SEX DIFFERENCES IN THE EFFECTS OF STRESS ON EMOTION RECOGNITION

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Alexandra Ennis

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Abstract

Research suggests that females are generally better at emotion recognition than males, but emotion type may moderate this difference. Stress responses may also be moderated by sex, and may affect emotion recognition. Minimal research has examined the effect of stress on sex differences in emotion recognition. The present study examined the moderating effects of sex, stress (high/low), cortisol reactivity (responders/non-responders), and emotion type (threat/non-threat) on auditory and visual emotion recognition accuracy and reaction time (RT). A psychosocial stress task was used to effectively induce stress, as demonstrated by significant stress group differences in subjective stress, cortisol, and heart rate (HR) increases. For facial emotion, a significant interaction showed that females who demonstrated a cortisol stress response were slower than non-responders, whereas male responders were faster than non-responders. An interaction trend emerged for facial emotion when controlling for RT, in which females were faster than males in the low stress condition, but slower than males in the high stress condition. For auditory emotion, cortisol responders demonstrated increased accuracy and decreased RT for threat emotions, but sex did not moderate these effects. Collectively the results suggest that stress and cortisol reactivity may improve emotion recognition, but only in males on facial tasks.

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Dedication

I would like to dedicate this to all of my family and friends who have helped and supported in getting to this point in my academic career. A special thanks to Christian for his love and support, and for putting up with me through it all.

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Sex Differences in the Effects of Stress on Emotion Recognition

Emotion recognition is an important aspect of all social interactions and, along with empathy, is an important aspect of social cognition (Quintana, Guastella, Outhred, Hickie, & Kemp, 2012). Emotion recognition is a key aspect of non-verbal communication and takes place primarily in visual and auditory domains. Visual emotion recognition involves recognizing emotional facial expressions (Quintana et al., 2012), while auditory emotion recognition involves recognizing emotional intonations of a person's voice (Whittle, Yucel, Yap, & Allen, 2011). Together, both domains work to communicate a person's emotional status and are important in guiding social interactions.

Generally, the recognition of emotions can be broken into two major categories, positive emotions (e.g., happy, surprised) and negative emotions (e.g., sad, angry; Hampson, van Anders, & Mullin, 2006). In relating the positive and negative valences of emotion to general action tendencies of approach or avoidance, emotions may also be split into threat (e.g., anger, fear) and non-threat (e.g., happy, sad) categories (Green & Phillips, 2004; Williams, Palmer, Liddell, Song, & Gordon, 2006). The different emotional types are processed differently, such as different patterns of event-related potentials to threat-related and non-threat-related emotional expressions (Williams et al., 2006), with some literature suggesting that the sex of the viewer may also influence the speed and/or accuracy of recognition (Hampson et al., 2006; Stevens & Hamann, 2012). Further, some research suggests that different physiological or affective states, such as stress—characterized by subjective experiences, activation of the sympathetic nervous system (SNS), and activation of the hypothalamic-pituitary-adrenal (HPA) axis—may influence the speed and accuracy of emotion recognition (Feeney, Gaffney, & O'Mara, 2012). Despite evidence of sex differences in both stress responses (e.g., Kajantie & Phillips, 2006) and emotion

recognition (e.g., Hampson et al., 2006; Stevens & Hamann, 2012), there is very little research on sex differences in the effects of psychosocial stress on emotion recognition. The present study adds to this research area by examining the differential effects of stress on sex differences in emotion recognition.

Sex Differences in Emotion Recognition

Research on sex differences in emotion recognition has generally shown females to be better at emotion recognition than males (e.g., Duesenberg et al., 2016; Hampson et al., 2006; Stevens & Hamann, 2012). Some research suggests that females are only better than males at recognizing subtle emotions, but there is no difference between the sexes in highly expressive stimuli (Duesenberg et al., 2016; Hoffman, Kessler, Eppel, Rukavina, & Traue, 2010), while other research suggests that female superiority in recognizing emotions exists in highly expressive stimuli as well (Hampson et al., 2006; Whittle et al., 2011).

Sex differences in emotion recognition may also be related to threat or non-threat related emotions. Females have been found to be more accurate and have quicker response times in recognizing threat emotions than males (Hampson et al., 2006; McClure et al., 2004). These differences are also related to different patterns of brain activation, with evidence indicating sex differences in response to different valences and threat versus non-threat categories of emotional stimuli (McClure et al., 2004; Stevens & Hamann, 2012; Williams et al., 2005).

Existing neuroimaging research suggests that different patterns of brain activation are displayed in females compared to males during emotion recognition. Greater levels of limbic regions (amygdalae, anterior cingulate, and thalamus), inferior frontal cortex, and temporal cortex activation have been observed in females during auditory and visual tasks of emotion recognition compared to males (Whittle et al., 2011). Further, during auditory emotion

recognition tasks, females have higher activation in the left middle temporal gyrus, while males have higher activation in the right middle frontal gyrus (Whittle et al., 2011). The differences in activation suggest that males and females may use different cognitive strategies in recognizing emotions, which may contribute to differences in emotion recognition accuracy.

Stress Responses

In response to stress, several physiological pathways are activated, including the SNS and the HPA axis (Kajantie & Phillips, 2006). The SNS is a component of the peripheral nervous system and its activation, which is commonly known as the "fight or flight" response, involves a large number of physiological changes, amongst which is an increase in HR (Thayer, Ahs, Fredrikson, Sollers, & Wager, 2012). The increase in HR affects brain functioning, preferentially impacting regions such as the medial prefrontal cortex (mPFC) and the amygdala, which are important for many mental processes, including decision making and emotion regulation (Thayer et al., 2012). Experiences of stress also activate the HPA axis in the brain, which increases the secretion of glucocorticoids, such as cortisol (Duesenberg et al., 2016; Paris et al., 2010). The HPA axis is the primary circuit of the neuroendocrine stress system, and is an essential pathway in the moderation of many psychological processes, such as social facets of cognition, decision making, learning and memory, and emotion processing and regulation (Duesenberg et al., 2016; Peters et al., 2016).

Of importance to the present study, research suggests that there are sex differences in reactions to stress; however, the actual differences vary across studies. Some results indicate sex differences in self-report measures of stress, but not in HR variability or cortisol levels in reactivity to a social stress test (Kelly, Tyrka, Anderson, Price, & Carpenter, 2008), while others found sex differences in both HR and cortisol stress responses (Bangasser & Valentino, 2014).

A review by Paris and colleagues (2010) found that sex differences in stress responses may be primarily modulated by the type of stressor (such as psychosocial or physical stressors) and individual differences in other hormones such as estrogen and testosterone.

