Emotion

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CITATION

Schmidt-Kassow, M., Günther, A.-N., Salim-Latzel, M., Kaiser, J., & Paulmann, S. (2024). Perceived prolonged stress leads to difficulties in recognizing sadness from voice cues in men but not women.. *Emotion*. Advance online publication. https://dx.doi.org/10.1037/emo0001393

AMERICAN PSYCHOLOGICAL ASSOCIATION

Emotion

© 2024 The Author(s)
ISSN: 1528-3542

https://doi.org/10.1037/emo0001393

Perceived Prolonged Stress Leads to Difficulties in Recognizing Sadness From Voice Cues in Men but Not Women

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It has long been known that stress has detrimental effects on cognition (e.g., Alderson & Novack, 2002; Lupien & Lepage, 2001), most notably documented for memory functions (e.g., Schwabe & Wolf, 2013). Interestingly, less is known about the effects of stress on other cognitive functions including language processing. Here, we have examined the effects of self-reported prolonged stress on recognition of emotional language content with a particular emphasis on gender differences. We tested how well 399 participants with different perceived stress levels recognized emotional voice cues. Findings confirm previous results from the emotional prosody literature by demonstrating that women generally outperform men in the vocal emotion recognition task. Crucially, results also revealed that medium levels of perceived stress impair the ability to detect sadness from voice cues in men but not women. These findings were not modulated by task demands (e.g., speeded response) or better acoustic discrimination abilities in women. Results are in line with the idea that perceived stress has a different impact on men versus women and that women have a higher level of experience in voice sadness recognition, potentially due to their predominant role as primary caretakers.

Keywords: prolonged stress, emotion recognition, affective prosody, gender

Supplemental materials: https://doi.org/10.1037/emo0001393.supp

Physical or psychological stress has detrimental effects on the human brain, most notably on the hippocampus and prefrontal cortex (Lupien & Lepage, 2001; McEwen, 2007; Radley & Morrison, 2005). Previous studies have shown that chronic exposure to stress hormones can lead to cognitive impairments (Alderson & Novack, 2002; Lupien & Lepage, 2001). While much research has focused on exploring how stress impacts on memory (Guenzel et al., 2013; Schwabe & Wolf, 2013; Wolf, 2008), little is known about how prolonged stress affects other cognitive functions such as processes related to language. The present study aimed to extend the existing findings to an underresearched cognitive domain, namely, emotional language perception. This focus is warranted given the prominence of emotional interactions in our daily life: from sending our friends excited sounding voice messages about social events to talking in a frightened way about our health concerns with our general practitioner. The quality of our interactions has been linked to measures of well-being (e.g., Bernstein et al., 2018), which once more emphasizes the important role that social interactions have in our daily life. When communicating verbally (e.g., by voice message, phone, or face to face), the way we say things (i.e., prosodic modulation) has been argued to carry as much meaning as what we are saying (e.g., Paulmann & Pell, 2011). Indeed, listeners can pick up on nuances in speech that allow them to infer how a speaker feels (e.g., Banse & Scherer, 1996) even when *what* is said and *how* it is said does not match (e.g., "I am fine" spoken in a sad voice; Schirmer & Kotz, 2003), or when a listener and a speaker do

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Amie M. Gordon served as action editor.

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The authors have no conflicts of interest to disclose. Part of this research was supported by a research promotion fund from the Psychology Department, University of Essex, awarded to Silke Paulmann.

Maren Schmidt-Kassow played a lead role in conceptualization, software, and visualization and an equal role in formal analysis, investigation, methodology, writing–original draft, and writing–review and editing. Alessia-Nadia Günther played a lead role in investigation, a supporting role in formal analysis, writing–original draft, and writing–review and editing, and an equal role in project administration. Martiel Salim-Latzel played a supporting role in formal analysis, investigation, project administration, software, and writing–review and editing. Jochen Kaiser played a lead role in resources and writing–review and editing and a supporting role in formal analysis. Silke Paulmann played a lead role in funding acquisition and an equal role in conceptualization, formal analysis, investigation, methodology, writing–original draft, and writing–review and editing.

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not share a common language (i.e., cross-cultural communication; Pell et al., 2009). Overall, significant progress has been made in understanding the significance of emotional prosody in speech processing not only in healthy participants (cf. Kotz & Paulmann, 2011; Paulmann, 2016, for reviews) but also in patients with major depression. Depressed individuals frequently selectively focus on negative information (Peckham et al., 2010) while disregarding positive information (Kellough et al., 2008), which contrasts with the pattern exhibited by healthy individuals (Pool et al., 2016). Specifically, depressed individuals exhibit a negative bias toward ambiguous stimuli (Kan et al., 2004) and a decreased perception of positive prosody (Schlipf et al., 2013). Furthermore, they rate happy prosody as less intense when compared to healthy controls (Koch et al., 2018). Given this knowledge on the depressive brain, surprisingly little is known about how a healthy listener's psychological state affects the way emotional prosody is perceived. The present study aims to fill this gap in the literature by exploring how perceived stress affects the way listeners detect emotions from voice cues. We have focused on prolonged perceived stress (over a period of 4 weeks), given that recent events like the emergence of COVID-19 have led to a general increase in stress levels (Adams et al., 2021; Husky et al., 2020; Kowal et al., 2020), yet only little is known on how perceived stress impacts on social interactions (Ceccato et al., 2018; Dissing et al., 2019). Moreover, existing research has demonstrated a robust positive correlation between perceived stress and various aspects such as depression, anxiety, fatigue, and procrastination. In contrast, the correlation between perceived stress and life satisfaction was found to be negative (Klein et al., 2016). Consequently, perceived stress exerts an influence on a broad spectrum of factors linked to mental well-being. In this study, our objective was to investigate the impact of perceived stress on our communication skills.

