UNIVERSITY OF CENTRAL OKLAHOMA

GRADUATE COLLEGE

YOUR POKER FACE UNDER PRESSURE: AUTONOMIC NERVOUS SYSTEM AROUSAL AS A MODERATOR OF THE REALTIONSHIP BETWEEN EXPRESSIVE SUPPRESSION AND FACIAL AFFECT SENSITIVITY

A THESIS

SUBMITTED TO THE GRADUATE FACULTY

In partial fulfillment of the requirements for

the degree of

MASTER OF SCIENCE IN EXPERIMENTAL PSYCHOLOGY

By

KALA ANDERSON

Edmond, Oklahoma

2026

YOUR POKER FACE UNDER PRESSURE: AUTONOMIC NERVOUS SYSTEM AROUSAL AS A MODERATOR OF THE REALTIONSHIP BETWEEN EXPRESSIVE SUPPRESSION AND FACIAL AFFECT SENSITIVITY

A Thesis APPROVED FOR THE

DEPARTMENT OF PSYCHOLOGY

BY

Alicia McLean
____

Alicia McLean, Ph.D., J.D.

____

Robert Mather, Ph.D.

Peter Rerick
____

Peter Rerick, Ph.D.

Table of Contents

Acknowledgments

Completing this thesis has been one of the most rewarding experiences of my academic journey. This project required countless hours of planning, data collection, analysis, writing, and revision, and it would not have been possible without the encouragement, guidance, and support of so many. I am sincerely grateful to everyone who contributed to this achievement, whether through mentorship, collaboration, or encouragement.

First, I would like to express my deep gratitude for my professors, Dr. Alicia McLean, Dr. Robert Mather, Dr. Peter Rerick, Dr. Mark Hamlin, and Dr. Vickie Jean, whose expertise, mentorship, and dedication to student success has helped me grow as a scientist and as an academic.

I would also like to extend my appreciation to the Jackson College of Graduate Studies, the UCO Department of Psychology, the College of Education and Professional Studies, and the UCO Office of High Impact Practices for providing the resources, opportunities, and institutional support that made this research possible.

To my peers and colleagues, thank you for your encouragement, collaboration, and willingness to share ideas throughout this journey. Whether through discussing research, offering feedback, celebrating successes, or providing reassurance during challenging moments, your friendship and support has left an indelible impact on me.

Next, I would like to thank my family. Your love and patience has been a source of strength and motivation for me. Thank you for supporting me through the good times and the bad.

Finally, I would like to thank everyone who contributed to this research, including the participants who generously volunteered their time. Your contributions made this work possible.

List of Figures

Abstract

Expressive suppression is an emotion regulation strategy that involves inhibiting the outward expression of emotion and can influence both the experience and perception of emotions (Gross, 1998a). Research suggests that expressive suppression impairs facial affect sensitivity, or the ability to accurately identify emotions in others' facial expressions (Schneider, Hempel, & Lynch, 2013). The present study investigates the impact of expressive suppression on university students' facial affect recognition and whether autonomic nervous system (ANS) arousal moderates this relationship. Participants completed a facial effect recognition task involving gradually morphed expressions ranging from neutral to full emotional intensity. During the task, participants were instructed to either suppress their expressions or maintain a natural, relaxed expression. ANS arousal was induced via cold pressor intervention, and heart rate was measured using electrocardiography (ECG). Response time, accuracy, and heart rate change over time were assessed using multiple analyses of variance. Although results were not significant, several outcomes trend in the hypothesized direction, suggesting that a more robust sample is necessary to fully investigate the role of ANS arousal on the relationship between expressive suppression and facial affect sensitivity.

Your Poker Face Under Pressure: Autonomic Nervous System Arousal as a Moderator of the Relationship Between Expressive Suppression and Facial Affect Sensitivity

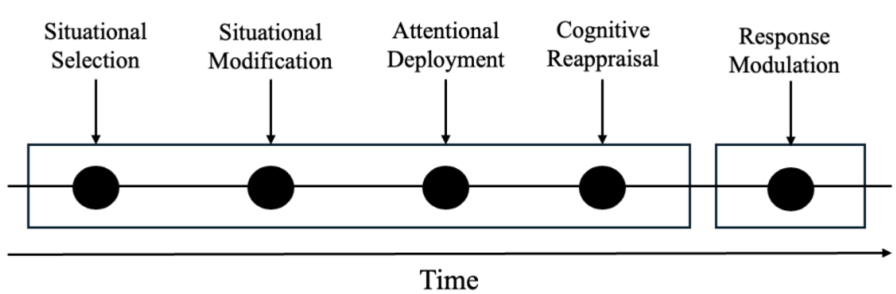
Expressive suppression is an emotional regulation strategy that involves the inhibition of outward expressions of emotion, particularly facial expressions, to modulate an emotional response or influence a social situation (Gross, 1998b; Gross & Thompson, 2007). Facial affect sensitivity (FAS) refers to individuals' ability to identify and interpret facial expressions of emotions in others. FAS is an essential part of interpersonal communication and relationships; people use interpretations of facial expressions to assess others' attitudes and intentions (Horstmann, 2003). Research by Schneider, Hempel, and Lynch (2013) found that ES significantly impairs FAS performance. Autonomic nervous system arousal has an understudied and contradictory role in the relationship between these two variables. Research has shown that expressive suppression both increases ANS arousal (Butler, et al., 2003) and the exacerbates perceptions of arousal intensity (Knauft, et al., 2026). Moreover, research demonstrates that ANS arousal improves FAS (Balconi & Pozzoli, 2009). Building on these findings, the present study examined whether ANS arousal moderates the relationship between ES and FAS. It was hypothesized that the combination of ANS arousal and expressive suppression would produce the greatest impairment in facial affect sensitivity relative to the control and spontaneous expression conditions. Specifically, participants in the ANS arousal and expressive suppression condition were expected to demonstrate the poorest accuracy, the slowest response times (RTs), and the greatest heart rate reactivity, due to the effortful nature of expressive suppression.

Emotional Regulation

The process model of emotional regulation describes emotional regulation (ER) as conscious or unconscious process that moderates the intensity, duration, and behavioral or physiological response to an emotion. The process model is rooted in the modal model of emotion, which describes how emotions are generated (Gross & Thompson, 2007). Gross and Thompson (2007) suggest that emotions unfold in a temporal sequence: a situation occurs that captures ones' attention, the situation is appraised, and the system produces a behavioral and physiological response. The process model of emotional regulation describes five ER strategies that occur at different positions during an emotional experience (see Figure 1). These strategies include situational selection, situational modification, distraction, cognitive reappraisal, and/or response modulation (Gross & Thompson, 2007). Situational selection involves making choices to decrease the likelihood of ending up in an undesirable situation, like avoiding going to my mother-in-law's house for Thanksgiving. Situational modification involves making choices to change or leave an undesirable situation, leaving Thanksgiving dinner early, for example. Distraction, or attentional deployment, involves individuals diverting their attention from adverse events, such as ignoring my mother-in-law and focusing on football.

Figure 1

Process Model of Emotional Regulation (Gross & Thompson, 2007). Created in Microsoft PowerPoint.



Expressive suppression is a form of response modulation, the only response-focused ER technique described by the process model of emotional regulation. ES occurs after an emotional experience has begun, resulting in the downregulation of expressive behavior (Gross, 1998a).

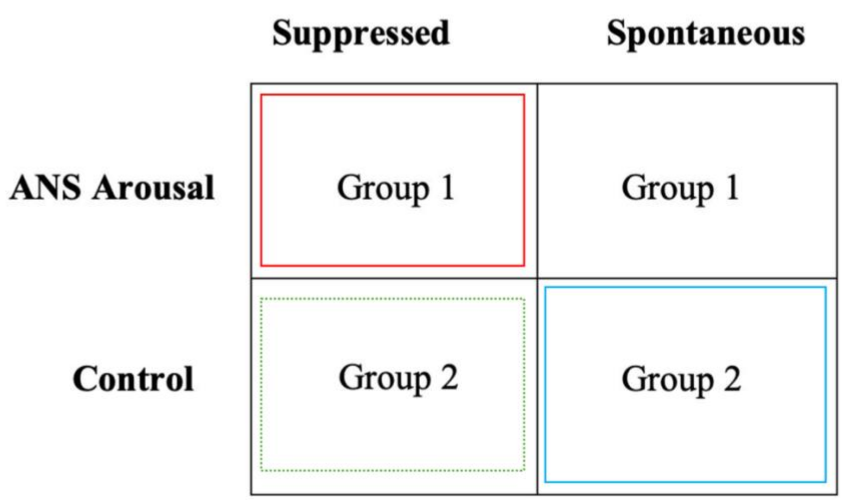
Holding my tongue and modifying my body language after my mother-in-law insults my grandmother's cornbread recipe, for example. Cognitive reappraisal is one of the four antecedent-focused ER strategies, meaning it occurs before the onset of an emotional response, giving an individual time to re-evaluate and change their perception of an emotion and how they respond (Gross & John, 2003). For example, my mother-in-law just experienced divorce and is feeling lonely, so I decide to have patience before she ever insults my cornbread. Compared to ES and control conditions, participants using cognitive reappraisal reported more positive emotions, less negative emotions, less behavioral avoidance (Gross, 1998b). Of all the emotional regulation strategies described by the process model, ES is associated with the most emotional, cognitive, and social consequences. ES has been shown to increase physiological arousal consistent with the emotion being suppressed. For example, the suppression of fear is associated with an increase in heart rate, respiration, and galvanic skin response, which is the pattern of physiological arousal typically associated with a fear response (Colby, Lanzetta, & Kleck, 1977; Notarius & Levenson, 1979). Habitual use of expressive suppression is associated with impaired attentional control (Zhao, et al., 2026), poorer executive function (Niermeyer, et al., 2019), learning (Suchy, et al. 2019), memory (Greenaway, et al., 2026), and planning (Niermeyer, Franchow, & Suchy, 2016). Additionally, habitual expressive suppression is associated with impaired empathy (Anderson, et al., 2021) and poorer social functioning (Butler, et al., 2003). ES is effective in the short-term, when dealing with acute stress or trauma (Gan, et al., 2014), but becomes maladaptive with habitual use and may result in a higher incidence of PTSD and depression (Moore, Zoellner, & Mollenholt, 2008).

