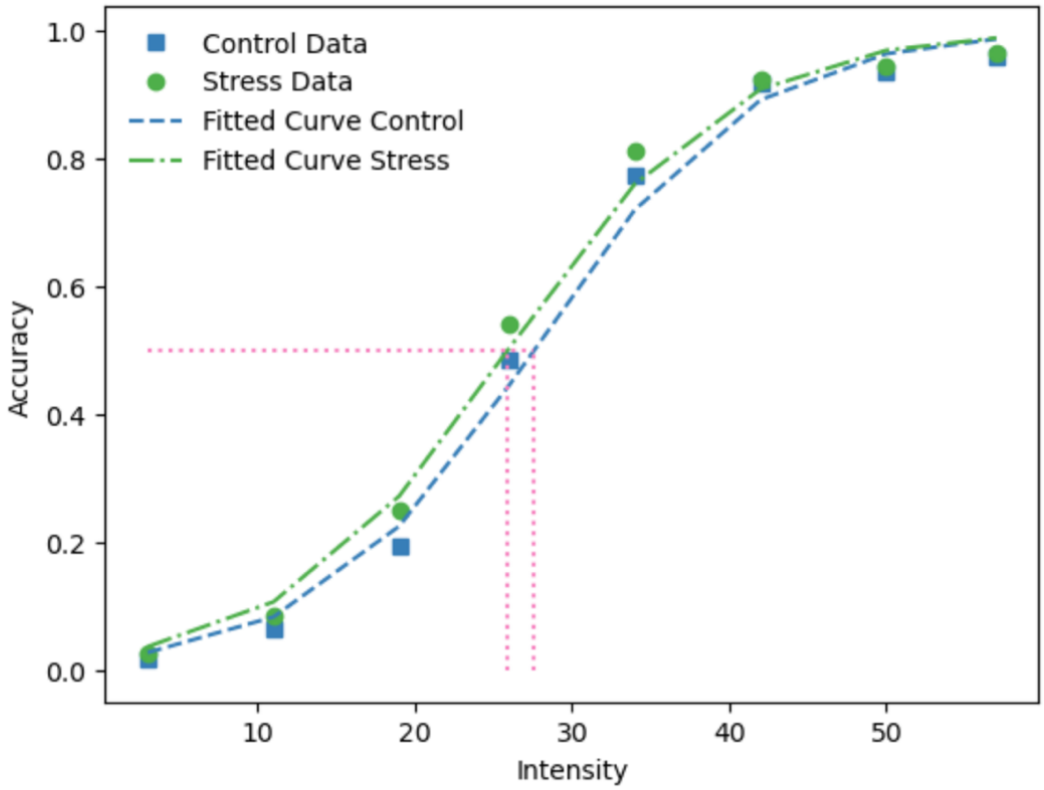
Table 1: Results fixed Effects of GLMM

Predictors	*Estimates*	*SE*	*z value*	*p*
gender	-0.047	0.147	-0.320	0.749
anger	-0.423	0.121	-3.503	<0.001***
disgust	-0.326	0.120	-2.707	0.007**
fear	0.393	0.121	3.260	0.001**
sadness	-0.141	0.120	-1.170	0.242
intensity	0.170	0.007	24.405	<0.001***
condition	0.278	0.136	2.041	0.041*

Note. Significance codes: * p < 0.05; ** p < 0.01; *** p < 0.001

Figure 5

Fitted sigmoid curve of control and experimental data with the intensity threshold for accuracy above 0.5 (above chance).



Discussion

This thesis sought to address the question of if and how acute stress affects facial emotion recognition. To tackle this question a study was conducted in which the experimental group was subjected to a stressor, combining psychological and physiological attributes. Following this exposure, a facial emotion recognition task had to be completed, depicting five different emotions in varying degrees of intensity. The findings were contrasted with a control group. The participant pool consisted of 84 individuals.

Acute Stress and Emotion Recognition

Acute stress was induced by utilizing the MAST. The effectiveness of the stress induction was demonstrated through significant differences in subjective ratings between the control group and the experimental group in both STAI-5 and the primary scale of the PASA.

The results from this study suggest that acute stress indeed facilitates emotion recognition performance. Participants in the experimental group, which were subjected to acute stress and psychologically experienced the situation as stressful, were significantly better at correctly identifying emotions than the non-stressed control group. Meaning, that they showed an improved ability to correctly classify distinct emotions.