Chronic Stress

Long-lasting stress leads to a chronic activation of the hypothalamic–pituitary–adrenal (HPA) axis resulting in a release of glucocorticoids (mainly cortisol in humans) from the adrenal cortex (Lupien et al., 2009). A chronically activated hypothalamic–pituitary–adrenal axis may result in a wide range of psychological and physiological impairments. These include, inter alia, psychiatric (Juruena, 2014), cardiovascular (Girod & Brotman, 2004), or neurological (Burns et al., 2014; Hemmerle et al., 2012) diseases. Furthermore, auditory processing (e.g., affected by hearing loss or tinnitus) has been reported to be affected by chronic stress (Horner, 2003), and it has been shown that brain structures involved in emotion processing and regulation (Dixon et al., 2017) are affected by chronic stress. These are the prefrontal cortex, the amygdala, and the hippocampal formation (Lupien et al., 2009). Therefore, considering the previous findings collectively, it is reasonable to suggest that chronic stress affects the recognition of emotions in speech.

Gender, Stress, and Emotion

Previous studies have suggested that stress manifests differently for men and women, that is, between puberty and menopause, women seem to have lower acute stress reactivity than men in the same age groups as measured by sympathoadrenal and HPA axis activity (de Weerth & Buitelaar, 2005; Kajantie & Phillips, 2006; Kudielka & Kirschbaum, 2005; Matthews & Rodin, 1992; Oyola & Handa, 2017; Panagiotakopoulos & Neigh, 2014). Furthermore, data from rodents have shown that chronic stress impairs male performance on numerous behavioral cognitive tasks, whereas it enhances or does not impact female cognitive function (Bowman et al., 2022).

On the other hand, women are often reported to be more likely than men to develop stress-related mental health problems such as depression or anxiety disorders (Bangasser et al., 2019; Hodes & Epperson, 2019; Stadtler & Neigh, 2023), which has been repeatedly reported in studies during the COVID-19 pandemic (Peyer et al., 2024; Sardella et al., 2022; Tharp et al., 2021; Yalçın et al., 2022). In line with these findings, women report higher levels of stress, and the experience of stress seems to be different: While women tend to feel emotionally exhausted, men feel more depersonalized (Hewitt et al., 1992; Klein et al., 2016; Purvanova & Muros, 2010). Given these gender differences in stress reactivity and resilience, there are good reasons to assume that perceived stress may affect cognitive performance in men and women differently. Hence, the present study will test for such gender differences when looking at the effects of perceived stress over a period of 4 weeks on emotional speech recognition.

So far, gender differences in emotional speech perception tasks have only been explored without taking stress levels of listeners into account. For example, Lambrecht et al. (2014) asked women and men to categorize nonverbal (audio, audiovisual, and visual) emotional stimuli. Women outperformed men in this task. Similar results were found when looking at the audio domain only (e.g., Demenescu et al., 2015; Lausen & Schacht, 2018; Paulmann & Uskul, 2014; Scherer et al., 2001). Research suggests that women may excel in prosocial emotion processing, particularly in relation to negative emotions (Bonebright et al., 1996; Schienle et al., 2005; Schirmer et al., 2005, 2007). Additionally, brain imaging studies have shown that women have a larger anterior cingulate (AC) volume than men, a structure that has been linked both to sadness (Eisenberger et al., 2003) and empathy processing (Singer et al., 2006). Previous research has shown that chronic stress can lead to a reduction in the volume of the anterior cingulate (MacLullich et al., 2006). Therefore, it is reasonable to assume that prolonged stress levels can particularly affect the recognition of sadness.

Despite a wealth of evidence supporting an emotion recognition advantage in women, not all past studies have reported this effect (e.g., Paulmann et al., 2008; Raithel & Hielscher-Fastabend, 2004; Sauter et al., 2013), suggesting that the "female advantage" in recognizing emotions from vocal cues is not straightforward. Indeed, some research suggests that recognition differences between men and women can be mediated through a range of additional factors that include both listener (e.g., Lambrecht et al., 2014) and stimulus-specific characteristics (Lausen & Schacht, 2018). To the best of our knowledge, the influence of prolonged perceived stress level of participants has not been considered to play a mediating role. This is surprising given the well-documented gender differences when looking at the fields of stress and emotional prosody recognition in isolation. Moreover, some limited evidence has already started to link stress and emotional prosody albeit for *acute* levels of stress, only. For example, Paulmann et al. (2016) have reported reduced emotional prosody recognition success in listeners that participated in a subpart of the Trier Social Stress

Test (Kirschbaum et al., 1993) prior to the recognition task. In this past study, however, gender differences were not investigated (Paulmann et al., 2016) so that the interaction between stress and gender on emotional tone of voice recognition remains to be tested.

In short, to investigate the relationship of perceived stress, emotion recognition, and gender, we conducted an online study with two experimental conditions. Specifically, we collected the participants' perceived stress level of the past 4 weeks and then asked them to participate in a vocal emotion recognition task. To this aim, pseudosentences (e.g., "Hung nestered the flugs") spoken in four different emotions (happiness, pleasant surprise, sadness, fear) or in neutral tone were presented. Furthermore, we included the factor task load, that is, in one of the experimental conditions, we manipulated the task demands by adding a time limit, that is, participants had to identify the presented emotional category under time pressure, while in the other experimental condition no time limit was set. Previous studies have shown that women tend to use emotional prosody earlier than men (Schirmer et al., 2002, 2005). Therefore, it is expected that men will be more strongly affected by increased task demands than women. Additionally, there may be an additive effect of perceived stress and task load in men, but not in women.

Based on the literature reviewed above, our hypotheses were (1) women are better at recognizing (negative) emotions than men; (2) perceived stress impacts vocal emotion recognition in men and women differently given the different stress reactivity and resilience in men and women; (3) and we predicted that increased task demands, specifically perceived time pressure, will result in decreased emotion recognition performance. Additionally, task load was expected to have an additive effect on the perceived stress response in men, but not in women.