The use of ES increases sympathetic nervous system activity, which may be due to increased cognitive load associated with the effort exerted during the use of ES (Gross, 1998a;

Gross & Levenson, 1993, 1997). Indeed, the study by Schneider, Hempel, and Lynch (2013) questioned whether the impairment of FAS caused by ES was due to the cognitive load associated with holding one's face still. The researchers included a cognitive load control condition, instructing participants to mimic the target expression. They found there was no significant difference between the cognitive load condition and the spontaneous expression condition; they concluded that the impairment in FAS performance was due to impaired facial mimicry and afferent feedback from the facial muscles, not the cognitive load associated with holding one's face still. Indeed, research has shown that reduced facial muscle movement associated with Botox treatment also results in impaired FAS (Neal & Chartrand, 2011). In the original study by Schneider, Hempel, and Lynch (2013), participants were instructed to identify facial expressions while holding a suppressed expression, a spontaneous expression, or a mimicked expression. There was no precipitating autonomic or emotional event preceding the task, however; the use of expressive suppression was purely motor rather than a dynamic integration between motor, perceptual, and emotional systems, such is the case with emotional regulation. Consequently, although Schneider et al. (2013) demonstrated that ES impairs FAS, it remains unclear whether similar impairments occur when ES is used during genuine physiological arousal, as would be expected during naturally occurring emotional regulation. Therefore, in this study, researchers sought to induce a state of physiological arousal to approximate a state of high stress or emotionality. Moreover, there is a gap in the literature regarding the role of ANS arousal in the relationship between ES and FAS. Research has shown that expressive suppression both increases ANS arousal (Butler, et al., 2003) and the exacerbates perceptions of arousal intensity (Knauft, et al., 2026). Indeed, research demonstrates that ANS arousal improves FAS (Balconi & Pozzoli, 2009; Baudouin, et al., 2025). The researchers hypothesized, consistent with the Yerkes-Dodson law, that although moderate ANS arousal may facilitate FAS, the additional physiological and cognitive demands imposed by expressive suppression would elevate arousal beyond its optimal level. Indeed, a meta-analysis conducted by Tyra, Fergus, and Ginty (2024) suggests that suppression may exacerbate stress-induced physiological arousal. Consequently, the combined effects of ANS arousal and ES were expected to disrupt perceptual processing, resulting in poorer FAS performance (See Figure 2).

Figure 2

Hypothesized results; individuals in the ANS/suppressed expression (red) condition are expected to have the poorest performance, while participants in the control/spontaneous group (blue) were expected to have the best performance. The suppressed/control group (green) represents Schneider, Hempel, and Lynch's (2013) hypothesized outcome. A significant difference in performance in the suppressed expression condition between ANS and control groups would indicate a moderating influence of ANS arousal on FAS.



An important consideration in this study is the robust effect of sex on FAS. Schneider, Hempel, and Lynch (2013) found a significant difference in expression recognition ability between the sexes, with females outperforming males. This result is found in many studies, suggesting males are less accurate in perceiving and less sensitive to differences in facial expressions compared to females (Montagne, et al., 2005; Wingenbach, Ashwin, & Brosnan, 2018). Therefore, it is hypothesized that female participants will outperform male participants on the FAS task. Moreover, the ability to recognize facial expressions is a key component of affective empathy, or our understanding of others' emotional state. Studies have shown that individuals high in empathy allocate more attention to facial expressions, compared to those low in empathy (Choi, et al., 2014). Therefore, it is hypothesized that individuals that report higher empathy on the Perth Empathy Scale (PES; Brett et al., 2023) will have better performance on the perceptual task. Additionally, because habitual cognitive reappraisal is associated with better cognitive and behavioral outcomes compared to ES (Cutuli, 2014; Yan, et al., 2022), it is hypothesized that individuals who report greater habitual cognitive reappraisal use on the Emotional Regulation Questionnaire (ERQ; Gross & John, 2003) will have better performance than those who report habitual ES. Lastly, because the ability to recognize emotional expressions is thought to result from one's ability to mimic or simulate that expression, one could assume that the inability to accurately identify one's own emotions hinders the ability to recognize emotions in others. Indeed, research has demonstrated this is the case (Parker, Taylor, & Bagby, 1993). Therefore, it is hypothesized that individuals that score highly on the Perth Alexithymia Questionnaire (PAQ-S; Preece, Becerra, Robinson, & Dandy, 2018) would have the poorest accuracy and slowest RTs on the perceptual task.

Embodied Simulation

The impairment in FAS performance during ES may be understood through the embodied simulation framework. Schneider, Hempel, and Lynch (2013) proposed that ES disrupts facial mimicry, thereby reducing the afferent feedback generated by facial muscle activity during emotion perception. Rather than attributing impaired performance solely to the cognitive demands of maintaining a neutral facial expression, they argued that restricting facial movement interferes with the sensorimotor processes that normally support emotion recognition. From this perspective, emotion perception is not purely a visual decoding process but is partly supported by embodied mechanisms that link perception and action, or embodied simulation (Niedenthal, et al., 2010).

Embodied simulation is rooted in the broader theory of embodied cognition, the idea that cognitive processes emerge from dynamic interactions among perceptual, motor, and sensory systems rather than operating independently of the body. In this view, perceiving another person’s emotional expression automatically engages corresponding sensorimotor representations in the observer, allowing the expression to be understood through partial internal simulation. Facial mimicry represents the observable motor component of this process, involving subtle and often unconscious activation of facial muscles that correspond to the observed expression. The facial feedback hypothesis further suggests that this muscle activity generates afferent signals that contribute to the neural representation of the perceived emotion, thereby supporting more accurate emotion recognition (Gallese, 2007). Accordingly, ES may impair FAS by limiting facial mimicry and reducing the afferent feedback necessary for effective embodied simulation. A closely related account is provided by grounded cognition theory. Barsalou (1999) argues that conceptual knowledge is not stored in abstract, amodal symbols, but is instead grounded in perceptual, motor, and introspective states derived from prior experience. In the embodied view, concepts, like emotional expressions, are represented as perceptual symbol systems. Within these systems, conceptual processing involves the partial reactivation or simulation of modality-specific neural states associated with earlier perceptual and bodily experiences. For example, perceiving another person’s expression of anger, and engaging in facial mimicry, may partially reactivate corresponding sensorimotor and affective states in the observer, supporting understanding of the emotion through embodied simulation mechanisms. Moreover, embodied simulation differs from traditional theories of emotion recognition like basic emotions theory (Ekman, 1992), which suggests humans are born with a limited set of innate, discrete emotions that are expressed through stable facial muscle patterns that are universally recognized (Izard, 1994); in other words, emotions represent biologically hardwired emotion programs or amodally represented concepts. Dimensional perspectives of emotion recognition are based on the work of William James, who suggested facial expressions are processed along affective dimensions, positive or negative valence and arousal (Baudouin, et al., 2025).

Psychophysiological Coherence

Although embodied simulation provides a compelling mechanistic explanation for the effect of ES on FAS, emotion perception also depends upon coordinated interactions among physiological, behavioral, and cognitive systems. Levenson (2014) described this coordination as psychophysiological coherence, suggesting that emotions organize multiple response systems into an integrated functional state that promotes adaptive behavior. Or, more simply put, emotions arise from the coordination of bodily experiences and are influenced by context and experience. Moderate autonomic arousal may enhance attentional focus (Lee, et al., 2018) and facilitate perceptual processing, thereby improving the detection of emotionally salient stimuli (Balconi & Pozzoli, 2009). However, ES may disrupt this coordinated response by requiring individuals to inhibit one component of the emotional system while physiological arousal continues to increase. Rather than functioning independently, physiological activation and expressive behavior may interact dynamically during emotion perception. Consequently, intentionally suppressing facial expressions during heightened physiological arousal may reduce the efficiency with which perceptual, motor, and autonomic systems operate together.

This prediction is consistent with the Yerkes-Dodson law (Yerkes & Dodson, 1908), suggesting an inverted U-shaped relationship between arousal and performance. Moderate levels of arousal generally facilitate attention and performance, whereas excessive arousal impairs complex cognitive processes that depend upon executive control and attentional resources. Because ES is cognitively demanding and disrupts facial mimicry, the additional experience of ANS arousal may push individuals beyond the optimal level of physiological activation for accurate perception of expression. Rather than producing independent or additive effects, expressive suppression and ANS arousal may interact nonlinearly, with heightened physiological reactivity amplifying the perceptual costs associated with disrupted embodied simulation. Previous research on psychophysiological coherence has primarily focused on the coordination of emotional experience, physiological responding, and expressive behavior during emotion elicitation (Mauss et al., 2005; Levenson, 2014). Comparatively, little research has examined how autonomic arousal influences perceptual processing when expressive behavior is intentionally constrained. The present study extends this literature by investigating whether ANS reactivity moderates the relationship between ES and FAS.