The activation of various brain regions due to cortisol may also vary based on sex. Kogler and colleagues (2016) assessed cortisol levels and resting-state functional connectivity (rsFC) of the left and right amygdalae and found sex differences in activation patterns in response to cortisol. Specifically, cortisol levels in females were negatively associated with rsFC between the amygdalae and the striatal regions, mid-orbital frontal gyrus, anterior cingulate gyrus, middle and superior frontal gyri, supplementary motor area, and parietal-occipital sulcus, while cortisol levels in males were positively associated with rsFC between the left amygdala and the other regions. Cortiocotropin-releasing factor (CRF) receptor signalling may also be sex biased. Research suggests that females' locus coeruleus may be more sensitive to CRF, causing an enhanced stress response, as well as estrogen having a positive effect on the release of CRF (Bangasser, Wierseilis, & Khantsis, 2016; Valentino, Van Bockstaele, & Bangasser, 2013). Collectively, these studies suggest that sex differences in response to stress are not only found behaviourally, but in patterns of neural activation as well.

Stress and Emotion Recognition

Based on the patterns of brain activation in response to stress, it is logical to suggest that stress will modulate emotion recognition. In regards to the HPA axis of stress reactions, research has shown higher cortisol levels at rest to be associated with quicker identification of emotional facial expressions, as well as being associated with a greater tendency to judge neutral faces as emotional (Feeney et al., 2012). Related to this, Quintana and colleagues (2012) found that HR

variability at rest was positively associated with performance on emotion recognition tasks. Thus, stress responses do seem to modulate emotional processes.

There is preliminary evidence suggesting that sex may be differentially related to stress effects on emotion recognition. Smeets, Dziobek, and Wolf (2009) found that after a stressor performance on a measure of social cognition was better in males with high cortisol levels compared to males with low cortisol, whereas females with low cortisol were more accurate than females with high cortisol. Somewhat counter to this, a study by Duesenberg and colleagues (2016) examining the direct effects of cortisol (rather than psychosocial stressors) found no effect of hydrocortisone (an exogenous equivalent of cortisol) administration on sex differences in emotion recognition.

The Present Study

These differences in findings, and the lack of other research, led to the focus of the present study, examining sex differences in the effects of stress responses on emotion recognition. The differential findings may be due to the limited emotion recognition tasks, as well as the use of hydrocortisone administration rather than the individuals participating in a social stress test. Despite the differences in results of behavioural studies, sex differences in brain activation (such as norepinephrine arousal and structural differences in the locus coeruleus) suggest that females may be biased toward increased arousal in response to emotional events (Bangasser et al., 2016), and thus may have an advantage in emotion recognition tasks under conditions of stress.

Based on the extant literature (namely, Hampson et al., 2006; McClure et al., 2004; Smeets et al., 2009), it was hypothesized that when stressed, females would demonstrate greater accuracy and quicker RTs for threat compared to non-threat emotions, but would have decreased

accuracy and increased RTs overall compared to non-stressed females. For males, it was expected that under conditions of stress they would demonstrate increased accuracy and decreased RTs overall, with greater accuracy and quicker RTs for non-threat emotions specifically. It was expected that these effects would be present for both auditory and visual emotion recognition.

Method

Participants

The present study was approved by the University of Regina Research Ethics Board (see Appendix A). Eighty-five participants (55 females, 30 males) aged 18-31 years (M = 21.23 years, SD = 3.12) were recruited from the University of Regina's Department of Psychology Pool of Research Participants. Exclusion criteria were for factors associated with atypical cortisol levels, and for those that could have affected the integrity of the hormone assay (Salimetrics, 2015). Specifically, participants were excluded if they were habitual smokers or nicotine users (Granger et al., 2007), were currently using hormone medications or contraceptives (e.g., Birth control pills or Depo-Provera) or had used them in the past 3 months (Granger, Hibel, Fortunato, & Kapelewski, 2009; Roche, King, Cohoon, & Lovallo, 2013), were currently pregnant or lactating (Geisbrecht, Campbell, & Letourneau, 2015), had any oral injuries or disease that could cause bleeding or high levels of bacteria (Salimetrics, 2015), or had self-reported a diagnosis with a mental illness (Zandstra, Ormel, Nederhof, Hoekstra, & Hartman, 2015). In addition, individuals with a major medical condition were excluded, as they could have had adverse reactions to the stress manipulation (Duesenberg et al., 2016). Finally, individuals with any uncorrected visual or auditory impairments were excluded in order to avoid impacts on the visual and auditory tasks. All participants signed a written informed consent form

and were given a 2% bonus mark applied to their final grade in one of the psychology courses registered in the Participant Pool.

Stress Manipulations

High stress condition. The Trier Social Stress Test (TSST) was used for the high stress condition manipulation in the present study. The TSST is a psychosocial laboratory stressor that was developed by Kirschbaum, Pirke, and Hellhammer (1993). It is 12 minutes long, and consisted of a 2 minute speech preparation period in which the participant was asked to write a speech for an interview for their ideal job, followed by a 5-minute speech in which the participant was asked to speak the entire time, and finished with a 5-minute mental arithmetic task wherein the participant was asked to serially subtract by 7s from 2000 as quickly and accurately as possible. The tasks were performed in front of a panel of two unresponsive judges. The TSST has been used in numerous studies and is known to reliably provoke a robust cortisol response, as well as the sympathetic stress response (Allen et al., 2016).

Low stress condition. The low stress condition manipulation was modeled after the TSST. It was also 12 minutes long, consisting of a 2-minute speech preparation period wherein the participant was asked to prepare a speech about their favourite book or movie, followed by a 5-minute speech in which the participant was asked to speak the entire time, and finished with a 5-minute simple counting task wherein the participant was asked to count aloud. The tasks were performed in a private room alone.

Emotion Recognition Tasks

Visual emotion recognition. A computerized facial emotion recognition task, administered via Eprime (2) software, was used to assess visual emotion recognition. For this task, the participants viewed a video of a face changing from a neutral expression to one of six

basic emotional expressions (anger, fear, happiness, sadness, surprise, and disgust). Participants were asked to indicate which emotion was displayed by pressing the number on a keyboard that corresponded to the number displayed with the written emotion word on the computer screen. Each emotional expression was shown five times in a random order, resulting in 30 trials in total. Response time and accuracy of responses were measured. The faces used in this task were taken from Matsumoto and Ekman's data set (1988), and made into videos using Abrosoft FantaMorph (2016) morphing software.