Additionally, to investigate if the effect of acute stress on emotion recognition, could be explained by the intensity differences between both groups, an interaction term was included in a second model. Here, the interaction between condition and intensity turned out not to be significant. This implies that there is no significant difference in how the intensity of the displayed emotion influences emotion recognition in the control condition when contrasted with the experimental condition. Thus, intensity does not appear to alter the relationship between stress and emotion recognition, at least for the intensities included in this task. What must be noted is, that the emotions are displayed in relatively low intensities (only until 57%), compared to previous studies. It could be, that the effect of stress on emotion recognition only manifests itself at higher intensity levels. Nevertheless, when looking at emotion recognition performance at the highest intensity level (see Figure 5), there already appears to be a high performance accuracy (>90%). This implies that regardless of the condition the participants were capable of recognizing emotions at high intensities. The hypothesis, that, under acute stress, less information may be needed to understand and recognize specific emotions, therefore still remains unclear, which warrants future investigations. The intensity itself, however, is a significant predictor, indicating that alterations in intensity levels are associated with alterations in the probability of correctly identifying the emotion. In other words, the ability to correctly recognize the emotions is influenced by the intensity level of the emotion the participants are perceiving. Taken together, the influence of acute stress and emotion recognition seems to be more complex than initially presumed.

The findings of this study are in line with Deckers et al. (2015) and Domes & Zimmer (2019), who both used versions of the TSST to illicit psychosocial stress, with stressed participants displaying an increased emotion recognition performance. While Deckers (2015) showed a general increase in detection performance over all six tested emotions, Domes & Zimmer (2019) found an increase in both included emotions (happy and angry) in this case also regardless of intensity. These combined results are consistent with Hermans et al. (2014) theory which proposes that acute stress incites shifts in information processing through an adapted allocation of resources. Stress, eliciting neuromodulatory changes, could trigger a shift in functional connectivity from the executive control network towards the utilization of the salience network which could consequently alter cognitive abilities. The upregulation of regions that constitute the salience network play an essential role in prioritizing relevant stimuli from the environment and assessing their significance (Seeley et al., 2007). The downregulation of the executive control network in the aftermath of acute stress impairs the ability to employ higher-order cognitive processes, which require adaptable and strategic thinking. This is also associated with a decreased ability to follow goal-directed behavior (Plessow et al., 2012). Therefore, the shift in processing modality favors habitual and rigid response patterns over the execution of cognitively more demanding objectives (Nitschke & Bartz, 2023; Wirz et al., 2018). Emotion recognition is an evolutionary passed-down and adapted process (De Waal & Preston, 2017). Humans display this innate ability immediately after being born with otherwise limited cognitive resources (Heck et al., 2018). It could be presumed, that emotion recognition does not require complex processing and goal-directed behavior but it is more of an unpremeditated process, sometimes also motivational (Weisz & Cikara, 2021). Especially, when taking the simplistic nature of the task into account constituting static pictures of faces, it could be assumed, that the use of reflexive processes was not required. Nevertheless, more complex scenarios, such as emotion recognition with several contextual cues or combining different modalities could necessitate the recruitment of additional resources. It would be interesting to investigate this in future studies.

The shift towards the salience network also entails a switch from endogenous attention towards exogenous attention in order to facilitate the processing of contextually salient stimuli (Hermans et al., 2011, 2014; Wirz et al., 2018). Information, transmitted by faces depicting emotions could be considered contextually salient, due to the heightened significance they take on in circumstances of acute stress. Emotional cues could provide essential information about the perceived threat, making them particularly relevant (Olsson et al., 2020). The increased vigilance, however, is not necessarily directed towards all emotions. Not every emotion can provide clues on how to deal with a stressful situation. In this study, there were no hypotheses regarding specific emotions. Nevertheless, there were differences in recognition performance (see Table 1). When contrasted with happiness, sadness, as opposed to the other emotions with a negative valence, did not reach statistical significance. Nevertheless, these findings must be interpreted with caution because the significance only regards the specific contrast (with happiness). Previous research also reported emotion-specific differences in recognition performance after acute stress. Daudelin-Peltier et al. (2017) found an impaired recognition of disgust and increased performance for surprise, whereas Von Dawans et al. (2020) results indicate a higher sensitivity towards positive emotions, such as happiness. Future research should investigate how the context of the stressful situation influences the recognition of specific emotions and if there are differences in how salient they are perceived by the participants, by for example including a subjective rating.