Methods

Participants

Participants (n = 27) were recruited using a combination of research pool, convenience, and snowball sampling methods. Undergraduate students were recruited through the University of Central Oklahoma's SONA research participation system and received course credit for participation. Graduate students were recruited via snowball sampling and word-of-mouth referrals. Additional community members were recruited through convenience and snowball sampling methods. Eligibility criteria included being 18 years of age or older and having normal or corrected-to-normal vision. Participants were excluded from analyses if they exhibited excessive ECG artifacts or failed to comply with task instructions. One participant was excluded from all analyses due to invalid data and procedural error. Three participants were excluded from the HR reactivity analysis due to excessive ECG artifacts or faulty equipment. Participants' ages ranged from 19-68. The sample was predominantly female (n = 20).

Materials

Autonomic nervous system (ANS) activity was recorded continuously using a BIOPAC MP150 system with an ECG100C amplifier module (BIOPAC Systems, Inc., Goleta, CA). Three LEAD110A shielded electrode leads and disposable EL503 Ag/AgCl electrodes were used for signal collection. Because the procedure involved submerging a hand in a bucket of water, and the completion of the experimental task involved precise hand movement, a standard lead-II placement with an electrode on the participants' wrist would be problematic. An electrode was placed on the right ankle (ground), the left ankle (VIN+), and the right side of chest, under the collarbone (VIN-). Although the electrode positions differed from conventional Einthoven lead-II placement, the ECG signal remained a measurement of cardiac electrical potential between two body-surface locations. The electrode locations were modified to accommodate experimental task requirements while maintaining a stable ECG recording. Similar departures from standard limb-lead placement have been reported in exercise ECG and ambulatory monitoring applications (Sheppard, et al., 2011). Because electrode locations differed from the standard Einthoven configuration, the recorded waveform should be regarded as a modified ECG lead rather than a true lead-II recording. Consequently, waveform morphology may differ from standard clinical ECG recordings, the signal was used for physiological data rather than diagnostic interpretation.

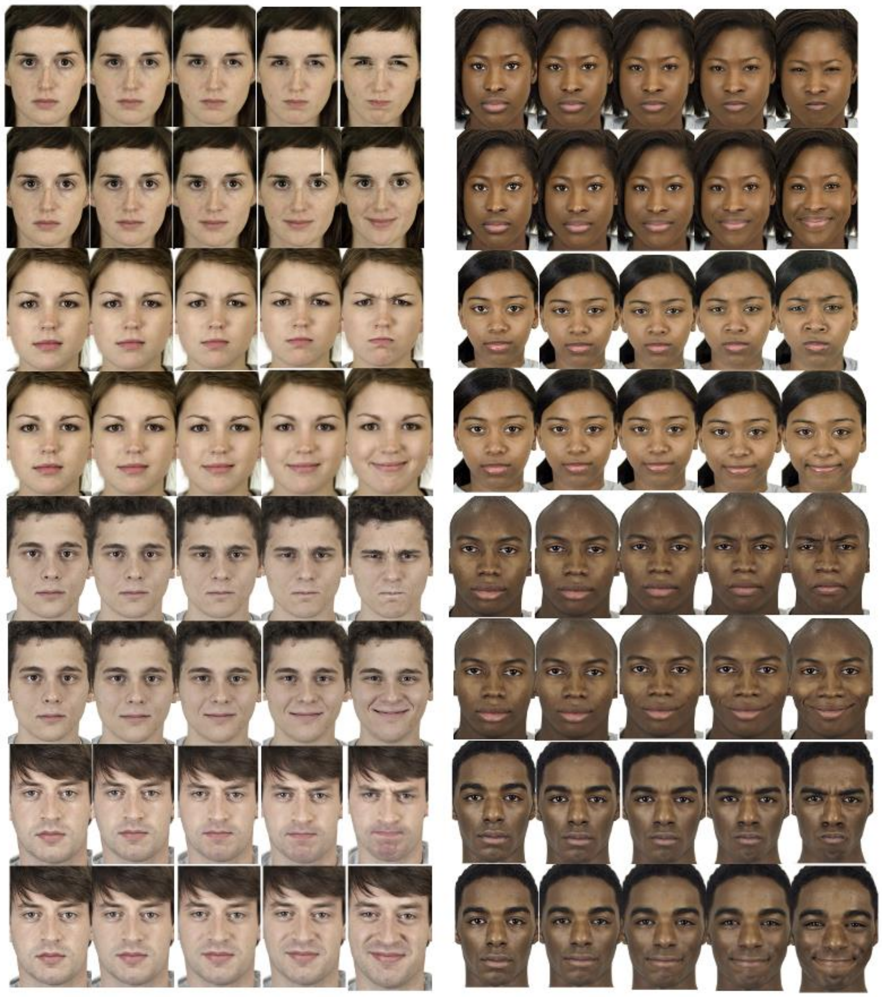
The ECG signal was sampled at a gain of 2000, the mode was set to normal. The 0.5 Hz high-pass filter was used to reduce baseline drift caused by respiration, movement, and electrode polarization effects while preserving the ECG waveform. The 35 Hz low-pass filter was enabled to attenuate high-frequency noise and electrical interference. Data acquisition was performed using BIOPAC AcqKnowledge software. Prior to participant testing, an empty graph template was created and the ECG100C amplifier was added through the Data Acquisition setup menu. Software parameters were matched to the hardware configuration to ensure consistency between the amplifier and acquisition software (Ex. Gain: 2000; Mode: NORM; HP: 0.5 Hz; 35 Hz LPN: ON). Acquisition channels were configured and labelled as follows: Channel 1 (Lead I); Channel 2 (Lead II); Channel 3 (Chest). A calculated channel (Lead III) was created within AcqKnowledge using the equation: Lead III = Lead II − Lead I. This calculation was implemented using the software's "Math" preset function to derive the third Einthoven lead from the recorded signals. The sampling rate was set to 1000 Hz using the "Record and Append Using Memory" acquisition mode with automatic acquisition length. A sampling frequency of 1000 Hz was selected to provide adequate temporal resolution for accurate identification of R-wave peaks and subsequent heart rate calculations.

ANS arousal was induced using a cold pressor task. Participants submerged their left hand in cold water maintained at approximately 5-7 °C for 30–60 seconds, depending on individual comfort and tolerance. A room-temperature water condition (20-22 °C) served as a control (See Figure 3). The cold pressor involved a 12-quart bucket measuring 15" x 12.75" x 6.5" with a metal mesh divider to separate the ice from the participants' hand. A submersible aquarium pump (160 gallons per hour, 10 watt) with plastic tubing was used to maintain water flow and decrease transient heat around the participants' hand. A submersible thermometer was used to monitor water temperature.

Facial affect sensitivity was assessed using a computerized task programmed in PsychoPy (Peirce et al., 2019). Stimuli were selected from the Chicago Face Database (CFD; Ma, Correll, & Wittenbrink, 2015), a standardized set of color facial photographs. Eight identities were selected: two black women, two black men, two white women, and two white men (See Figure 5). Targets of varied race and sex were used to account for variability along the affective dimension of emotion recognition (Baudouin, et al., 2025). For example, negatively valanced facial expressions, like anger, are more readily recognized in males (Tipples, 2019) and black people (Shapiro, et al. 2009), while positively valanced expressions like joy are more easily identified in females (Becker, et al., 2007). For each identity, five images were used representing graded emotional intensities: neutral (0%), 20%, 40%, 60%, and 100% intensity of either anger or happiness. In this study, anger and happiness were used as the target emotions due to limited morphed expression stimuli via CFD. Because joy and anger are considered highly valanced and among the easiest expressions to recognize (Springer, et al., 2007; Mancini, et al., 2013), researchers in this study determined that the use of two target emotions was appropriate. However, this does lend an additional limitation to the present research. The use of the remaining universal emotions, like surprise, fear, and disgust, would contribute significantly to the question at hand, as these emotions are differentially valanced; therefore, ES and FAS may interact variably under conditions of arousal.

Figure 3

Morphed facial expression stimuli sourced from Chicago Faces Database (Ma, Correll, & Wittenbrink, 2015).