Method

Participants

To the best of our knowledge, no studies have examined behavioral measures of emotional language processing with subjective stress ratings. Therefore, we based our power analysis on studies that have correlated subjective stress ratings with other cognitive measures that may contribute to our effects, namely, (working) memory and attention processes, as well as studies that compared different stress groups with regard to their emotion recognition performance. Shields et al. (2017) have reported negative correlations of subjective feelings of stress with performance on (working) memory tasks, with an average correlation coefficient $r = -0.2$. Wu et al. (2019) have found a correlation with false alarm rate in a Go/NoGo task of $r = 0.23$. With an α level of .05 and a power of 0.8, this results in a required group size of 146–194 subjects (calculated with the program G*Power 3.1.9.7). Paulmann et al. (2016) have reported a medium effect size for the finding that stressed participants perform worse in a linguistic emotion recognition task compared to unstressed participants, resulting in a required sample size of 192 participants. Therefore, we aimed for a sample size of 200 participants per gender, resulting in 400 participants in total.

Four hundred five German native speakers were recruited via the experimental hosting platform Prolific (https://www.prolific.co). Participants gave informed consent prior to accessing the experimental studies. Inclusion criteria were right-handedness, age between 18 and 45 years, and no auditory and/or visual restrictions, nor any confirmed psychiatric or neurological diagnosis. All participants were asked to sit in an undisturbed environment and had to use a desktop PC with headphones. If they were trying to use a tablet or smartphone, the experiment did not start. All methods were carried out according to the guidelines of the Declaration of Helsinki, and the study was approved by the local Ethics Committee (ethics code 20-805). Six participants were excluded either due to self-identifying as gender-diverse (and thus failing our binary gender criteria, $N = 5$), because they failed to identify all neutral sentences ($N = 1$) or because we have identified them as potential bots ($N = 10$; for the rationale, please see below).

A total of 389 participants were included in the final statistical analysis (see below). One hundred ninety-four subjects participated in the experimental condition without a time limit (92 women); the other 205 subjects participated in the experimental condition with a time limit (91 women).The present study elected to consider participant reports as gender identification and use the terms women and men rather than female and male (https://orwh.od.nih.gov/sex-gender). Ages ranged from 18 to 43 years, M (with time limit) = 28.2, $SD = 5.7$; M (without time limit) = 28.1, $SD = 6.1$.

Materials

A total of 50 prerecorded German audio stimuli were used to test the participants' ability to recognize emotional content of speech sounds. Stimuli were previously used to test emotion perception (Paulmann & Kotz, 2008). Emotionally intoned pseudosentences were used to prevent a distortion of emotional prosody by semantic content and to ensure a sole focus on the speakers' voice parameters. The ability to recognize emotion in speech was measured for four different emotions, including two positive (happiness, pleasant surprise) and two negative emotions (fear, sadness), as well as a neutral intonation. To reduce the time spent on the recognition task and thus increase compliance to finish an online experiment, we decided to follow Paulmann et al. (2010) and presented 10 sentences per emotional category only (see also Paulmann et al., 2009) adding up to a total of 50 stimuli. Additionally, we integrated five simple math tasks in order to exclude fraudulent responders, such as computer bots or disengaged participants responding randomly to the experiments. Consequently, participants displaying both low mathematical performance (only 25% hit rate) and exceptionally fast reaction times (<200 ms) were excluded from the analysis ($N = 10$), as the combination of these characteristics raises concerns regarding the potential presence of bots. Due to a technical error, the computer program counted the math tasks as "sound trials" leading to a reduction in sound files presented, but these were distributed evenly across emotions. Thus, on average, only nine items were presented for each emotion condition. There were no significant differences between conditions ($p > .09$).

Procedure

The online studies were hosted via the crowdsourcing behavioral research platform Prolific (https://www.prolific.co), where registered users were preselected to match our study inclusion criteria. The study itself was programmed using the experiment building platform PsyToolkit (Stoet, 2010, 2017).

After answering questions on demographic data, participants completed the 10-item Perceived Stress Scale (PSS10; Klein et al., 2016) questionnaire to measure subjective stress perception during the past month. In Klein et al.'s study, scores on the PSS demonstrated good internal consistency (Cronbach $\alpha = .84$) and construct validity of the PSS10. In line with previous research, perceived stress was strongly positively correlated with depression and anxiety, fatigue, as well as procrastination, whereas the correlation between perceived stress and life satisfaction was negative. PSS10 results are presented as a score from 0 to 40 (0 = *not stressed*, 40 = *highly stressed*). Since the PSS10 is not a diagnostic instrument, there are no clear cutoffs (Klein et al., 2016), and comparisons can only be made between people in one sample. For this reason and to ensure equal group sizes for the analysis of variance (ANOVA) as described below, we used a tertile split resulting in the following three stress groups: "low stress" (0–14), "medium stress" (15–21), and "high stress" (22–37). This splitting is comparable to other studies using the PSS10 (e.g., Traoré et al., 2023). After the completion of the PSS10, we evaluated participants' coping strategies using the Stress and Coping Inventory (Satow, 2012). However, these strategies are not pertinent to the current analysis.

Following written instructions and up to 10 practice trials, with each including feedback about correct or incorrect responses, the emotional prosody recognition study started. Stimuli were presented in a random order and no feedback was given. Each trial was structured as follows: An emotional pseudosentence was played while a scale with five emotions and their corresponding keyboard number (1 = pleasant surprise, 2 = sadness, 3 = happiness, 4 = fear, 5 = neutral) was presented on the screen. Participants had to press the correct key on their keyboard as soon as the scale changed in color, as quickly as possible. For the experimental condition with a time limit, response time was limited to 1,500 ms; if participants failed to respond within this time limit, they were prompted to respond faster. Participants took an average completion time of 12 min to complete the study.