Auditory emotion recognition. Green's Emotion Perception Task (EPT; Green, Flaro, & Allen, 1999) was used as the measure of auditory emotion recognition. Participants heard sense and non-sense sentences spoken in one of four emotional intonations (anger, fear, happiness, sadness) and a neutral intonation. They then indicated which emotion was heard via keyboard press of the appropriate number matching the number of the written emotion word displayed on the computer screen. Each emotional intonation was heard 18 times, resulting in 90 trials (45 sense and 45 non-sense sentences) given in a random order. Response time and accuracy of responses were measured. The EPT has been shown to be reliable and valid in assessing auditory emotion recognition (Green et al., 1999).

Stress Measures

Cortisol. Salivary cortisol levels were assessed to examine HPA axis response to the stress manipulation. Three saliva samples were collected from each participant during the test session, using the passive drool method of saliva collection (Salimetrics, 2015). The saliva was stored at -40C and analyzed in-house using Salimetrics cortisol enzyme immunoassay kits.

Heart rate (HR). To assess SNS activation, participant's HR was measured. HR was measured using an iHealth HR monitor made by Apple. There were a total of five readings recorded during the test session.

State-Trait Anxiety Inventory-State (STAI-State; Spielberger, Gorsuch, Lushene, Vagg, & Jacobs, 1983). To measure the subjective stress experienced by participants, the STAI-State was used. The STAI-State is one of two subscales of the STAI. It is a 20-item self-report questionnaire that measures the anxiety a person feels at the present moment. All items are rated on a four-point scale (1 = *not at all*, 2 = *somewhat*, 3 = *moderately so*, 4 = *very much so*). Higher scores indicate greater anxiety. The STAI-State has good internal consistency, test-retest reliability, and demonstrates construct and concurrent validity (Spielberger et al., 1983, 1989).

Reaction Time (RT) Task

A basic RT task was used to account for individual differences in RT and possible differential effects of stress on RT. The task was a computerized measurement that has two components: one visual and one auditory. The task was modeled after the emotion recognition tasks of the present study in format, number of responses, and number of trials. The RT task allowed the current study to account for any effect general RT may be having on the emotion recognition task. For each trial of the visual RT task, participants saw an oval that was one of six colours (blue, green, red, yellow, purple, or orange) on a computer screen, and then selected the written option displayed on the screen that corresponded to the colour by selecting the number associated with the colour word using a keyboard. For each trial of the auditory RT component, participants heard one of five colour words (blue, green, red, yellow, or orange) via a headset, and then selected the written option displayed on a computer screen that corresponded to the

spoken word by selecting the number associated with the word using the keyboard. Participants were asked to respond as quickly and as accurately as possible.

Mood Measures

Center for Epidemiological Studies-Depression (CES-D; Radloff, 1977). The CES-D was used to determine if participants had any depressive symptoms that could influence cortisol levels or performance on the emotion recognition tasks. It is a 20-item self-report questionnaire that measures depressive symptoms experienced in the past week. Respondents indicate on a 4-point scale (0 = *Rarely or none of the time* (less than 1 day), 1 = *Some or a little of the time* (1-2 days), 2 = *Occasionally or a moderate amount of the time* (3-4 days), 3 = *Most or all of the time* (5-7 days)) how often they had spent feeling or behaving a particular way in the past week. Higher scores indicate greater depressive symptoms. The CES-D has high internal consistency and test-retest reliability, and has been shown to be valid across a demographic range (Radloff, 1977).

State-Trait Anxiety Inventory-Trait (STAI-Trait; Spielberger et al., 1983). The STAI-Trait was used to determine if participants had any symptoms of anxiety which could influence cortisol levels. The STAI-Trait is the second 20-item subscale of the STAI, and it measures the anxiety a person feels in general. All items are rated on a four-point scale (1 = *almost never*, 2 = *sometimes*, 3= *often*, 4 = *almost always*). Higher scores indicate greater anxiety. The STAI-Trait has good internal consistency, test-retest reliability, and demonstrates construct and concurrent validity (Spielberger, 1989; Spielberger et al., 1983).

Demographics/Saliva Screening Questionnaire

Participants were asked to complete a demographics questionnaire and saliva screening form. This form concerned general demographic information and addressed variables that could

have an impact on cortisol levels and/or the integrity of the hormone assay. Questions gathered information regarding food or drinks consumed prior to the testing session, participant's body-mass index, menstrual phase, any visual or auditory impairments, any mental or medical illnesses, and any hormone medications the participant had taken within the last 3 months.

Procedure

A 2 (stress group: high/low) x 2 (sex: males/females) between-subject design was employed. Male and female participants were randomly assigned to either the high (n = 32) or low stress (n = 53) condition. Participants were tested in sessions between 12h and 18h to minimize effects of diurnal cortisol fluctuations (Feeney et al., 2012). Participants were asked to avoid alcohol consumption and vigorous physical activities 24 hours before the testing session, caffeine use 4 hours prior to the session, and to avoid putting anything in their mouths (e.g., food, gum, beverages other than water) one hour prior to the session, in order to avoid factors that could affect the integrity of the assay or cortisol concentrations (Salimetrics, 2015).

Upon arrival to the test session, participants were asked to sign an informed consent form. They then rinsed their mouths with water to ensure no food particles would affect the saliva samples (Salimetrics, 2015). Then they completed a demographics questionnaire and saliva screening sheet, the STAI-State to establish baseline levels of subjective stress, as well as the two mood measures, CES-D and STAI-Trait. While these questionnaires were filled out, the first HR reading was recorded. Participants then gave the first saliva sample, which was used to determine baseline cortisol level.

Next, participants completed the stress manipulation task, with HR recorded during both the speech and math tasks. Participants then completed the visual and auditory emotion recognition tasks, during which HR was recorded. A second saliva sample was then taken, and

they completed the STAI-State a second time. Next, they gave their third, final saliva sample, then completed the visual and auditory basic RT measures. The emotion recognition and basic RT measures were given to participants in a counterbalanced order. Upon completion of all measures, participants were given an educational debriefing.

Results

Preliminary Analyses

Between-subject ANOVAs were performed to test for confounding variables and to check the stress manipulation. Two 2 (stress group: high/low) x 2 (sex: male/female) between-subject ANOVAs were performed to check if STAI-Trait or CES-D scores were confounding variables that differed between males and females, or between the stress groups. Both STAI-Trait and CES-D demonstrated statistically significant main effects of stress group, with the high stress group having higher scores on each, $F(1, 81) = 5.59$, $p < .02$, $\eta_p^2 = .07$ (high stress: $M = 41.95$, $SD = 1.93$; low stress: $M = 36.06$, $SD = 1.58$) and $F(1, 81) = 4.50$, $p < .04$, $\eta_p^2 = .05$ (high stress: $M = 14.76$, $SD = 1.59$; low stress: $M = 10.42$, $SD = 1.30$), respectively. The main effect of sex and the sex by stress group interactions were not significant for either analysis (all ps > .07).