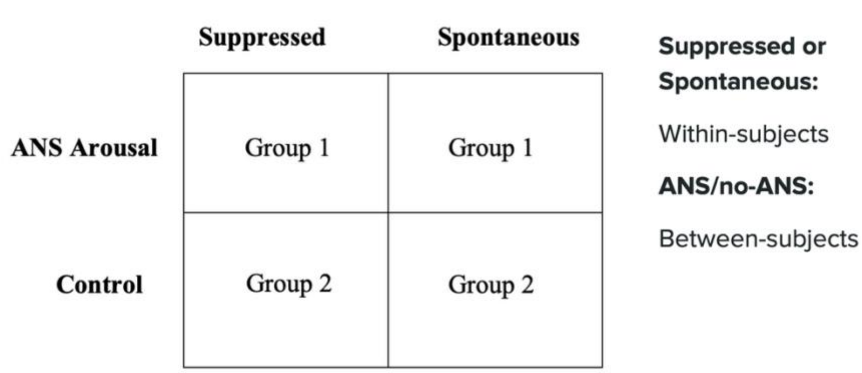


All images were presented in color. Each trial began with the neutral (0%) expression. The facial expression then progressively increased in intensity in a stepwise fashion (0% → 20% → 40% → 60% → 100%). Images were presented sequentially to create the percept of a gradually emerging emotional expression. The sequence terminated when the participant indicated recognition of the emotion. Participants were instructed to press specific keyboard keys to categorize the expression as either “happy” (“L” key) or “angry” (“A” key) as soon as they could confidently identify the emotion. Reaction time and the intensity level at which the participant responded were recorded. Expressive suppression was manipulated within subjects across two task blocks (See Figure 3). In the suppression condition, participants were instructed to maintain a neutral "poker face" and avoid any facial movement while completing the task. In the natural expression condition, participants were instructed to respond normally without attempting to regulate or suppress facial expressions. Block order was counterbalanced across participants. FAS was quantified through accuracy and response time (RT) data.

Participants completed self-report questionnaires via Qualtrics. First, they completed a survey of demographic information including age, race, and sex. Then, habitual emotion regulation strategy was assessed using the Emotion Regulation Questionnaire (ERQ; Gross & John, 2003). The ERQ is a 10-item self-report measure assessing two emotion regulation strategies: cognitive reappraisal and expressive suppression. Items are rated on a 7-point Likert scale ranging from 1 (strongly disagree) to 7 (strongly agree). Subscale scores were calculated according to published scoring guidelines, with higher scores reflecting greater habitual use of each strategy. Empathy was measured using the Perth Empathy Scale (PES; Brett et al., 2023). The PES is a 20-item self-report survey that assesses cognitive and affective empathy across both positive and negative emotional domains. Items are rated on a Likert scale, with higher scores indicating greater empathy. Alexithymia was assessed using the Perth Alexithymia Questionnaire (PAQ-S; Preece, Becerra, Robinson, & Dandy, 2018). The PAQ-S is 6-item self-report measure that assesses difficulties identifying and describing feelings across negative and positive emotional domains. Items are rated on a Likert scale, with higher scores indicating greater alexithymic traits.

Figure 4

Factorial Design



Procedure

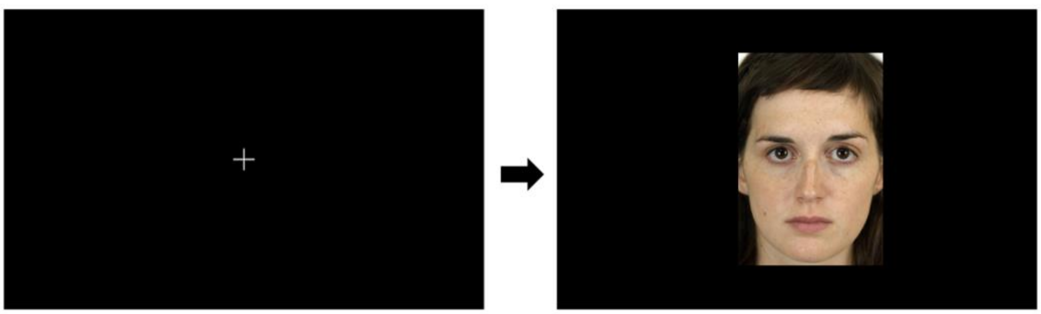
This study was conducted in the psychology laboratory on the University of Central Oklahoma campus. Upon entering the lab, participants were asked to read and sign an informed consent document, if they agreed to continue. The researcher prepared the participants' skin with an electrode abrading pad, to clear dead skin cells and reduce impedance. Next, the researcher applied electrode gel to each disposable Ag/AgCl electrode and placed the electrodes in a modified Lead II placement; one electrode was placed on each ankle and a third was placed under the right collarbone. To allow the electrode gel to set and further reduce impedance, the participants completed a battery of questionnaires including the ERQ, PES, and PAQ. Next, the researcher connected the electrodes to the ECG's lead wires. To collect a baseline and reduce noise from extraneous movement, the researcher instructed the participant to be seated near the cold pressor, with the apparatus to the left and the computer to the right. Once the participant was seated in the correct position, the researcher started the ECG and asked the participant to sit quietly for two minutes while a baseline HR was collected. After the two minutes passed, the participant was instructed to submerge their left hand, to the wrist, in the bucket of water. They were asked to keep their hand submerged up to a minute. In the ANS arousal condition, the water was exceptionally cold (5-7 °C). To avoid extreme distress or injury, the researcher reminded the participant that they could remove their hand at any time, and every 15 seconds, offered them an update on how much time had elapsed. After a minute (or less), participants were given paper towel to dry their hand. Then, the researcher asked them to move to the right side of the desk, facing the computer. The participants were 20-22 inches from the monitor.

The task was explained as such: participants would place an index finger on the "A" and "L" keys. They would see a series of faces that would start neutral but would progressively morph into an angry or happy facial expression. Their task was to indicate, as soon as they could, whether they saw an angry or happy expression by pressing the “A” or “L” keys, respectively. Between each target stimulus, a fixation cross appeared for 500ms (See Figure 5). The participant was prompted to take a 30 second break after the first block of stimuli was presented. While ANS arousal via cold pressor was the between-subjects variable in this study, embodied expression (suppressed/spontaneous) was the within-subjects variable. Each of the two blocks contained 16 trials, resulting in 32 total observations.

To control for order effects, the type of embodied expression used in each block was counterbalanced. For example, if participant A was in the ANS arousal condition and was told to suppress their expression during the first block, the next participant in the ANS arousal condition (participant C) would be instructed not to inhibit muscle reactivity during the first block. The same inverse relationship would exist between participants B and D, and so forth. In the suppressed expression condition, participants were asked to hold their facial muscles still; to avoid moving their eyebrows, mouths, and cheeks. A limitation to this study is the lack of a manipulation check, as the participant faced the computer, back to the researcher, during the task. In the spontaneous condition, the participants were told they could move their face, or not, whatever felt natural to them. An obvious concern with this design is the possibility of demand characteristics and cognitive load from engaging in suppression unduly influencing the results. Researchers did not include a separate cognitive-load control in the present study because prior work by Schneider, Hempel, and Lynch (2013) used a mimicry condition as a motor/cognitive control for expressive suppression and found that mimicry, a task requiring comparable voluntary facial control, did not produce the same decrement in facial affect sensitivity as suppression. Thus, Schneider et al.’s (2013) design indicates that performance costs observed in suppression are unlikely to be attributable solely to general task demands or motor/cognitive effort. Given this precedent, and because our primary theoretical focus is on autonomic mechanisms rather than task-demand confounds, researchers did not implement an additional cognitive-load manipulation. However, facial mimicry has been proposed as the mechanism behind the perceptual impairment (Neal & Chartrand, 2011; Schneider, Hempel, & Lynch, 2013), so the use of facial mimicry as a control for the impact of cognitive load may represent a confounding relationship.

Figure 5

Fixation cross to neutral target stimulus (0% prototypical expression)



Analysis

This study used a two-way, 2x2, between-within, mixed experimental design (See Figure 3). Due to the small sample size, multiple analyses were conducted. Researchers used IBM SPSS (version 28.0.0.0). Prior to analysis, trial-level response time and accuracy data were aggregated to the participant level. Mean response times, proportion accuracy scores, and heart rate change scores were calculated separately for the suppressed and spontaneous expression conditions. Because the expression conditions were counterbalanced across participants, scores were reorganized so that each participant had separate variables representing performance during the suppressed and spontaneous conditions regardless of the order in which the conditions were completed. An independent samples t-test was conducted to analyze sex differences in performance.

A 2x2 mixed-design analysis of variance (ANOVA) was conducted to examine the effects of arousal condition and expression condition on mean response time. Arousal condition (aroused vs. control) served as the between-subjects factor, and expression condition (suppressed vs. spontaneous) served as the within-subjects factor. An additional 2x2 mixed-design ANOVA was conducted to examine the effects of arousal condition and expression condition on heart rate change scores. Arousal condition (aroused vs. control) served as the between-subjects factor, and expression condition (suppressed vs. spontaneous) served as the within-subjects factor. Assumptions of normality were assessed using Shapiro-Wilk tests, skewness and kurtosis values, histograms, and Q-Q plots. Homogeneity of variance was assessed using Levene's test. Main effects and interaction effects were evaluated using an alpha level of .05. Because accuracy was derived from binary trial-level responses (correct vs. incorrect), responses were aggregated by condition to compute counts of correct and incorrect trials for each participant. Using the proportion scores derived from each block of the within-subjects factor (suppressed v. spontaneous), a final 2x2 mixed ANOVA was conducted to determine the effect of arousal and expressive suppression on task accuracy.

Several extreme values were identified in the response time and heart rate change variables. To reduce the influence of these observations while retaining participants in the analyses, outliers were Winsorized; extreme scores were replaced with the nearest non-outlying value. As noted previously, each dependent variable had two columns of scores, one for each within-subjects predictor. Distribution analyses revealed outliers in the spontaneous conditions of RT and HR change and suppressed condition of HR change. In total, two outliers were modified in both the spontaneous condition of RT and HR change. Three outliers were removed from the suppressed HR change condition. Following Winsorization, all variables demonstrated acceptable normality.