Data Analysis

The statistical analysis was performed with Jamovi 1.6.23.0. For the analysis of perceived stress, we calculated the stress score from the PSS10. Wagner's unbiased hit rate was used to statistically control for biases toward selecting a specific "default" emotion for exemplars (Sheppard et al., 2016; Wagner, 1993). In this calculation, the number one indicates the highest systematic selection of a correct emotion, and zero represents no systematic selection.

To test study Hypotheses 1 and 3, unbiased hit rates and reaction times were analyzed using a mixed analysis of covariance with the within-subject factor *Emotion* (fearful, happy, neutral, sad, [pleasantly] surprised) and the between-subjects factors *Task Load* (with time limit, without time limit), *Gender* (men, women), and *Stress Group* (low, medium, high) and the covariates age and percentage of correctly answered catch trials. All *p* values of post hoc comparisons were Bonferroni–Holm corrected (Holm, 1979). In order to test Hypothesis 2, a two-step hierarchical regression analysis for each *Emotion* was conducted. In the first step, PSS score and *Gender* were entered as predictors for the criterion unbiased hit rate. In the second step, PSS_squared and *Gender* were entered as predictors for the criterion unbiased hit rate in order to test for a quadratic correlation.

Transparency and Openness

We report how we determined our sample size, all data exclusions, all manipulations, and all measures in the study, and we follow Journal Article Reporting Standards (Kazak, 2018). All data are available at https://github.com/mschmidt-kassow/chronicstress_prosody. Data were analyzed using Jamovi, Version 2.3.21 (retrieved from https://www.jamovi.org). This study's design and its analysis were not preregistered.

Results

Age Effects

To test for age differences between stress groups, an ANOVA with the factors *Gender* and *Stress Group* resulted in a main effect for *Stress Group*, that is, low stressed participants were significantly older ($M = 29.7$ years) compared to medium, $M = 27.8$ years, $t(393) = 2.6$, $p = .026$, and highly stressed participants, $M = 26.7$ years, $t(393) = 4.07$, $p \leq .001$. Hence, we included *age* as a covariate in our mixed ANOVA.

Perceived Stress

Overall, perceived stress scores ranged from 3 to 37, with a mean score of 17.6 ($SD = 6.6$) in the experimental condition without time limit and 18.6 ($SD = 6.8$) in the experimental condition with time limit. The ANOVA showed a main effect of *Gender*, $F(1, 395) = 30.04$, $p \leq .001$, that is, women ($M = 20.0$, $SD = 0.47$) reported significantly higher perceived stress scores than men ($M = 16.5$, $SD = 0.4$). There was no interaction between *Experiment* and *Gender*. The tertile split resulted in a *low stress group* with values from 3 to 14 ($M = 10.4$, $SD = 2.9$, $N = 123$, 37 women), a *medium stress group* with values from 15 to 21 ($M = 17.8$, $SD = 1.8$, $N = 132$, 59 women), and a *high stress group* with values from 22 to 37 ($M = 25.1$, $SD = 3.1$, $N = 144$, 87 women).

Performance

In order to investigate whether the manipulation of task load was effective, we ran a mixed ANOVA for the analysis of *reaction times*. This analysis revealed a significant main effect of *Task Load*, $F(1, 375) = 51.75$, $p < .001$, $\eta_p^2 = 0.121$, that was informed by the interaction *Emotion* × *Task Load*, $F(4, 1500) = 8.18$, $p = .001$, $\eta_p^2 = 0.021$; *neutral* with time limit/without time limit = 449/660 ms (28.8/28.3), *fear* with time limit/without time limit = 591/986 ms (38.1/38.9), *sadness* with time limit/without time limit = 450/761 ms (29.9/29.3), *happiness* with time limit/without time limit = 591/935 ms (32.2/31.5), *pleasant surprise* with time limit/without time limit = 511/825 ms (32.0/31.3), indicating that in all conditions reaction times significantly decreased in the time limit condition, while at the same time mean reaction times were below the set time limit of 1,500 ms even in the without time limit condition. There were no further main effects nor interactions with the factors *Gender* or *Stress Group*.

To test for Hypotheses 1 and 3, we ran a mixed ANOVA for the analysis of hit rates. The omnibus ANOVA revealed significant main effects of *Emotion*, $F(4, 1500) = 17.19$, $p \leq .001$, $\eta_p^2 = 0.044$, showing that neutral sentences were the best recognized (Mean neutral = 0.92, $SE = 0.006$), followed by negative emotions

(Mean sadness = 0.76, *SE* = 0.009; Mean fear = 0.67, *SE* = 0.01) and positive emotions (Mean happiness = 0.50, *SE* = 0.009; Mean pleasant surprise = 0.44, *SE* = 0.01); *Gender*, $F(1, 375) = 17.55$, $p \leq .001$, $\eta_p^2 = 0.045$, showing that women performed better than men (Mean women = 0.69, *SE* = 0.01; Mean men = 0.63, *SE* = 0.008); and *Task Load*, $F(1, 375) = 6.99$, $p \leq .01$, $\eta_p^2 = 0.018$, indicating that increased task load resulted in decreased performance (Mean with time limit = 0.64, *SE* = 0.009; Mean without time limit = 0.68; *SE* = 0.009). Furthermore, we found significant interactions *Emotion* × *Gender*, $F(4, 1500) = 4.08$, $p = .003$, $\eta_p^2 = 0.01$, and *Emotion* × *Task Load*, $F(4, 1500) = 2.85$, $p = .023$, $\eta_p^2 = 0.008$, which were informed by the threefold interaction *Emotion* × *Gender* × *Stress Group*, $F(4, 1500) = 2.22$, $p = .023$, $\eta_p^2 = 0.012$. However, in contrast to predictions made by Hypothesis 3, we found no interaction of Gender × Task Load or Stress Group × Task Load.