The change in information processing towards saliency is induced by physiological changes triggered by acute stress, following the goal of restoring homeostasis and adapting to the unsteady environmental demands (De Kloet et al., 2005; Herman et al., 2016). As described above in more detail neuropeptides such as noradrenaline are secreted almost instantly after the encountering of a stressor. The heightened state of physiological arousal goes hand in hand with increased vigilance, making individuals more receptive to perceiving environmental stimuli. Following this, corticosteroids are secreted as the end product of the HPA-axis activation. Nevertheless, this study did not include biological data, such as cortisol or heart rate variability (indicating physiological arousal). Thus, there is no biologically validated indication, that the physiological components of the stress response were actually activated. Studies show, that the pharmacological suppression of the biological stress system influences how contextually relevant and potentially threatening stimuli are perceived (Ali et al., 2020). However, Domes & Zimmer (2019) found significant differences in emotion recognition performance between the stress and control condition, although salivary cortisol and alpha-amylase could not predict this, indicating an even more complex and multifaceted relationship.

The findings of this study are congruent with the theory of “tend-and-befriend” (Taylor et al., 2000). The concept proposes that in the aftermath of acute stress, humans are more inclined to seek out social contact and engage in caregiving behavior. It is argued that this type of behavior was evolutionary beneficial, especially for women, as it provided protection for themselves and their offspring in the face of adversity. Studies have been investigating this, showing, for example, an increase in prosocial behavior under acute stress (Buchanan & Preston, 2014), independent of the participant's gender (Von Dawans et al., 2020). This study also reveals no significant differences between men and women in how acute stress affects emotion recognition. However, this must be interpreted with caution, as the sample includes considerably fewer men (n = 26) than women (n = 58).

Limitations and Future Directions

Following on from the previous paragraph, the first limitation can be considered the imbalanced sample. Some research has indicated that there are physiological differences between men and women when responding to stress (Kudielka et al., 2009). For example, salivary cortisol increases in response to stress can be twice as high in men as in women, as a result of a higher HPA-axis activation (Kudielka & Kirschbaum, 2005; Stephens et al., 2016). In addition to this, the sole anticipation of a stressor already elicits a cortisol response in men, which is not the case in women (Kudielka et al., 2009). The physiological stress response in women seems also to depend on the menstrual cycle phase (Maki et al., 2015; Montero-López et al., 2018). Additionally, some studies show, that men and women engage specific neural networks during stress, such as a higher PFC activity in men and higher activity in limbic regions for women (Goldfarb et al., 2019). Thus, research indicates, that in some aspects differences between genders concerning the response to stress can arise. However, due to the underrepresentation of men in this sample and the resulting gender bias, there might not be enough data for this to be established. Future studies should address this.

An additional limitation is related to the operationalization of emotion recognition. In real-life scenarios, emotion recognition is much more than interpreting static faces of emotional expressions. Integrating several modalities in addition to facial expressions, such as speech (De Gelder & Vroomen, 2000) movements (Zhao et al., 2021) or situational factors such as context (Barrett et al., 2011; Yamashita et al., 2016). This makes it difficult to generalize the findings of this study to more complex daily life situations, which may require more computational resources and thus involve higher-order cognitive processes. Therefore, ecological validity may be lacking when considering the complex and dynamic interplay of contributing factors during social interactions and emotion recognition. Relating to the operationalization of emotion recognition, the choice of the respective emotions was based on Ekman (2005). However, surprise was not included in the set of emotions, although it is one of the six universal emotions identified. Surprise may have been especially interesting because it is sometimes regarded as a more complex emotion (Baron-cohen et al., 2008). Another limitation concerning the task is, that only low intensities were included, with the highest emotion intensity being 57%. The range of intensity levels included in this study may account for the statistically insignificant interaction effect. However, notably, accuracy for emotions displayed at >50% intensity was already quite high (>90% accuracy), for both groups. It might not have been possible to capture a significant difference in how intensity influences emotion recognition between both conditions. Future studies should consider a broader range of intensities and explore this relationship to a greater extent.