Heart rate change scores were calculated by subtracting baseline heart rate from task heart rate for each expression condition. ECG recordings were saved under participant identification numbers and time-stamped according to experimental phases, including baseline recording, cold pressor stress induction, and trial onset. For post-processing, ECG waveforms were duplicated and filtered using an infinite impulse response (IIR) filter. A 0.5 Hz high-pass filter was applied to remove low-frequency baseline drift, followed by a 40 Hz low-pass filter to reduce high-frequency noise. Average heart rates were subsequently calculated for each time period using the AcqKnowledge "find rate" function; due to noisy trial data, researchers identified and averaged the cleanest 30 second increment for each time period (baseline, trial 1, trial 2). Three participants were removed from the HR change analysis due to incomplete or illegible ECG recordings (n = 24).

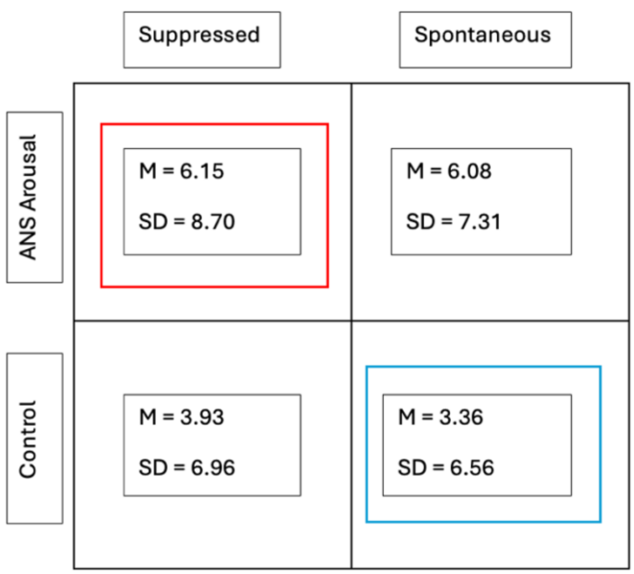
Results

Overall, the analysis did not yield statistically significant results. Regarding HR change scores (See Figure 6), participants in the within-subjects suppressed expression condition had higher HR change scores in both the between-subjects control (M = 3.93, SD = 6.96) and arousal condition (M = 6.15, SD = 8.70) compared to the spontaneous condition (M = 3.36, SD = 6.56; M = 6.08, SD = 7.31, respectively). However, the results of the ANOVA reveal that this relationship is not significant, $F(1, 22) = 1.130$, $p = .298$, $\eta p^2 = .043$. Additionally, there was no significant main effect of expression type on HR reactivity, $F(1, 22) = .039$, $p = .845$, $\eta p^2 = .002$.

Nor was there a significant interaction between expression type and arousal on HR reactivity, $F(1, 22) = .023$, $p = .882$, $\eta p^2 = .001$. Therefore, the hypothesis that participants in the expressive suppression and ANS arousal conditions would have the greatest HR reactivity was not confirmed. As expected, however, individuals in the ANS arousal condition had the greatest HR change scores in both the suppressed (M = 6.15, SD = 8.69) and spontaneous conditions (M = 6.08, SD = 7.30) compared to the control condition (M = 3.93, SD = 6.95; M = 3.36, SD = 6.56), suggesting that the cold pressor intervention was effective in eliciting ANS arousal.

Figure 6

The results of the HR reactivity analysis revealed that HR change scores trended in the hypothesized direction. The results of this ANOVA mimic the hypothesized results graph, though it lacks statistical significance.

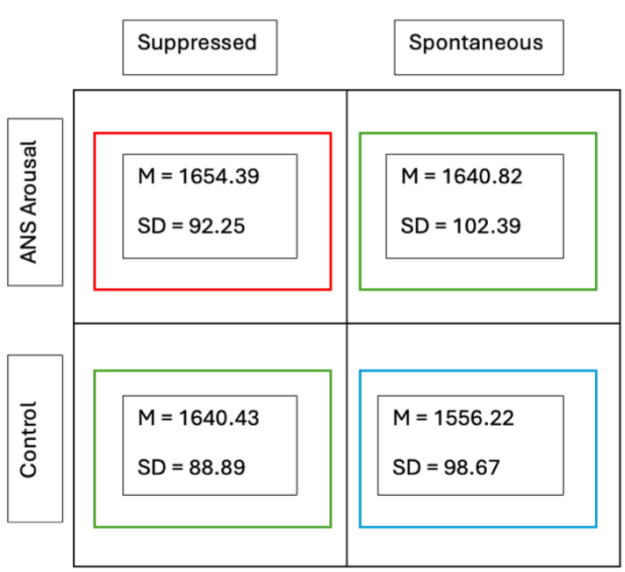


The average RT of the control condition (M = 1598.35, SD = 86.78) was less than the average RT of the arousal condition (M = 1647.61, SD = 90.06), suggesting participants in the arousal condition required more time to complete the task (See Figure 7). The average RT of the suppressed expression condition (M = 1647.43, SD = 64.05) was greater than that of the spontaneous expression condition (M = 1598.52, SD = 71.10), suggesting that participants in the suppressed expression condition completed the task slower than those in the spontaneous expression condition.

The participants in the suppressed expression/ANS arousal condition had the slowest mean RT (M = 1654.39, SD = 92.25); participants in the spontaneous expression/control condition had the fastest mean RT (M = 1556.22, SD = 98.67). Participants in the suppressed/control and spontaneous/arousal condition had nearly identical RTs (M =1640.43, SD = 88.89; M = 1640.82, SD = 102.39), suggesting the minor perceptual deficit related to suppression in the control condition had a similar impact as arousal in the spontaneous expression condition. The ANOVA analyzing the relationships between these groups revealed that they were not statistically significant, $F(1, 25) = .155$, $p = .697$, $\eta p^2 = .006$, however. Additionally, there was no significant main effect of expression type on RT, $F(1, 25) = .894$, $p = .353$, $\eta p^2 = .035$. There was no significant interaction between expression type and arousal, either, $F(1, 25) = .467$, $p = .501$, $\eta p^2 = .018$. Therefore, the hypothesis that participants in the ANS arousal and expressive suppression condition would have the slowest RTs was not confirmed.

Figure 7

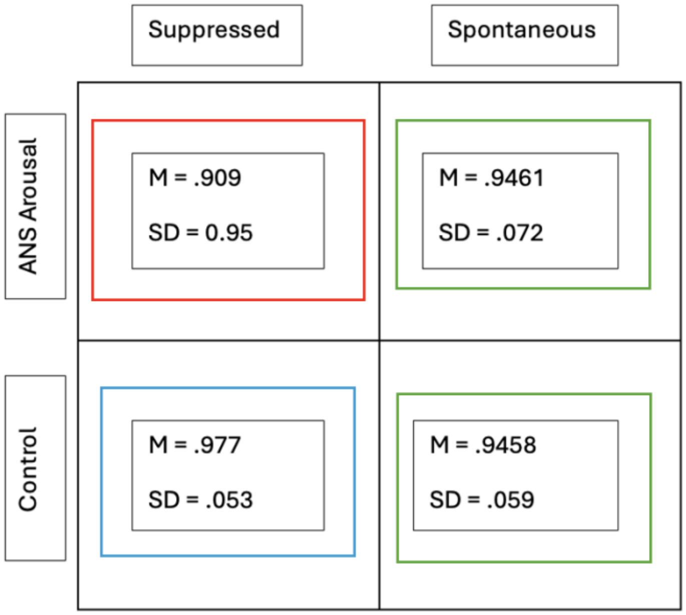
The results of the RT analysis revealed that RT scores trended in the hypothesized direction, though the relationships between the groups lacked statistical significance.



Participants in the ANS arousal and suppressed expression condition had the lowest accuracy scores on average (M = .909, SD = .095). Notably, participants in the suppressed expression and control arousal condition had the highest accuracy scores (M = .977, SD = .053). Participants in the ANS arousal (M = .9461, SD = .072) and control conditions (M = .9458, SD = .059) had very similar mean accuracy scores during the spontaneous expression trials. However, the ANOVA revealed that the there was no significant interaction between expression type and arousal on accuracy, $F(1, 25) = 3.83$, $p = .061$, $\eta p^2 = .133$. Therefore, the hypothesis that participants in the ANS arousal and suppressed expression condition would have the poorest accuracy was not confirmed (See Figure 8). Although the interaction did not reach statistical significance, the moderate effect size and near-significant p-value suggest that ANS arousal may influence facial affect sensitivity differently depending on whether individuals suppress their expressions or emote naturally. The near-significant difference in performance between the ANS arousal and control groups in the suppressed expression condition could be interpreted as evidence of a potential moderating influence of ANS arousal on FAS performance. Because statistical power was limited, future research with a larger sample is needed to determine whether this pattern reflects a true interaction.

Figure 8

The results of the accuracy analysis revealed that, as hypothesized, participants in the ANS arousal/suppressed expression condition had the poorest accuracy. However, it was hypothesized that the control/spontaneous condition would yield the greatest accuracy; instead, the control/suppressed expression condition had the greatest accuracy, which conflicts with Schneider, Hempel, and Lynch's (2013) results. The near-significant difference (p = .061) between the ANS arousal and control groups in the expression condition indicate a possible moderating effect of ANS arousal, which could be revealed with further testing.