Three 2 (stress group: high/low) x 2 (sex: male/female) ANOVAs were also used to check the effectiveness of the stress manipulation, and demonstrated significant effects of stress group for all three stress measures, with the high stress group having greater increases in each: STAI-change, $F(1, 81) = 11.27$, $p < .001$, $\eta_p^2 = .12$ (high stress: $M = 6.45$, $SD = 1.50$; low stress: $M = -.05$, $SD = 1.23$); cortisol response, $F(1, 72) = 13.87$, $p < .001$, $\eta_p^2 = .16$ (high stress: $M = .133$, $SD = .03$; low stress: $M = .001$, $SD = .02$); and HR response, $F(1, 76) = 10.01$, $p < .002$, $\eta_p^2 = .12$ (high stress: $M = 97.44$, $SD = 2.65$; low stress: $M = 86.72$, $SD = 2.12$). For HR, there was

also a statistically significant main effect for sex, $F(1, 76) = 5.06$, $p < .03$, $\eta_p^2 = .06$, with females having greater HR increases than males (females: $M = 95.89$, $SD = 2.08$; males: $M = 88.27$, $SD = 2.68$).

Main Analyses

Mixed-design 2 (stress group: high/low) x 2 (sex: male/female) x 2 (emotion type: threat/non-threat) x 2 (cortisol reactivity: non/responders) ANCOVAs, using CES-D and STAI-Trait as covariates, were used to examine sex and stress effects on the visual and auditory emotion recognition measures. With visual emotion recognition accuracy as the dependent variable, there was a trend for cortisol reactivity, $F(1, 65) = 3.50$, $p = .07$, $\eta_p^2 = .05$, with non-responders having higher accuracy than responders (responders: $M = .84$, $SD = .02$; non-responders: $M = .89$, $SD = .02$). No other main effects or interactions were significant (all ps > .34).

For visual emotion recognition RT, there was a statistically significant sex by cortisol reactivity interaction, $F(1, 65) = 6.0$, $p < .02$, $\eta_p^2 = .08$, with male responders having statistically significant faster RTs than non-responders, $t(27) = 2.19$, $p < .04$, and female responders having non-statistically significantly slower RTs than non-responders, $t(44) = 1.31$, $p = .20$ (see figure 1). There was also a trend for an emotion type by sex interaction, $F(1, 65) = 3.36$, $p = .07$, $\eta_p^2 = .05$, with statistically significantly slower RTs for threat emotions than non-threat emotions, for both males, $t(29) = 6.43$, $p < .001$, and females, $t(52) = 9.55$, $p < .001$ (see figure 2). No other main effects or interactions were significant (all ps > .11). When basic RT was controlled for in a subset of the participants, a trend for a sex by stress group interaction approached significance, $F(1, 12) = 3.52$, $p = .09$, $\eta_p^2 = .23$, with low stress males being slower than high stress males, $t(9)$

= 1.58, p = .15, and high stress females being slower than low stress males, $t(10)$ = .77, p = .46 (see figure 3). No other main effects or interactions were significant in this subset (all ps > .23).

For auditory emotion recognition accuracy, there was a statistically significant emotion type by cortisol reactivity interaction, $F(1, 67) = 7.81$, $p < .007$, $\eta_p^2 = .10$, with non-responders demonstrating statistically significantly greater accuracy for non-threat compared to threat emotions, $t(33) = 7.07$, $p < .001$, as well as a trend for responders demonstrating greater accuracy for non-threat compared to threat emotions, $t(42) = 1.81$, $p = .08$. There was also a trend for non-responders demonstrating greater accuracy than responders for non-threat emotions, $t(73) = 1.89$, $p = .06$, but no significant differences between the groups for threat emotions, $t(73) = 1.35$, $p = .18$ (see figure 4).

With auditory emotion recognition RT as the dependent variable there was a statistically significant emotion type by cortisol reactivity interaction, $F(1, 67) = 5.78$, $p < .02$, $\eta_p^2 = .08$, with statistically significantly faster RTs for non-threat emotions compared to threat emotions for both cortisol responders, $t(42) = 5.48$, $p < .001$, and non-responders, $t(33) = 7.37$, $p < .001$. There were no significant differences in RT between responders and non-responders for either threat, $t(73) = .67$, $p = .51$, or non-threat emotions, $t(73) = 1.19$, $p = .24$ (see figure 5). There was also a trend for a 3-way interaction of emotion type by stress group by cortisol reactivity, $F(1, 67) = 3.57$, $p = .06$, $\eta_p^2 = .05$, suggesting that non-responders in the high stress condition were driving the two-way interaction, demonstrating much slower RTs for threat emotions than for nonthreat emotions compared to all other groups.

When a subset of the sample was examined with basic auditory RT controlled for, the emotion type by cortisol reactivity interaction was strengthened, $F(1, 12) = 8.80$, $p < .01$, $\eta_p^2 = .42$, again showing that non-responders were much slower for threat emotions than non-threat

emotions, $t(5) = 3.23$, $p < .02$, as were responders, $t(16) = 5.01$, $p < .001$, with no significant differences between the groups for either threat, $t(73) = 1.57$, $p = .12$, or non-threat emotions, $t(73) = 1.15$, $p = .25$. A trend also emerged for an emotion type by sex interaction, $F(1, 12) = 4.39$, $p = .06$, $\eta_p^2 = .27$, which was superseded by a trend for an emotion type by sex by cortisol reactivity interaction, $F(1, 12) = 4.34$, $p = .06$, $\eta_p^2 = .27$. This three-way interaction shows that female non-responders, $t(3) = 4.73$, $p < .02$, female responders, $t(7) = 3.44$, $p < .01$, and male responders, $t(8) = 3.50$, $p < .01$, were statistically significantly faster at recognizing non-threat emotions compared to threat emotions, and that in the recognition of threat emotions male responders were statistically significantly faster than non-responders, $t(27) = 2.69$, $p < .01$. No other pairwise comparisons were significant in this interaction (all ps > .06; see figure 6). A trend for a stress group by sex by cortisol reactivity interaction was also observed, $F(1, 12) = 4.09$, $p = .07$, $\eta_p^2 = .25$, with male responders in the low stress group having statistically significantly faster RTs than non-responders, $t(15) = 2.58$, $p < .02$, and female non-responders in the low stress group having statistically significantly faster RTs than male non-responders in the same group, $t(22) = 2.82$, $p < .01$. No other pairwise comparisons were statistically significant (all ps > .07; see figure 7).