Post hoc *t* tests for the interaction *Emotion* × *Gender* revealed significant better performance for women for negative emotions only, *fear*: $t(375)=-4.32$, $p < .001$, *sadness*: $t(375)=-4.45$, $p < .001$, while performance in recognizing positive emotions did not differ significantly between men and women ($p > .5$).

Post hoc *t* tests for the interaction *Emotion* × *Task Load* revealed that fear and pleasant surprise but not sadness and happiness ($p > .05$) were recognized with higher accuracy in the *without time limit* condition, *fear*: $t(375) = 2.615$, $p = .05$, *pleasant surprise*: $t(375) = 3.18$, $p = .012$.

Resolving the threefold interaction *Emotion* × *Gender* × *Stress Group* by *Emotion* revealed a significant *Gender* by *Stress Group* interaction only for the emotion sadness, $F(2, 383) = 4.2$, $p = .01$, $\eta_p^2 = 0.02$; see Figure 1. Performance of women for recognizing sadness did not vary across stress groups (all *p*s > .5), while *medium stressed* men recognized sadness less accurately than men in the *low*, $t(206) = -2.32$, $p = .021$, and *high stress* group, $t(206) = -2.54$, $p = .012$, and also worse than *medium* stressed women, $t(129) = -4.34$, $p \leq .001$. Performance of men and women did not differ significantly in the low and high stress groups ($p > .05$).

Sensitivity Tests

To further elucidate the three-way interaction from the ANOVA with stress as a continuous variable (PSS10 score) and to test Hypothesis 2, we conducted a hierarchical regression with the factor gender for each emotion. Since plotting the data suggested a u-shaped progression in men (see Figure 1), we ran separate hierarchical regression models to test whether the PSS score linearly or quadratically predicts recognition rates as described in the data analysis section.

For the emotion *sadness*, the linear model, Model 1, Overall Model Fit: $R^2 = 0.054$, $F(3, 385) = 7.28$, $p < .001$, neither showed that the PSS score nor the interaction of PSS and gender significantly predicted unbiased hit rate for sadness recognition ($p > .5$). However, the quadratic model, Model 2, Overall Model Fit: $R^2 = 0.073$, $F(5, 383) = 6.04$, $p < .001$, resulted in a significant interaction *Gender* × *PSS*, $F(1, 383) = 5.8$, $p = .017$, indicating a u-shaped relation between perceived stress and sadness recognition in men but not women (see Figure 2). There was a significant improvement between Models 1 and 2, $F\text{change}(2, 383) = 4.00$, $p = .019$, $\Delta R^2 = .019$.

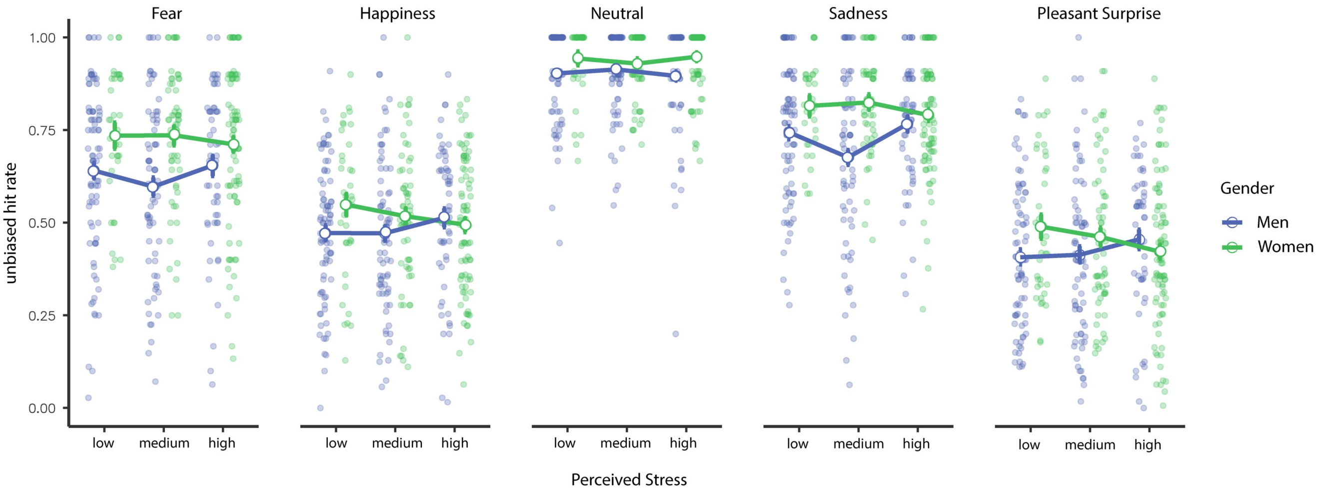
We additionally ran separate regressions for men and women. For both, we found that the linear model was not significant ($p > .5$). However, in men, but not women ($p > .5$), the quadratic model revealed significance, Overall Model Fit: $R^2 = 0.03$, $F(2, 206) = 3.2$, $p = .04$, and there was a significant improvement between the linear and the quadratic model, $F\text{change}(1, 206) = 5.95$, $p = .016$.

For the emotion *fear*, we found no significant results, neither for the linear nor for the quadratic model ($p > .07$).