As noted, a major limitation to this research the insufficient sample size; a more robust sample may have yielded different results. Most of the hypotheses were not confirmed. However, the results of an independent samples t-test revealed that, on average, females outperformed males on the perceptual task. In the both the suppressed and spontaneous condition, females had greater accuracy (M = .958, SD = .058 and M = .957, SD = .055 respectively) compared to males (M = .911, SD = .121 and M = .919, SD = .080, respectively). Females in the suppressed expression condition had the greatest overall accuracy (See Figure 9). There was no significant difference between male (M = .911, SD = .121) and female (M = .958, SD = 0.55) accuracy in the suppressed expression condition, $t(25) = -1.382$, $p = .179$, $d = -.582$; nor the spontaneous expression condition, $t(25) = -1.392$, $p = .176$, $d = -.586$.

Figure 9

Aggregated accuracy scores; female demonstrated an on-average advantage in accuracy. Women in the suppressed expression condition had the best overall accuracy. Males in the suppressed expression condition had the poorest overall accuracy.

	Spontaneous	Suppressed
Female	M = .957 SD = .055	M = .958 SD = .058
Male	M = .919 SD = .080	M = .911 SD = .121

.

Mean RT scores varied, with males (M = 1517.22, SD = 311.76) having quicker responses in the suppressed expression condition compared to females (M = 1630.53, SD = 387.51), but females (M = 1633.85, SD = 299.96) were faster than males (M = 1705.08, SD = 452.49) in the spontaneous expression condition (See Figure 10). In the spontaneous expression condition, females had the fastest RT and males as the slowest overall RT. However, males in the suppressed expression condition had the fastest overall RT. Notably, in addition to holding the distinction of having the fastest overall RT, males in the suppressed expression condition had the worst overall accuracy. There was no significant difference between male and female RT performance in the suppressed expression condition, $t(25) = -.731$, $p = .472$, $d = -.308$; nor the spontaneous expression condition, $t(25) = .494$, $p = .625$, $d = .208$.

Figure 10

Aggregated RT scores; male participants in the suppressed expression condition had the fastest overall RT, while male participants in the spontaneous expression condition had the slowest overall RT.

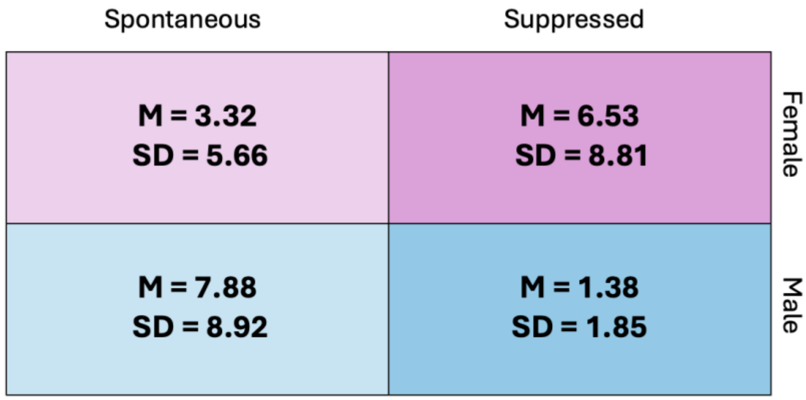
	Spontaneous	Suppressed
Female	M = 1633.85 SD = 299.96	M = 1630.53 SD = 387.51
Male	M = 1705.08 SD = 452.49	M = 1517.22 SD = 311.76

Additionally, there was no significant sex difference in HR change scores in the suppressed condition, but females had a greater HR change when holding a suppressed facial expression (M = 6.53, SD = 8.81) compared to males (M = 1.38, SD = 1.85), though the difference was not significant, $t(22) = -1.621$, $p = .117$, $d = -.683$. There was no significant difference in HR change in the spontaneous expression condition, either. In this condition, males displayed greater HR change scores (M = 7.88, SD = 8.92) compared to females (M = 3.32, SD = 5.66), $t(22) = 1.607$, $p = .121$, $d = .677$. Therefore, in terms of accuracy, females demonstrated the hypothesized advantage in the suppressed expression condition, thought the difference was not significant (See Figure 11). However, in the suppressed expression condition, males demonstrated a mean advantage in RT and had lower HR reactivity scores in the suppressed expression condition compared to females. Moreover, females demonstrated a RT advantage in the spontaneous expression condition and exhibited less HR reactivity in the spontaneous expression condition compared to males. Additionally, men in the spontaneous expression condition had the greatest overall HR reactivity, and in the same condition they yielded the slowest overall RT. In the suppressed expression condition, this relationship was inverse: males in the suppressed expression condition had the lowest overall HR reactivity and the fastest overall RT. Additionally, it is interesting to note that in the suppressed expression condition, men yielded the lowest overall HR reactivity, the poorest overall accuracy, and the fastest overall RT. The incongruence in sex sampling (male n = 7; female n = 20) may have led to skewed results, so future studies may use stratified sampling to ensure an evenly sexed sample.

Figure 11

HR reactivity quantified as HR change scores. Males in the spontaneous expression condition has the greatest HR reactivity, while males in the suppressed expression condition had the lowest

HR reactivity. HR reactivity was higher in the spontaneous expression condition for males, but higher in the suppressed expression condition for females.



The results of the ERQ-S revealed that participants reported using cognitive reappraisal (M = 15.89, SD = 3.34) as a habitual emotional regulation strategy more than expressive suppression (M = 12.43, SD = 5.04). Men (M = 18.12, SD = 2.10) reported using cognitive reappraisal more frequently than women (M = 14.79, SD = 3.31). The results of the PES demonstrated that participants scored higher in cognitive empathy on average (M = 36.46, SD = 7.64) compared to affective empathy (M = 31.25, SD = 7.04). The average total empathy score (M = 67.71, SD = 12.04) in this study compared to a normative sample suggests that our sample fell within the “average level of empathy” range (Brett, et al., 2023). On average, females scored higher (M = 70.21, SD = 11.93) on the PES compared to males (M = 62.88, SD = 11.77). In terms of cognitive empathy, males (M = 36.87, SD = 8.28) had a very slight advantage (M = 36.16, SD = 7.76). The PAQ-S revealed that, compared to a normative sample, our participants’ mean alexithymia scores (M = 16.50, SD = 5.80) fell within the average range (Preece, et al., 2023). Females scored higher (M = 18.15, SD = 5.39) than males (M = 13.37, SD = 5.50), suggesting females in the sample had a greater incidence of alexithymic traits compared to males.

To analyze the relationship between habitual expressive suppression and task accuracy via linear regression, difference scores were created to account for within-subjects' differences between the suppressed expression condition and the spontaneous suppression condition. Habitual expressive suppression use, as measured by the ERQ-S, was not a significant predictor of task accuracy, $F(1,26) = 1.685$, $p = .206$, $R^2 = .063$. Differences scores were created for HR change and RT, as well, and multiple additional linear regressions were conducted to determine the relationship between the DVs and survey measures. Empathy, as measured by the PES, was not a significant predictor of task accuracy, $F(1, 26) = 0.12$, $p = .913$, $R^2 = .000$. Alexithymic traits, measured via PAQ-S, did not predict task accuracy, either, $F(1, 26) = .445$, $p = .511$, $R^2 = .017$. Habitual expressive suppression was not a significant predictor of RT, $F(1, 26) = .189$, $p = .668$, $R^2 = .007$. Nor was empathy, $F(1, 26) = .725$, $p = .403$, $R^2 = .028$, or alexithymia, $F(1, 26) = .347$, $p = .561$, $R^2 = .014$. Lastly, habitual expression suppression was not a significant predictor of HR change, $F(1, 26) = 1.05$, $p = .314$, $R^2 = .041$. Nor was empathy, $F(1, 26) = .703$, $p = .410$, $R^2 = .027$, or alexithymia, $F(1, 26) = 1.882$, $p = .182$, $R^2 = .070$. An additional limitation is the large number of univariate analyses conducted. Performing numerous statistical tests increases the probability of Type I error through inflated familywise error rates. Because the sample size was insufficient to support a multivariate approach, separate analyses were conducted for each dependent variable. Future studies with larger samples should employ a multivariate analytic framework, such as MANCOVA, to evaluate these relationships simultaneously while better controlling for error.

Conclusion

The present study investigated whether ANS arousal moderates the relationship between ES and FAS. It was hypothesized that participants instructed to suppress their facial expressions while experiencing experimentally induced ANS arousal would demonstrate reduced facial affect sensitivity, reflected by lower accuracy, slower response times, and greater HR reactivity compared to participants in the spontaneous expression and control conditions. Overall, these hypotheses were not supported. Mixed-design ANOVAs revealed no statistically significant effects of expressive suppression, ANS arousal, or their interaction on HR change, RT, or accuracy. Although participants in the ES and ANS arousal conditions generally showed patterns that aligned with the predicted direction of effects, these differences did not reach statistical significance.