As already discussed above, physiological stress markers, such as salivary cortisol and heart rate variability are not included in this thesis. To reliably assess acute stress biological parameters are necessary, as they provide objective measures of the stress response (Dickerson & Kemeny, 2004). Moreover, to assess the experimental manipulation of inducing stress physiological correlates provide an objective measure assessing the efficacy of the stress manipulation. Considering that the MAST was specifically recruited to yield activations from both HPA-axis and SAM-axis (Smeets et al., 2012) this becomes even more relevant. Additionally, given the complexity of the stress response (De Kloet et al., 2005; Joëls & Baram, 2009), it is not sufficient for a holistic understanding of the effects of stress on emotion recognition to only include subjective data reflecting the psychological state.

Conclusion

Taken together, this thesis suggests that acute stress significantly affects emotion recognition. This may be due to a shift in information processing, towards salient features, which would imply that social information is considered a salient feature when faced with adversity. These findings could serve as an indication of the importance of emotion recognition as an evolutionarily passed down advantageous ability for individuals. Nevertheless, it could not be completely resolved, if this reported effect is due to a reduced need for information under acute stress to be able to accurately recognize and understand specific emotions. These results may be considered a consequence of only including a limited range of emotional intensities, and thus not being able to fully capture the potential relationship. The impact acute stress has on emotion recognition appears to be more intricate and complex than originally presumed. This highlights the need for future research to investigate if a potential threshold at different intensity ranges exists. In addition, research into other potential underlying mechanisms and moderating factors, such as specific cognitive processes that could explain the effect acute stress has on emotion recognition is needed, which may also account for the heterogenous findings of previous research. Nevertheless, this study provides further insight into how humans deal with stress and what social interactions signify to us: a resource.

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Appendix

Items for Primary Appraisal Secondary Appraisal (PASA)

1. Ich fühle mich durch die Situation nicht bedroht.
2. Die Situation ist für mich von Bedeutung (relevant).
3. In dieser Situation weiß ich, was ich tun kann.
4. Es hängt hauptsächlich von mir ab, ob ich die Situation bewältige.
5. Diese Situation ist mir sehr unangenehm.
6. Diese Situation lässt mich kalt.
7. Ich weiß überhaupt nicht, was ich jetzt machen soll.
8. Ich kann mich am besten selbst durch mein Verhalten vor Misserfolg in dieser Situation schützen.
9. Ich fühle mich nicht beunruhigt, da die Situation keine Bedrohung für mich darstellt.
10. Die Situation ist keine Herausforderung für mich.
11. In dieser Situation fallen mir viele Handlungsalternativen ein.
12. Ich kann sehr viel von dem, was in dieser Situation passiert, selbst bestimmen.
13. Diese Situation macht mir Angst.
14. Diese Situation fordert mich heraus.
15. Für diese Situation fallen mir viele Lösungen ein.
16. Wenn ich die Situation bewältige, ist das Folge meiner Anstrengung und meines persönlichen Einsatzes.

Items for The State-Trait Anxiety Inventory-5 (STAIS-5)

Ich bin…

1. angespannt
2. aufgeregt
3. besorgt, dass etwas schiefgehen könnte.
4. beunruhigt.
5. nervös.
6. gestresst.

German Abstract

Wie beeinflusst akuter Stress die Art und Weise, wie Menschen Emotionen erkennen? Akuter Stress ist ein alltägliches Phänomen. Das Erkennen von Emotionen ist eine entscheidende Fähigkeit für erfolgreiche Kommunikation und eine Voraussetzung für den Aufbau sinnvoller Beziehungen. Als soziale Wesen sind die Menschen aufeinander angewiesen, werden aber häufig mit Stresssituationen konfrontiert. Daher haben frühere Studien diesen Zusammenhang bereits untersucht, sind aber zu keinem eindeutigen Ergebnis gekommen. Ziel dieser Arbeit war es, die Beziehung zwischen akutem Stress und Emotionserkennung weiter zu untersuchen, indem ein Stressor verwendet wurde, welcher physische und psychosoziale Merkmale kombiniert. Hinzufügend wurde die Intensität der dargestellten Emotionen variiert, um die ökologische Validität zu erhöhen. 84 Teilnehmer unterzogen sich dem Maastricht Acute Stress Test (MAST) oder der Kontrollbedingung, gefolgt einer Aufgabe, welche das Erkennen von Emotionen in Gesichtern untersuchte. Als Reaktion auf den MAST zeigten die Teilnehmer eine höhere Emotionserkennungsleistung, unabhängig von der Intensität der dargestellten Emotionen. Diese Ergebnisse deuten darauf hin, dass akuter Stress die Verarbeitung sozialer Reize, wie unter anderem Gesichtsausdrücke, erleichtert.