Discussion

Sex Differences in Emotion Recognition

Analyses indicated there were no significant main effects or interactions regarding sex differences in emotion recognition; however, there was a trend for an emotion type by sex interaction in visual emotion recognition RT, with both females and males demonstrating significantly slower RTs for threat compared to non-threat emotions. This was unexpected, as the limited current research suggests that females have greater accuracy and quicker RTs for

threat emotions compared to non-threat emotions (Hampson et al., 2006; McClure et al., 2004). There was also a trend for an emotion type by sex interaction in auditory RT when basic auditory RT was controlled for in a subsample of participants; however, this interaction was superseded by an emotion type by sex by cortisol reactivity interaction. These trends do not support the current literature that females are better at emotion recognition than males, but, along with other results suggest that sex differences in emotion recognition may be moderated by the effects of stress.

Sex Differences in Stress Responses

As hypothesized, results indicated a significant sex by cortisol reactivity interaction in visual emotion recognition RT, wherein male responders were significantly faster than non-responders, and female responders were slower than non-responders. Two interactions also approached significance: a sex by stress group interaction in visual emotion recognition RT and a stress group by sex by cortisol reactivity interaction in auditory emotion recognition RT (with basic auditory RT controlled for). In both the visual and auditory tasks, males who were more stressed (in the high stress condition or showed a cortisol response) were faster than males who were less stressed, whereas females who were more stressed were slower than females who were less stressed. These three interactions support the hypothesis that in both auditory and visual domains of emotion recognition, stressed males would be better at emotion recognition than non-stressed males, while stressed females would be worse than non-stressed females. These findings are also in line with the findings of Smeets and colleagues (2009), who also found that males with higher cortisol levels (compared to males with lower cortisol) and females with lower cortisol levels (compared to females with higher cortisol) demonstrated increased accuracy on a social cognition measure.

Stress Effects on Emotion Recognition

There were significant interactions between emotion type and cortisol reactivity in both auditory emotion recognition accuracy and RT, wherein participants who did not show a cortisol response demonstrated increased accuracy and decreased RTs for non-threat compared to threat emotions. Cortisol responders, on the other hand, demonstrated a small, non-significant increase in accuracy and decrease in RT for threat emotions; however, both responders and non-responders were faster at recognizing non-threat compared to threat emotions in both visual and auditory domains. These results suggest that when a person is not stressed, recognition of non-threat emotions is significantly better than recognition of threat emotions, and that this tendency may remain after experiences of stress as well. This finding is contrary to much of the literature on emotion recognition, which indicates that people generally have faster RTs for recognizing threat compared to non-threat emotions (Williams et al., 2006).

Sex Differences in Stress Effects on Emotion Recognition

When basic auditory RT was controlled for in a subsample of participants there was a trend for a three-way interaction of sex by emotion type by cortisol reactivity in auditory emotion recognition RTs. In this trend, female responders, female non-responders, and male responders were all significantly faster at recognizing non-threat emotions compared to threat emotions. Male non-responders also showed much faster RTs for non-threat compared to threat emotions, but this result was not significant – likely due to the very small sub-sample size of only two. These findings do not support the hypotheses, as it was expected that stressed females would differ from non-stressed females, stressed females would be better at recognition of threat emotions compared to non-threat, and that stressed males rather than non-stressed males would be better at recognizing non-threat emotions. On the other hand, male responders were found to

be significantly faster than non-responders at recognizing threat emotions, which does support the hypothesis that when stressed, males would demonstrate increased accuracy and decreased RTs in the recognition of threat emotions, compared to males that were not stressed.

Conclusion

The current study investigated whether sex moderates the effects of stress on emotion recognition. Overall, the results suggest that stress may only enhance visual emotion recognition in males, but not for auditory emotion recognition or for females. Emotion recognition may also be better for non-threat compared to threat emotions in all people, regardless of experiences of stress.

The primary strength of this study was the examination of multiple stress measures, as well as multiple domains of emotion recognition. No other study could be found that has assessed all of the same factors at the same time, thus this study was better able to directly examine the relationships between these variables. A limitation of this study was a small sample size, with unequal males and females and high and low stress groups, as a larger sample size would have likely produced more significant results, such as the interaction trends that approached significance in this sample. The high CES-D and STAI-Trait scores in the high stress group are also a concern, as they were significant confounding variables. This problem was unexpected, as stress groups were randomly assigned, and would thus be difficult to better control for.

Future research should focus on trying to enhance the sex by cortisol reactivity or stress group interactions found in this study. Very little research has examined the effects of stress on emotion recognition, and even less research has examined this relationship in regards to sex differences. Previous studies have primarily examined stress responses on cortisol levels, HR,

and subjective feelings individually, but the present study examined all three responses concurrently, attempting to more fully assess experiences of stress in the three major domains in which they are presented. The present study also uniquely contributes to the literature by examining the effects of stress on both visual and auditory emotion recognition tasks, as most of the previous research has focused on visual emotion recognition only. Assessing both domains poses a more ecologically valid approach, as both domains are important aspects of social interaction in every day life.

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Appendix A: Research Ethics Approval

University of Regina

Research Ethics Board
Certificate of Amendment and Renewal Approval

PRINCIPAL INVESTIGATOR	DEPARTMENT	REB#
Alexander Cameron	Psychology	2015-165

SUPERVISOR (S)
Dr. Laurie Sykes Tottenham

TITLE
The Effects of Stress on Emotion Recognition

AMENDMENT APPROVAL OF	ORIGINAL DATE of APPROVAL	NEXT RENEWAL DATE	DATE OF AMENDMENT APPROVAL
• Addition of computerized reaction time measure • Add Alexandra Ennis to research team	November 10, 2015	November 10, 2017	November 16, 2016

Full Board Meeting ☐ Delegated Review ☒

RENEWAL CERTIFICATION
The University of Regina Research Ethics Board has renewed the above-named research project for an additional 12 months beginning November 10, 2016.

Any significant changes to your proposed method, or your consent and recruitment procedures should be reported to the Chair of the Research Ethics Board for consideration in advance of implementation.

AMENDMENT CERTIFICATION
The University of Regina Research Ethics Board has reviewed the changes to the above-named research project as outlined in your memo dated November 2, 2016 and they are approved.