Among the three dependent variables, accuracy demonstrated the strongest evidence for a potential interaction. Although the interaction between ES and ANS arousal missed statistical significance ($p = .061$), the moderate effect size ($\eta p^2 = .133$) suggests a potential relationship. Participants in the ANS arousal and ES condition produced the lowest average accuracy scores, whereas those in the suppression and control condition produced the highest. Given the limited statistical power associated with the relatively small sample, it is possible that this trend reflects an underlying effect that could emerge more clearly in a larger sample. Consequently, the present findings should not be interpreted as evidence that no relationship exists, but rather that sufficient evidence was not obtained to support the proposed hypotheses under the current study conditions.

Despite the absence of support for the primary hypotheses, several exploratory findings warrant consideration. Females demonstrated greater FAS accuracy than males during the suppressed expression condition, though this difference was insignificant, consistent with previous literature suggesting that females often outperform males on FAS tasks (Schneider, Hempel, & Lynch, 2013). Indeed, the PES revealed that females in this sample had greater affective empathy than males, a trait associated with the identification of facial expressions (Moret-Tatay, et al., 2022) Sex differences were also observed in HR reactivity, although the pattern differed across expression conditions. Females exhibited greater HR reactivity during ES, while males demonstrated greater heart rate reactivity during spontaneous expression. Although these findings should be interpreted cautiously because they were exploratory, insignificant, and based on a modest sample, they suggest that biological sex may influence behavioral and physiological responses during emotional regulation and facial affect perception. Future studies should examine these relationships with larger and more balanced samples to better investigate the impact of sex on the relationship.

The survey findings similarly provided useful descriptive information, despite failing to predict performance. Participants reported using cognitive reappraisal more frequently than ES as a habitual emotion regulation strategy, consistent with previous research indicating that cognitive reappraisal is generally the more commonly employed by healthy, normative individuals (Kelley, et al., 2020). Females reported greater affective empathy than males, consistent with previous research (Elkin, et al., 2021). Likewise, males reported greater habitual cognitive reappraisal, which aligns with research suggesting men use cognitive reappraisal more effortlessly and flexibly than females (McRae, et al., 2008). Participants' overall empathy and alexithymia scores fell within normative ranges, suggesting that the sample was generally representative with respect to these individual difference variables. Habitual ES, empathy, and alexithymic traits did not significantly predict task accuracy, response time, or heart rate change. These findings suggest that, within this sample, stable individual differences in ER tendencies and emotional functioning were not associated with performance on the experimental facial affect recognition task.

Several limitations should be considered when interpreting these findings. The most substantial limitation was the relatively small sample size, which reduced statistical power and increased the likelihood of Type II error. Although several outcomes followed the hypothesized direction, the study may have been underpowered to detect small or moderate effects. Additionally, participants completed only one laboratory session, limiting the ability to examine the consistency of these effects over time. The sample was also drawn primarily from a university population, which may limit the generalizability of the findings to broader or more diverse populations. Finally, although the cold pressor task is a well-established method of inducing physiological arousal, individual variability in stress responsiveness may have reduced the consistency of the arousal manipulation across participants.

An additional limitation of the present design is that researchers did not include an independent, experimentally equated cognitive-load control (e.g., a nonaffective secondary task) to rule out alternative accounts based purely on attentional or working-memory demands. Although Schneider et al. (2013) used a mimicry condition to equate the motor and attentional demands of facial control and argued that suppression effects were not due to general task load, researchers cannot rule out the possibility that some portion of the suppression-related impairment arises from domain-general cognitive demands. Future work should include an explicit load-matched control or use dual-task methods to more directly test and quantify that possibility.

Overall, the present study contributes to the growing literature examining the perceptual impact of ES and ANS arousal. Although the primary hypotheses were not supported, the observed trends suggest that these relationships remain worthy of further investigation. Future research should replicate the present design using larger and more diverse samples, stronger statistical power, and additional physiological measures of ANS activity to clarify whether ANS arousal meaningfully moderates the relationship between ES and FAS. Continued investigation of these processes may improve understanding of how physiological states and emotion regulation strategies jointly influence perception. Although the present findings did not provide empirical support for the hypothesized moderation model, the results suggest that any perceptual costs associated with ES under conditions of arousal are likely subtle and may require greater statistical power or more sensitive experimental methods to detect. Likewise, the present findings neither support nor refute predictions derived from embodied simulation, psychophysiological coherence, or the Yerkes-Dodson frameworks, but indicate that these theoretical relationships likely require further empirical examination. The pattern of results, namely the descriptive statistics, are consistent with the possibility of moderation. Moreover, the present study is the first to test the effect of ES and experimentally induced ANS arousal on FAS. This study expands Schneider, Hempel, and Lynch's (2013) work to a psychophysiological paradigm and investigates the role of a precipitating autonomic event in the relationship between ES and FAS.

References

Anderson, S. R., Li, W., Han, S., & Reynolds Losin, E. A. (2021). Expressive suppression to pain in others reduces negative emotion but not vicarious pain in the observer. *Cognitive, affective & behavioral neuroscience*, *21*(2), 292–310. https://doi.org/10.3758/s13415-021-00873-1

Balconi, M., & Pozzoli, U. (2009). Arousal effect on emotional face comprehension: Frequency band changes in different time intervals. *Physiology & Behavior*, 97(3–4), 455–462. https://doi.org/10.1016/j.physbeh.2009.03.023

Barsalou L. W. (1999). Perceptual symbol systems. *The Behavioral and brain sciences*, *22*(4), 577–660. https://doi.org/10.1017/s0140525x99002149

Baudouin, J. Y., Gallian, F., Pinoit, J. M., & Damon, F. (2025). Arousal, valence, and discrete categories in facial emotion. *Scientific reports*, *15*(1), 40268. https://doi.org/10.1038/s41598-025-24032-5

Becker, D. V., Kenrick, D. T., Neuberg, S. L., Blackwell, K. C., & Smith, D. M. (2007). The confounded nature of angry men and happy women. *Journal of Personality and Social Psychology, 92*(2), 179–190. https://doi.org/10.1037/0022-3514.92.2.179

Brett, J. D., Becerra, R., Maybery, M. T., & Preece, D. A. (2023). The Psychometric Assessment of Empathy: Development and Validation of the Perth Empathy Scale. *Assessment*, 30(4), 1140-1156.https://doi.org/10.1177/10731911221086987.

Butler, E. A., Egloff, B., Wilhelm, F. H., Smith, N. C., Erickson, E. A., & Gross, J. J. (2003). The social consequences of expressive suppression. *Emotion*, 3(1), 48–67. https://doi.org/10.1037/1528-3542.3.1.48

Colby, C. Z., Lanzetta, J. T., & Kleck, R. E. (1977). Effects of the expression of pain on autonomic and pain tolerance responses to subject-controlled pain. *Psychophysiology*, *14*(6), 537–540. https://doi.org/10.1111/j.1469-8986.1977.tb01194.x

Choi, D., Nishimura, T., Motoi, M., Egashira, Y., Matsumoto, R., & Watanuki, S. (2014). Effect of empathy trait on attention to various facial expressions: evidence from N170 and late positive potential (LPP). *Journal of physiological anthropology*, 33(1), 18. https://doi.org/10.1186/1880-6805-33-18

Cutuli D. (2014). Cognitive reappraisal and expressive suppression strategies role in the emotion regulation: an overview on their modulatory effects and neural correlates. *Frontiers in systems neuroscience*, 8, 175. https://doi.org/10.3389/fnsys.2014.00175

Ekman, P. (1992). An argument for basic emotions. *Cognition and Emotion, 6*(3-4), 169–200. https://doi.org/10.1080/02699939208411068

Elkin, B., LaPlant, E. M., Olson, A. P. J., & Violato, C. (2021). Stability and Differences in Empathy Between Men and Women Medical Students: a Panel Design Study. *Medical science educator*, 31(6), 1851–1858. https://doi.org/10.1007/s40670-021-01373-0

Gallese V. (2007). Embodied simulation: from mirror neuron systems to interpersonal relations. *Novartis Foundation symposium*, *278*, 3–221.

Gan, Y., Wen, Y., Wang, J., Rodriguez, M., Gong, X., & Xie, X. (2014). Is expressive suppression an effective coping strategy? A study of Chinese rescue medical staff following an earthquake. *Asian Journal of Social Psychology*. 17. 10.1111/ajsp.12059.

Greenaway, K. H., Lin, S. C., O'Brien, S. T., Garrett, P. M., Marris, J., & Kalokerinos, E. K. (2026). Do expressive suppression and cognitive reappraisal affect memory?. *Emotion*, 26(1), 1–13. https://doi.org/10.1037/emo0001562

Gross, J. J., & Levenson, R. W. (1993). Emotional suppression: Physiology, self-report, and expressive behavior. *Journal of Personality and Social Psychology*, 64(6), 970-986. https://doi.org/10.1037/0022-3514.64.6.970

Gross, J. J., & Levenson, R. W. (1997). Hiding feelings: The acute effects of inhibiting negative and positive emotion. *Journal of Abnormal Psychology*, 106(1), 95-103. https://doi.org/10.1037/0021-843X.106.1.95

Gross J. J. (1998a). Antecedent- and response-focused emotion regulation: divergent consequences for experience, expression, and physiology. *Journal of Personality and Social Psychology*, 74(1), 224-237. https://doi.org/10.1037//0022-3514.74.1.224

Gross, J. J. (1998b). The emerging field of emotion regulation: An integrative review. *Review of General Psychology*, 2(3), 271-299. https://doi.org/10.1037/1089-2680.2.3.271

Gross, J. J., & John, O. P. (2003). Individual differences in two emotion regulation processes: Implications for affect, relationships, and well-being. *Journal of Personality and Social Psychology*, 85(2), 348-362. https://doi.org/10.1037/0022-3514.85.2.348

Gross, J. J., & Thompson, R. A. (2007). Emotion Regulation: Conceptual Foundations. In J. J. Gross (Ed.), *Handbook of emotion regulation* (pp. 3–24). The Guilford Press.