For the emotion *happiness*, the linear model, Model 1, Overall Model Fit: $R^2 = 0.014$, $F(3, 385) = 1.89$, $p = .13$, showed that the interaction of PSS and gender significantly predicted unbiased hit rate for happiness recognition, $F(1, 385) = 4.38$, $p = .047$, indicating that there was a negative linear relationship between PSS scores and happiness recognition in women but not in men. The quadratic model (Model 2) resulted in

Figure 1

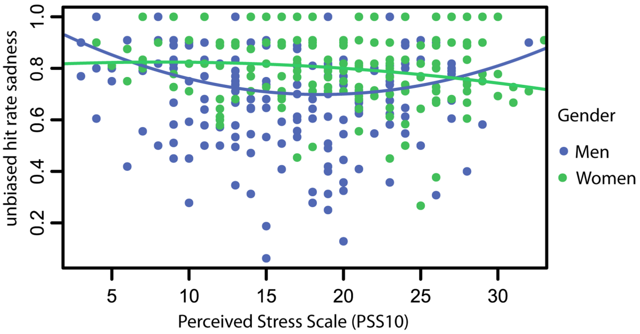
Emotion Recognition Rates



Note. The figure shows mean Hu score rates and standard errors for each emotional category and perceived stress group (low, medium, high). Men are plotted in blue; women are plotted in green. See the online article for the color version of this figure.

Figure 2

Relationship Between PSS10 Scores and Unbiased Hit Rate for Sadness Plotted Separately for Men and Women



Note. See the online article for the color version of this figure.

no significant effect ($p > .2$). However, when we ran separate regressions for men and women, we found no significant effect at all (all *ps* > .1).

For the emotion *pleasant surprise*, again the linear model, Model 1, Overall Model Fit: $R^2 = 0.019$, $F(3, 385) = 2.48$, $p = .06$, showed that the interaction of PSS and gender significantly predicted unbiased hit rate for pleasant surprise recognition, $F(1, 385) = 5.82$, $p = .016$, indicating that there was a negative linear relationship between PSS scores and pleasant surprise recognition in women but not in men. The quadratic model (Model 2) resulted in no significant effect ($p > .2$). We additionally ran separate regressions for men and women. For both, we found that the quadratic model was not significant ($p > .5$). However, in women, but not men ($p > .5$), the linear model revealed marginal significance, Overall Model Fit: $R^2 = 0.021$, $F(1, 178) = 3.85$, $p = .05$, indicating that surprise recognition decreases with increasing PSS scores.

Discussion

The present study explored how prolonged perceived stress affects an important component of human interactions, namely, how emotions are perceived through voice cues. Based on past findings on emotional (prosody) perception (e.g., Eisenberger et al., 2003; MacLullich et al., 2006; Paulmann & Uskul, 2014; Schirmer et al., 2005, 2007) and effects of chronic psychological stress on cognitive functions within (e.g., Laures-Gore et al., 2019; Sirianni, 2004) and outside the language domain (e.g., Alderson & Novack, 2002; Lupien & Lepage, 2001), we predicted that (a) women are better at recognizing emotions than men; (b) perceived stress may alter vocal emotion recognition in men and women differently given the different stress reactivity and resilience in men and women; and (c) that increased task demands can have an additive effect on the perceived stress response, leading to worse emotion recognition performance than perceived stress alone. The current data largely support these hypotheses. First, we largely confirm findings from previous studies, showing that women outperform men, here specifically in detecting negative emotions (Hypothesis 1, Schienle et al., 2005; Schirmer et al., 2005, 2007). Furthermore, our results revealed that perceived stress affects men and women's sadness recognition differently (Hypothesis 2). Thus, our data show that perceived stress does not affect emotion recognition in women but there is a u-shaped relationship between sadness recognition and perceived stress in men. While our data provide no support for a modulatory effect of task demands on the effect of stress on emotion recognition (cf. Hypothesis 3), we found that time pressure led to decreased performance in recognizing fear and pleasant surprise. Although the interpretation of this finding requires some caution and has to be replicated in future studies, previous research has already shown that fear and pleasant surprise are emotions that can be especially complex and difficult to categorize (Paulmann et al., 2008). Paulmann et al.'s (2008) data show that pleasant surprise stimuli were the most difficult to categorize, a finding reported across different listener age groups. Similarly, fearful expressions have previously been linked to lower emotion recognition rates. Specifically, the acoustic diversity of this emotion is greater than that of sadness or happiness (Paulmann et al., 2008), leading to greater overlap with other emotions, which can make recognition more difficult, especially if recognition time is limited. Taking these past findings into account, it is thus reasonable to assume that a reduction in information processing time (i.e., when a speeded response is required) poses additional challenges to listeners and thus leads to enhanced difficulties when assessing these two emotions.