ONGOING REVIEW REQUIREMENTS
In order to receive annual renewal, a status report must be submitted to the REB Chair for Board consideration within one month of the current expiry date each year the study remains open, and upon study completion. Please refer to the following website for further instructions:
http://www.uregina.ca/research/for-faculty-staff/ethics-compliance/human/forms1/ethics-forms.html

Ara Steininger
Research Ethics Board

Please send all correspondence to:

Research Office
University of Regina
Research and Innovation Centre 109
Regina, SK S4S 0A2
Telephone: (306) 585-4775 Fax: (306) 585-4893
research.ethics@uregina.ca

Appendix B: Figures

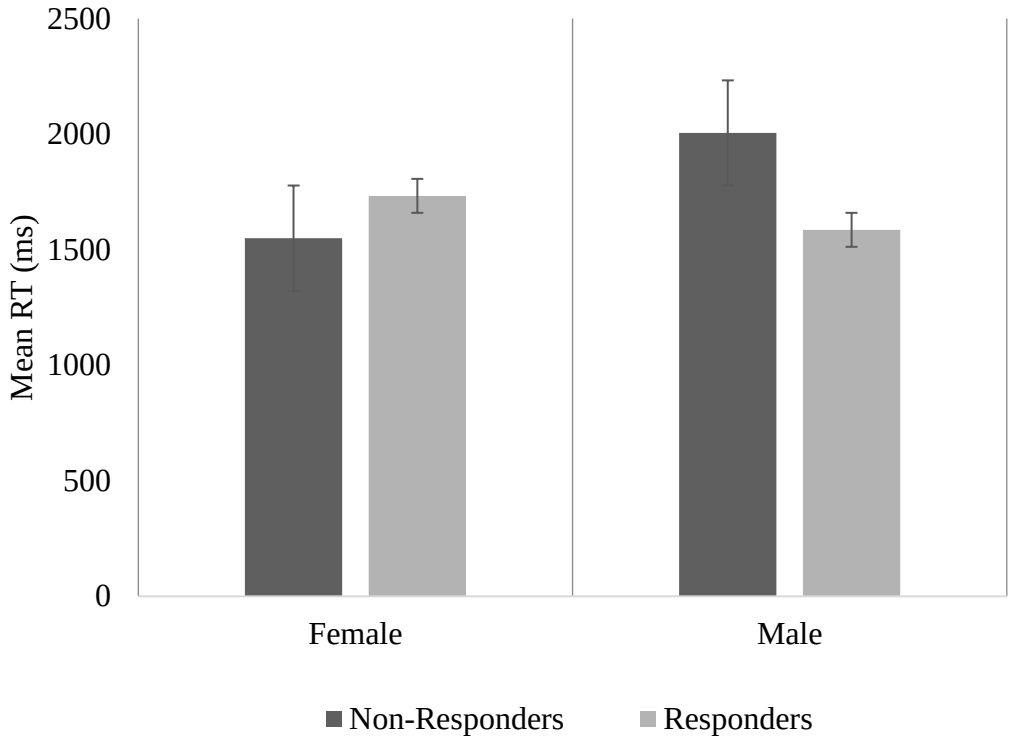

Figure 1. Visual emotion recognition RT: sex by cortisol reactivity interaction.

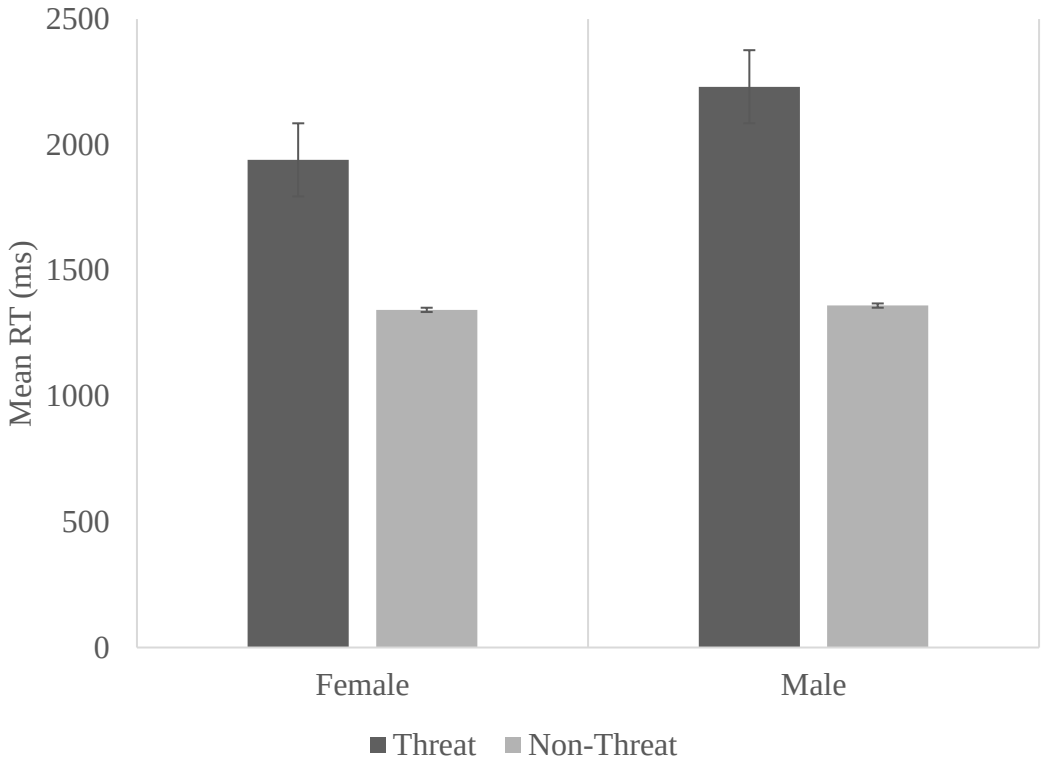

Figure 2. Visual emotion recognition RT: sex by emotion type interaction.

