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Ginty, Annie T; Oosterhoff, Benjamin; Young, Danielle; Williams, Sarah

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EFFECTS OF AROUSAL REAPPRAISAL ON THE ANXIETY RESPONSES TO STRESS: BREAKING THE CYCLE OF NEGATIVE AROUSAL INTENSITY AND AROUSAL INTERPRETATION

Annie T. Ginty[1], Ph.D., Benjamin J. Oosterhoff[2], Ph.D., Danielle A. Young[1], Psy.D., & Sarah E. Williams[3], Ph.D.

[1]Department of Psychology and Neuroscience, Baylor University, Waco, Texas, USA

[2] Department of Psychology, Montana State University, Bozeman, Montana, 59717, USA

[3]School of Sport, Exercise, and Rehabilitation Sciences, University of Birmingham, Birmingham, UK

Corresponding author information: Annie T. Ginty, Baylor University, Department of Psychology and Neuroscience, One Bear Place 97334, Waco, TX 76798, USA, Annie_Ginty@baylor.edu.

Abstract

Arousal reappraisal has been shown to be an effective strategy during stress to improve anxiety. However, the exact psychological mechanism through which arousal reappraisal improves anxiety is unknown. In a large, cross-sectional study (Study 1, N = 455) participants engaged in an acute psychological stress task and rated their levels of physiological arousal, cognitive anxiety, and somatic anxiety, and whether they perceived this physiological arousal, cognitive anxiety, and somatic anxiety as helpful or hurtful (i.e., interpretation). Structural equation models supported a previously hypothesized model demonstrating that higher levels of physiological arousal were interpreted more negatively and this negative interpretation was associated with higher levels of anxiety intensity and more negative interpretations of anxiety. In an independent sample (Study 2, N = 155) participants were randomly assigned to an arousal reappraisal intervention or control condition prior to engaging in the psychological stress task. Results indicated that arousal reappraisal resulted in more positive interpretations of physiological arousal and anxiety. Results also supported a previously hypothesized model demonstrating that arousal reappraisal "broke" the connection between physiological arousal intensity and physiological arousal interpretation. The present studies suggest that arousal reappraisal could possibly be acting through improving interpretations of physiological arousal symptoms.

Keywords: reappraisal, stress, anxiety

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Effects of Arousal Reappraisal on the Anxiety Responses to Stress: Breaking the Cycle of Negative Arousal Intensity and Arousal Interpretation

Psychological stress has been associated with adverse mental and physical health outcomes across the lifespan (e.g., Epel et al., 2018; McFarlane, 2010; Cohen et al., 2007; Steptoe & Kivimaki, 2012). While short-term responses to acute stress may indeed be adaptive in appropriately mobilizing the resources needed for behavioral responses to actively cope with acute stress (Obrist et al., 1981; Ginty et al., 2017; Gianaros & Jennings, 2017; Schniderman et al., 2005), long term exposure to stress (i.e., chronic stress) can be detrimental through 'wear and tear' on physiological systems (Cohen et al., 2007; Cohen et al., 2016) and lead to adverse health outcomes (e.g., Cohen et al., 2007). Indeed, stress is generally viewed as negative with emphasis placed on avoiding or reducing exposure to stress (Souza-Talarico et al., 2016; Rudland et al., 2018; Crum et al., 2013; Richardson et al., 2012). However, eliminating or reducing exposure to stress is not always possible.

One way to manage stress is through the use of cognitive reappraisal, which focuses on changing or reinterpreting beliefs of stressful situations (e.g., Gross, 1998; Lazarus & Folkman, 1984; Kross & Ayduk, 2011; Liu et al., 2019) and can help manage negative emotional, cognitive, and physiological responses (Cutuli, 2014; Gross, 1998). Arousal reappraisal may be viewed as an extension of the cognitive reappraisal literature, which specifically emphasizes altering the appraisals of physiological arousal that occur during acute stress from harmful to helpful, enhancing, or facilitative for performance (Beltzer et al., 2014; Lindquist & Barrett, 2008; Lindquist et al., 2011). Laboratory studies suggest that using arousal reappraisal to manipulate stress appraisals directly improves acute stress responses and can result in more positive stress related outcomes (e.g., Jamieson et al., 2010; Jamieson et al., 2012; John-Henderson et al., 2015; Jamieson et al., 2016; Jamieson et al., 2018; Moore et al., 2015; Crum et al., 2020).

A stress related outcome which can be improved by arousal reappraisal is anxiety. In the broadest sense, stress is anything that alters the equilibrium of the individual (Selye, 1936). Anxiety is a state that includes behavioral, affective, and cognitive changes in response to stressor or a potential stressor as an effort to avoid or reduce the impact of the threat (Grupe & Nitschke, 2013). Often, anxiety includes feelings of worry and concern and increases in physiological activity (i.e., increased heart rate; Buss et al., 1955). Research demonstrates that while there are individual differences in the intensity of anxiety experienced, acute psychological stress often elicits feelings of anxiety both in anticipation of and during stressful scenarios (Hofmann et al., 2009; Jamieson et al., 2016; Trotman et al., 2018; Williams et al., 2017). Anxiety is typically regarded as ‘negative,’ however, evidence suggests anxiety can be perceived by the individual as debilitative (i.e., harmful) or facilitative (i.e., helpful; Jones & Hanton, 1996).