Women Are Better at Recognizing Emotions Than Men

Past research has repeatedly pointed to an advantage of women over men when processing emotional prosody cues (e.g., Demenescu et al., 2015; Lausen & Schacht, 2018; Paulmann & Uskul, 2014; Scherer et al., 2001), an effect also observed here. For example, Collignon et al. (2010) studied the perception of fear and disgust and reported that women outperformed men in discriminating these two negative emotions. In line with this result, other studies have reported an overall advantage for women when testing how well both sexes could identify several different vocal emotions (e.g., anger, disgust, fear, happiness, surprise, sadness), though the effects were often small in magnitude (e.g., 3% difference reported in Paulmann & Uskul, 2014; 2% difference in accuracy reported in Scherer et al., 2001). Perhaps not surprisingly then, other similar studies have not reported the same advantage (e.g., Paulmann et al., 2008; Raithel & Hielscher-Fastabend, 2004), suggesting that other factors (e.g., task effects; stimulus differences) may contribute to the divergent picture. Indeed, Schirmer et al. (2002, 2005) studied this issue at the neural level and reported that women were not necessarily *better*, but used available information at different time points. Looking at emotional vocal processing on the word level in two cross-modal priming studies, they found that women's event-related brain potential priming effects were elicited ~150 ms earlier than men's respective prosody/word priming effects (Schirmer et al., 2002). In a follow-up study, Schirmer et al. (2005) explored whether emotional vocal attributes were processed preattentively in the same way by men and women. While so-called mismatch negativity responses to emotional deviants were indeed elicited for both men and women, women showed enhanced mismatch negativity to emotional versus neutral deviants, an effect not observed for men. Taken together, these results suggest that women may attend to vocal attributes differently (e.g., more quickly, more intensely) than men but that this processing difference does not necessarily have to result in a recognition advantage for emotional prosody. Crucially, the authors have argued that the "social relevance" of a stimulus is of particular importance when exploring differences between men and women. That is, highly relevant stimuli (e.g., negative vs. neutral vocal arousal) might capture a woman's attention more easily than that of a man. Given the acoustic proximity between sadness and fear, one must consider that women might simply have been better at acoustic discrimination, and the reported effect is not emotion-specific. To test for this possibility, we also computed a post hoc ANOVA for confounds in negative and positive emotion conditions (see Supplemental Material). This post hoc analysis revealed that men and women show comparable confusion rates in positive emotions and at any stress level, while women are better than men in discriminating sadness from fear, particularly under medium stress. The finding that women are better at identifying and discriminating negative emotions is in line with the "social relevance" hypothesis. In the present study, we looked at two socially highly relevant emotions, namely, fear and sadness, and compared emotion recognition success to two positive emotions, specifically happiness and pleasant surprise. Arguably, these positive emotions are of less direct relevance (e.g., in terms of action preparation) to listeners. Since women were not better at discriminating happiness from surprise, but they were superior in discriminating sadness from fear than men (especially when medium stressed), we argue that our findings lend further support to the notion that women pay more attention to socially relevant stimuli.

Are Women Better or Men Worse? Women's Perceived Stress Does Not Correlate With Speech Emotion Recognition, but Men's Sadness Recognition Decreases Under Medium Stress

The present study found that sadness recognition in men is worse under medium perceived prolonged stress, while a previous study on acute stress (Paulmann et al., 2016) provided evidence that stress decreases *overall* emotion recognition performance (and gender effects were not analyzed). Since neither the former nor the present study has analyzed biological markers of stress induction, the reason for this discrepant finding remains speculative. One obvious difference between studies is that here we look at prolonged and perceived rather than acute stress. The latter response is short-lived whereas the former is more stable. Future studies could thus directly compare the influence of prolonged versus acute stress on emotional communication abilities.

Irrespective of differences in stress assessment, it might be that women show a lower endocrinological stress response than men and, consequently, performance is stable because their endocrinological system is not perturbed. Alternatively, women might be better in coping with stress with regard to vocal emotion recognition. In their review, Campbell and Ehlert (2012) concluded that in only about 25% of the studies, there were associations between cortisol responses and perceived emotional stress variables. Hence, previous studies have shown that although women tend to report more stress and anxiety during and after acute stress exposure than men (Kelly et al., 2008; Kirschbaum et al., 1999; Merz & Wolf, 2016), men tend to have higher physiological stress reactivity than women (Kajantie & Phillips, 2006; Kudielka & Kirschbaum, 2005; Oyola & Handa, 2017; Panagiotakopoulos & Neigh, 2014). This pattern of results changes after menopause when women show an increased sympathoadrenal responsiveness (de Weerth & Buitelaar, 2005; Matthews & Rodin, 1992). Although physiological markers are missing in the present study, the results suggest that the gender difference is not due to differences in cortisol levels. Our data show selective impairments in men under a medium level of stress, while performance in the high stress group does not differ from that of women. This argues against a linear relationship between cortisol levels and the recognition of sadness, as we would otherwise expect a further drop in performance in the high stress group. Furthermore, it has been argued that acute stressors, depending on strength and duration, might be beneficial for cognitive tasks (Domes et al., 2002; Schwabe et al., 2008; Smeets et al., 2007); however, here, we find no indication that increasing task demands (which may have served as an acute stressor) can "counteract" the effects of perceived prolonged stress.

The observed difficulty is in line with past studies that showed that sadness recognition is particularly difficult for men when compared to women (e.g., Fujisawa & Shinohara, 2011; Zupan et al., 2017). It has been argued that anatomical brain differences could contribute to these results. For instance, previous studies have reported that women have a larger AC than men, a structure involved in sadness (Eisenberger et al., 2003) and empathy processing (Singer et al., 2006). Furthermore, chronic stress has been shown to lead to a volume reduction of the AC (MacLullich et al., 2006), that is, one would expect poorer recognition of sadness under prolonged stress. Hence, it may be speculated that an increased larger AC in women helps them to cope with a perceived stressor better compared to men. Indeed, there is preliminary evidence that the AC is linked to stress coping in mice (Lee et al., 2016). This is interesting insofar as previous studies that have investigated the effect of chronic stress primarily included men (Lupien et al., 2009; Maheu et al., 2004) or found no gender-specific effect (Martin et al., 2015; Raio et al., 2013).