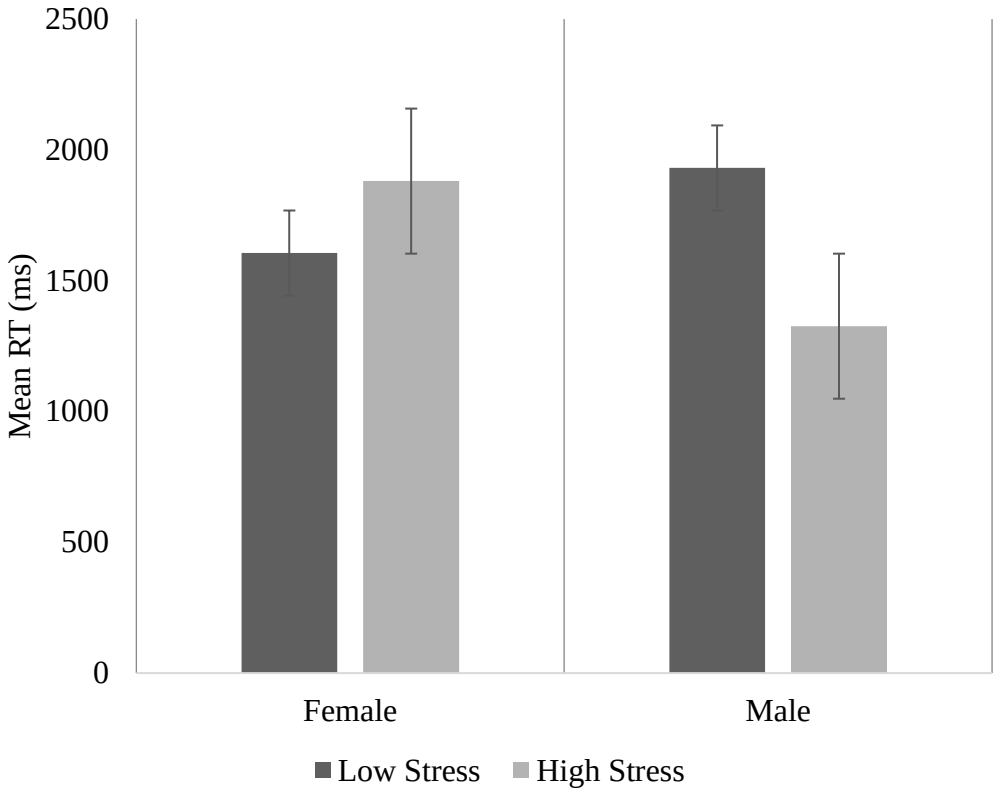

Figure 3. Visual emotion recognition RT (with basic RT covariate): sex by stress group interaction.

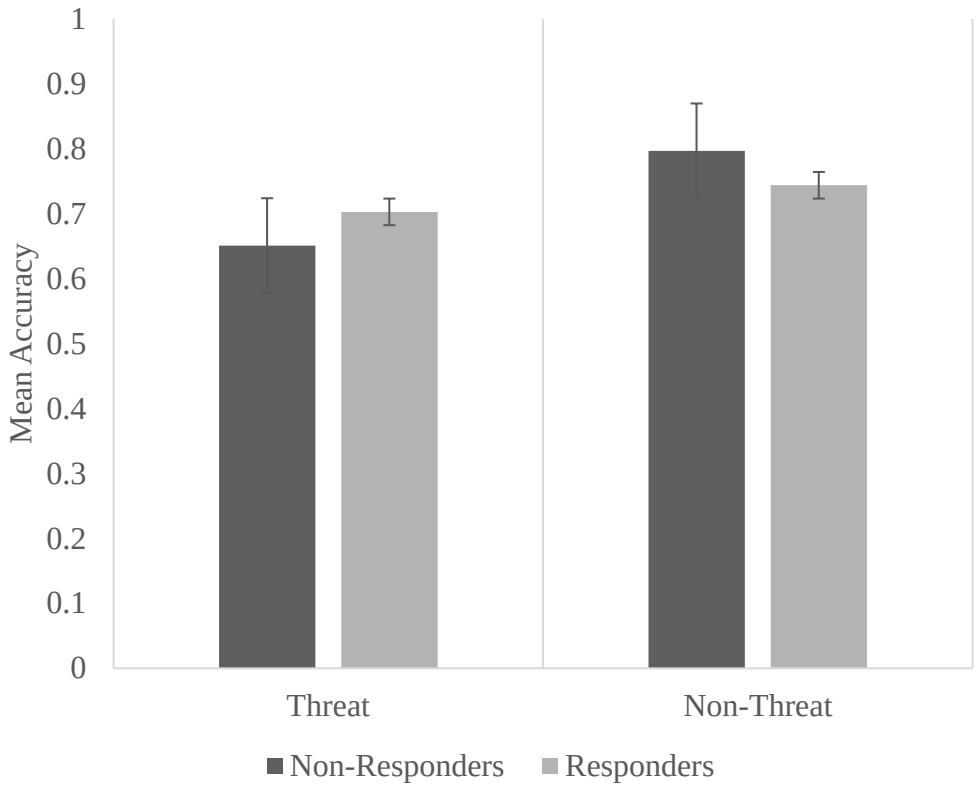

Figure 4. Auditory emotion recognition accuracy: emotion type by cortisol reactivity interaction.

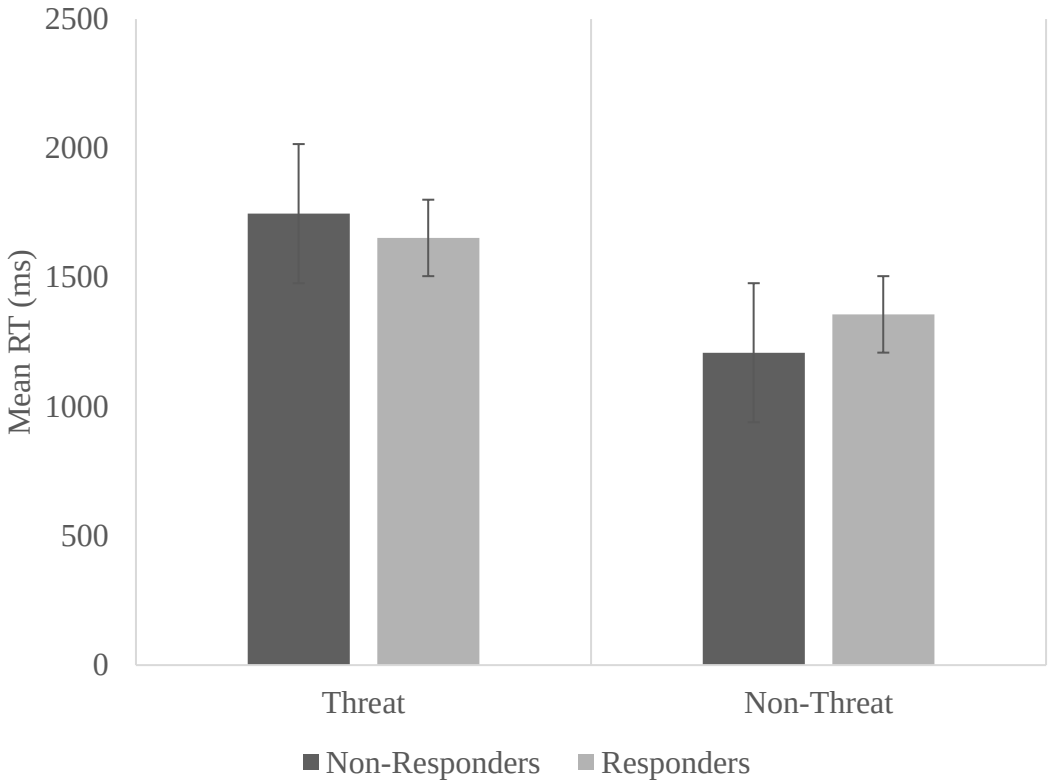

Figure 5. Auditory emotion recognition RT: emotion type by cortisol reactivity interaction.