Horstmann, G. (2003). What do facial expressions convey: Feeling states, behavioral intentions, or actions requests? *Emotion, 3*(2), 150–166. https://doi.org/10.1037/1528-3542.3.2.150

Izard, C. E. (1994). Innate and universal facial expressions: Evidence from developmental and cross-cultural research. *Psychological Bulletin, 115*(2), 288–299. https://doi.org/10.1037/0033-2909.115.2.288

Kelley, N. J., Glazer, J. E., Pornpattananangkul, N., & Nusslock, R. (2019). Reappraisal and suppression emotion-regulation tendencies differentially predict reward-responsivity and psychological well-being. *Biological psychology*, 140, 35–47. https://doi.org/10.1016/j.biopsycho.2018.11.005

Knauft, K., Tyra, A. T., Fergus, T. A., Williams, S. E., & Ginty, A. T. (2026). Expressive suppression strengthens coherence between arousal intensity and arousal interpretation. *British journal of psychology*, 10.1111/bjop.70062. Advance online publication. https://doi.org/10.1111/bjop.70062

Lee, T.H., Greening, S. G., Ueno, T., Clewett, D., Ponzio, A., Sakaki, M., & Mather, M. (2018). Arousal increases neural gain via the locus coeruleus–norepinephrine system in younger adults but not in older adults. *Nature Human Behaviour, 2*(5), 356–366. https://doi.org/10.1038/s41562-018-0344-1

Levenson, R. W. (2014). The autonomic nervous system and emotion. *Emotion Review, 6*(2), 100–112. https://doi.org/10.1177/1754073913512003

Ma, D. S., Correll, J., & Wittenbrink, B. (2015). The Chicago Face Database: A free stimulus set of faces and norming data. *Behavior Research Methods*, *47*(4), 1122-1135.

Mancini, G., Agnoli, S., Baldaro, B., Ricci Bitti, P. E., & Surcinelli, P. (2013). Facial expressions of emotions: Recognition accuracy and affective reactions during late childhood. *The Journal of Psychology, 147*(6), 599–617. https://doi.org/10.1080/00223980.2012.727891

Mauss, I. B., Levenson, R. W., McCarter, L., Wilhelm, F. H., & Gross, J. J. (2005). The tie that binds? Coherence among emotion experience, behavior, and physiology. *Emotion*, *5*(2), 175–190. https://doi.org/10.1037/1528-3542.5.2.175

McRae, K., Ochsner, K. N., Mauss, I. B., Gabrieli, J. J. D., & Gross, J. J. (2008). Gender Differences in Emotion Regulation: An fMRI Study of Cognitive Reappraisal. Group processes & intergroup relations : *GPIR*, 11(2), 143–162. https://doi.org/10.1177/1368430207088035

Montagne, B., Kessels, R. P. C., Frigerio, E., de Haan, E. H. F., & Perrett, D. I. (2005). Sex differences in the perception of affective facial expressions: Do men really lack emotional sensitivity? *Cognitive Processing*, 6(2), 136–141. https://doi.org/10.1007/s10339-005-0050-6

Moore, S. A., Zoellner, L. A., & Mollenholt, N. (2008). Are expressive suppression and cognitive reappraisal associated with stress-related symptoms? *Behaviour research and therapy*, 46(9), 993–1000. https://doi.org/10.1016/j.brat.2008.05.001

Moret-Tatay, C., Mundi-Ricós, P., & Irigaray, T. Q. (2022). The Relationship between Face Processing, Cognitive and Affective Empathy. *Behavioral sciences (Basel, Switzerland)*, *13*(1), 21. https://doi.org/10.3390/bs13010021

Neal, D. T., & Chartrand, T. L. (2011). Embodied emotion perception: Amplifying and dampening facial feedback modulates emotion perception accuracy. *Social Psychological and Personality Science, 2*(6), 673–678. https://doi.org/10.1177/1948550611406138

Niedenthal, P. M., Mermillod, M., Maringer, M., & Hess, U. (2010). The Simulation of Smiles (SIMS) model: Embodied simulation and the meaning of facial expression. *The Behavioral and brain sciences*, *33*(6), 417–480. https://doi.org/10.1017/S0140525X10000865

Niermeyer, M. A., Franchow, E.I., & Suchy, Y. (2016). Reported Expressive Suppression in Daily Life is Associated with Slower Action Planning. *The Journal of the International Neuropsychological Society*, 22, 671-681.

Niermeyer, M., Ziemnik, R., Franchow, E., Barron, C., Suchy, Y. (2019). Greater Naturally-Occurring Expressive Suppression is Associated with Poorer Executive Functioning and Motor-Sequence Learning Among Older Adults. *Journal of Clinical and Experimental Neuropsychology*, 41(2), 118-132.

Notarius, C. I., & Levenson, R. W. (1979). Expressive tendencies and physiological response to stress. *Journal of Personality and Social Psychology, 37*(7), 1204 - 1210. https://doi.org/10.1037/0022-3514.37.7.1204

Parker, J. D., Taylor, G. J., & Bagby, R. M. (1993). Alexithymia and the recognition of facial expressions of emotion. *Psychotherapy and psychosomatics*, 59(3-4), 197–202. https://doi.org/10.1159/000288664

Peirce, J., Gray, J. R., Simpson, S., MacAskill, M., Höchenberger, R., Sogo, H., Kastman, E., & Lindeløv, J. K. (2019). PsychoPy2: Experiments in behavior made easy. *Behavior research methods*, *51*(1), 195–203. https://doi.org/10.3758/s13428-018-01193-y

Preece, D. A., Mehta, A., Petrova, K., Sikka, P., Bjureberg, J., Chen, W., Becerra, R., Allan, A., Robinson, K., & Gross, J. J. (2023). The Perth Alexithymia Questionnaire-Short Form (PAQ-S): A 6-item measure of alexithymia. *Journal of affective disorders*, *325*, 493–501. https://doi.org/10.1016/j.jad.2023.01.036

Schneider, K. G., Hempel, R. J., & Lynch, T. R. (2013). That "poker face" just might lose you the game! The impact of expressive suppression and mimicry on sensitivity to facial expressions of emotion. *Emotion*, 13(5), 852–866. https://doi.org/10.1037/a0032847

Shapiro, J. R., Ackerman, J. M., Neuberg, S. L., Maner, J. K., Vaughn Becker, D., & Kenrick, D. T. (2009). Following in the wake of anger: when not discriminating is discriminating. *Personality & social psychology bulletin*, *35*(10), 1356–1367. https://doi.org/10.1177/0146167209339627

Sheppard, J. P., Barker, T. A., Ranasinghe, A. M., Clutton-Brock, T. H., Frenneaux, M. P., & Parkes, M. J. (2011). Does modifying electrode placement of the 12 lead ECG matter in healthy subjects? *International Journal of Cardiology, 152*(2), 184–191. https://doi.org/10.1016/j.ijcard.2010.07.013

Springer, U. S., Rosas, A., McGetrick, J., & Bowers, D. (2007). Differences in startle reactivity during the perception of angry and fearful faces. *Emotion, 7*(3), 516–525. https://doi.org/10.1037/1528-3542.7.3.516

Suchy, Y. Niermeyer, M., Franchow, E., Ziemnik, R. (2019). The deleterious impact of expressive suppression on test performance persists at one-year follow-up in community-dwelling older adults. *The Journal of the International Neuropsychological Society*, 25(1), 29-38.

Tipples J. (2019). Recognising and reacting to angry and happy facial expressions: a diffusion model analysis. *Psychological research*, *83*(1), 37–47. https://doi.org/10.1007/s00426-018-1092-6

Tyra, A. T., Fergus, T. A., & Ginty, A. T. (2024). Emotion suppression and acute physiological responses to stress in healthy populations: a quantitative review of experimental and correlational investigations. *Health psychology review*, 18(2), 396–420. https://doi.org/10.1080/17437199.2023.2251559

Wingenbach, T. S. H., Ashwin, C., & Brosnan, M. (2018). Sex differences in facial emotion recognition across varying expression intensity levels from videos. *PloS one*, 13(1), e0190634. https://doi.org/10.1371/journal.pone.0190634

Yerkes, R.M. and Dodson, J.D. (1908), The relation of strength of stimulus to rapidity of habit-formation. *Journal Comparative Neurology and Psychology*, 18: 459-482.

Yan, C., Ding, Q., Wang, Y., Wu, M., Gao, T., & Liu, X. (2022). The effect of cognitive reappraisal and expression suppression on sadness and the recognition of sad scenes: An event-related potential study. *Frontiers in psychology*, 13, 935007. https://doi.org/10.3389/fpsyg.2022.935007

Zhao, J., Li, D., Li, K., (2026). Effects of uncertainty stress on attentional control in college students: Mediating effect of problematic mobile phone use and moderating effect of expressive suppression. *BMC Psychology*, 14, Article 614. https://doi.org/10.1186/s40359-026-04393-w