While all of these possibilities may provide plausible explanations for why men are generally worse at detecting sadness, the question still remains as to why performance follows a u-shaped curve, that is, why sadness recognition selectively deteriorates under *moderate* stress. One reason might be evolutionary pressure. That means that in females, there is a universal evolutionary requirement to promote optimal growth and development of the offspring and maternal stress negatively impacts on prenatal and postnatal development (Kaiser & Sachser, 2005; Kajantie & Phillips, 2006; Vehmeijer et al., 2019). Accordingly, stressful situations can lead to "tend and be a friend" responses for women while men are more likely to show "fight or flight" responses (S. E. Taylor et al., 2000) since competition and fighting have been important factors for survival in men. In line with this, women's behavior is described as more oriented toward cooperation than competition which could result in increased emotional sensitivity and responsiveness (see also Weiß et al., 2023 for recent gender-specific data on associations between mental health and personal concerns and support). Here, this approach might lead to a stable vocal emotion recognition response in women across different stress levels. This approach is in line with "The Primary Caretaker Hypothesis" discussed by Babchuk et al. (1985). Given the historical context where women managed household responsibilities while simultaneously caring for their infants without continuous visual contact, the ability to discern emotional signals from vocal cues could be considered crucial for their overall well-being. Even today, women still take care of their offspring to a significantly higher percentage than men, resulting in a simply higher level of experience in voice emotion recognition. In contrast, for men, evolutionary mechanisms might make them more likely to take in the “big picture” only, that is, to focus on the most relevant (acoustic) parameters and to ignore the details. With such an approach, a rough discrimination between positive and negative emotions is sufficient to decide for “fight or flight.” Another possible explanation for the decreasing sensitivity to sadness in medium stressed men could also be a kind of resilience factor for the men, given the evidence that men are more resilient compared to women (Bangasser et al., 2019; Hodes & Epperson, 2019). By reducing sensitivity to negative emotions, they initially “protect” themselves from empathic stress (Blons et al., 2021), which may make them more resilient. However, why does an auditory “quick and dirty” discrimination or the proposed protection mechanism only affect men in the medium perceived stress condition? Or more specifically, why are men better at detecting emotional vocal signals under high as compared to medium perceived prolonged stress? One answer might be that under high stress conditions, men may switch to some kind of hyperresponsiveness (Schultz-Krohn, 2013). Hyperresponsiveness is characterized by an excessively strong reaction to a sensory, nonnoxious stimulus mediated by a heightened state of arousal which in turn leads to a collapse of the proposed strategies. The idea that under heightened arousal particularly strong attention is paid to socially relevant sensory stimuli is also in line with results provided by Wirkner et al. (2019) who reported evidence for enhanced attentional processing toward new stimuli under high chronic stress conditions; however, they included only women and not men in their sample.

Finally, it is important to note that our current results on perceived stress and emotion recognition may be influenced by an unmeasured parameter that coincidentally correlates with the perceived stress level. We only measured perceived stress (PSS10) and did not use objective parameters such as hair cortisol, which could have provided more accurate data. It is possible that men in the medium and high stress group have different levels of emotional self-awareness, which may affect their self-reported stress levels. Emotional self-awareness enables individuals to comprehend the reasoning and physiological correlates underlying each emotion (Rieffe et al., 2008). G. J. Taylor and Bagby (2013) argue that individuals who are unaware of their own emotional states may struggle to empathize with others and regulate their emotions effectively. This is supported by research indicating that emotional self-awareness is necessary for empathy as it enables perspective-taking and self–other differentiation (Decety & Jackson, 2004, 2006; Haley et al., 2017; Lane & Schwartz, 1987; Moriguchi et al., 2007; Trentini et al., 2022). Social stress has been shown to reduce sensitivity and responsiveness in mother–child interactions (Muller-Nix et al., 2004; Rani et al., 2016). Conversely, reduced stress levels have been found to increase empathic behavior in both humans and rodents (Martin et al., 2015). Michalec (2010) suggested that medical students may adapt to stress experienced during medical school by becoming less empathetic, potentially to decrease their vulnerability to stress. It is possible that men in the medium stress group were less empathetic than those in the high stress group, and therefore less aware of their own stress levels. Previous studies have shown that low empathy can decrease emotion recognition, particularly for sadness (Maximiano-Barreto et al., 2022). If men in the medium stress group were less empathetic on average, this could explain their performance dip. However, it is important to note that Duesenberg et al. (2016) found no effect of empathy on emotion recognition, but did find a gender effect. Therefore, this speculative approach does not fully explain a general male disadvantage under medium stress; it only suggests that empathy differences in men may be a potential mediator of the stress effect, a possibility that future studies may wish to take into account.

Recommendation for Future Studies

Taken together, we found evidence that women show stable emotion recognition performance under different perceived stress levels, while there is a u-shaped relationship between perceived stress and sadness recognition in men. These findings are independent of task demands (time pressure). Although we tested a large sample ($N \sim 400$), the interpretation of why only the medium stressed men group shows this difficulty remains difficult to interpret with much certainty. We thus recommend for future studies to collect both objective (hair or saliva cortisol) and subjective (self-assessment data) stress parameters to allow for a combined analysis. Our online data collection approach did not allow for such a direct comparison. Following the idea that medium stress levels might be linked to differences in other emotion functions (e.g., empathy), additional background data could be collected to shed light on these types of speculations. Specifically, such a parallel survey would help to clarify to what extent the perceived stress level depends on an individual’s empathy and how the two parameters interact with each other. Different scenarios are conceivable here: (a) Empathic people are more aware of their own stress and rate it as higher; (b) empathy and perceived stress are independent of each other, but both influence the recognition of emotions, that is, the more empathetic, the better the recognition, the more stressed, the worse the recognition; (c) the higher the perceived stress level, the lower the ability to empathize, that is, under stress the ability to empathize decreases and with it the recognition of emotions in speech. Our data do not initially suggest this connection, but it would have to be considered in future studies. Furthermore, to control for hormonal differences in samples, it could be useful to also test postmenopausal women in future studies. This would test whether the stable performance in women is hormonally driven or whether the better performance in emotion recognition is a skill learned through socialization that remains stable even under stress.

Finally, in studies of gender and sex, it’s crucial to address an often-overlooked limitation: the inconsistency in measurement methods across the literature. While our article emphasizes maintaining the terminology used in cited studies (“men” and “women”), it is unclear whether these labels are based on self-reported gender identity or assigned sex at birth in each study. This variability poses challenges in synthesizing findings and calls for caution in drawing conclusions. Additionally, the observed effects may be shaped by a complex interplay of social and biological factors, highlighting the need for further interdisciplinary research to clarify their relative contributions.

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Received June 21, 2023
Revision received March 25, 2024
Accepted April 17, 2024 ■