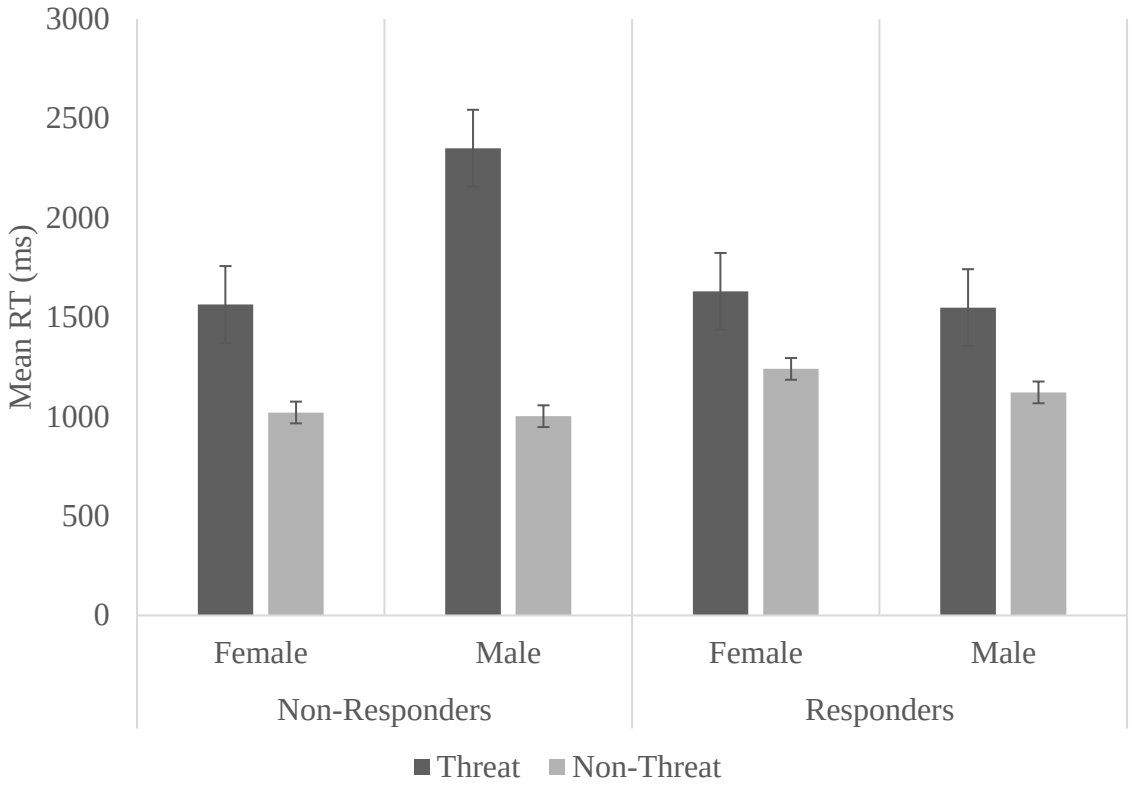

Figure 6. Auditory emotion recognition RT (with basic RT covariate): emotion type by sex by cortisol reactivity interaction.

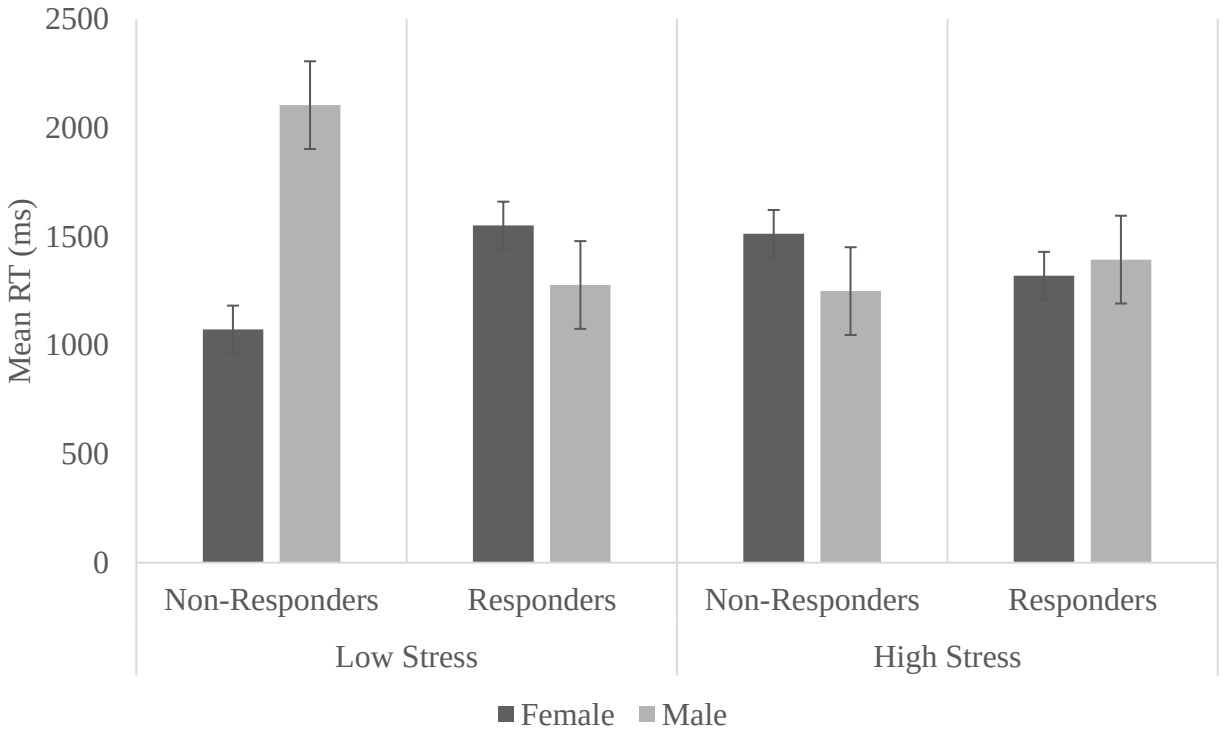

Figure 7. Auditory emotion recognition RT (with basic RT covariate): stress group by sex by cortisol reactivity interaction.