Arousal reappraisal is beneficial in reducing the intensity of anxiety experienced in response to stress. In experimental studies, arousal reappraisal has been associated with lower levels of self-report or experimenter observed anxiety across a range of tasks: Graduate Research Examinations (Jamieson et al., 2010), socially evaluative speech (Beltzer et al., 2014; Hofman et al., 2009; Jamieson et al., 2013), and math examinations (Jamieson et al., 2016). While the majority of work has focused on the impact of arousal reappraisal on anxiety intensity, one study examined if arousal reappraisal altered the directional interpretation (i.e., if the individual saw the anxiety as facilitative or debilitative) of the anxiety experienced. In a study of 50 participants randomly assigned to arousal reappraisal or control, Moore et al. (2015) demonstrated that those in the arousal reappraisal group had more facilitative interpretations of their somatic anxiety levels (referred to in the manuscript as physiological arousal) in anticipation of the task compared to the control group. Taken together, this body of research suggests arousal reappraisal is beneficial in reducing levels of anxiety and assisting with more positive interpretations of anxiety. However, the exact psychological mechanisms through which arousal reappraisal is having these benefits remain largely unknown, as does the impact of arousal reappraisal on cognitive anxiety interpretation.

Jamieson et al. (2013) proposed a model explaining 'how' arousal reappraisal may result in more facilitative responses to stress. In the proposed model, stress exposure increases physiological arousal which is interpreted negatively (i.e., harmful), this negative interpretation of arousal leads to negative outcomes such as anxiety. In the same paper, Jamieson et al. (2013) propose that arousal reappraisal "breaks" the association between the increase in physiological arousal and the negative interpretation of this arousal, which allows for more positive stress related outcomes (i.e., lower levels of anxiety, better performance). While the outcomes of the proposed models have been demonstrated in the work described above, the full model has never been tested. Therefore, it remains unclear if the pathways proposed in Jamieson et al. (2013) are the mechanisms through which stress results in negative outcomes and if arousal reappraisal does indeed "break" the association.

The purpose of this two-study paper is to use a rigorous laboratory stress paradigm to 1) test the original model proposed by Jamieson et al. (2013) in a large sample utilizing a cross-sectional approach and 2) conduct an experimental laboratory study, using the same rigorous stress paradigm, in an independent, large sample to examine if arousal reappraisal "breaks" the association described in the model.

Study 1

Aims and Hypotheses

The aim of Study 1 was to formally test pathways between a stressful situation and emotion outcomes proposed by Jamieson et al. (2013). Specifically, Study 1 examined the association between physiological arousal intensity, interpretation of the physiological arousal, and emotions experienced (i.e., anxiety intensity and direction interpretation). Based on Jamieson et al. (2013)'s model, it was hypothesized that during acute psychological stress, higher levels of perceived physiological arousal would be associated with greater negative perceptions of arousal and that these perceptions would be related to greater levels of anxiety and more negative interpretations of these symptoms. The hypothesized model is displayed in Figure 1.

Method

Participants

Four hundred and fifty-nine young adults were recruited using the first authors university's online SONA psychology subject pool. A minimum sample size was determined using the 15 participants per parameter as an upper limit recommendation by Tabachnick and Fidell (2013). We had 9 primary effects of interest. Thus, our minimum sample size was N = 135 for this study. To maximize precision in our estimates, we continued to collect as many data points as possible until resources were expended. Exclusion criteria included: a current illness or infection or a history of cardiovascular disease at the time of partaking in the study. Participants were asked to refrain from the following before their laboratory visit: engaging in vigorous exercise or consuming alcohol 12 h prior, consuming food or any beverage other than water 2 h prior to testing. Participants received 2 h SONA research credits for their participation. All participants provided informed consent prior to the start of the study. The study was conducted in accordance with the Declaration of Helsinki and the study was approved by the first author's university's institutional review board.

Measures

Perceived physiological arousal intensity and interpretation. Separate items were employed to assess the extent to which participants perceived themselves to be experiencing physiological arousal (i.e., intensity), as well as the extent to which participants viewed these symptoms as being facilitative or debilitative towards upcoming performance (i.e., direction interpretation). Intensity ratings were made on a 7-point Likert-type scale from 1 *(not at all)* to 7 *(extremely)* while direction interpretation ratings were made on a 7-point Likert-type scale from -3 *(very debilitative/negative)* to +3 *(very facilitative/positive).*

Cognitive and somatic anxiety. The Immediate Anxiety Measures Scale (IAMS; Thomas et al., 2002) assessed the intensity and directional interpretation of cognitive anxiety and somatic anxiety. For the purpose of the present study, self-confidence which is also assessed by the IAMS was not included. To assess anxiety intensity, individuals first rate the extent they are experiencing each construct (i.e., cognitive anxiety or somatic anxiety) on a 7-point Likert-type scale from 1 *(not at all)* to 7 *(extremely)*. To assess direction interpretation of these symptoms, individuals then rate the extent to which the symptoms for each construct are considered to be helpful or hurtful towards performance. Responses are made on a 7-point Likert-type scale ranging from -3 *(very debilitative/negative)* to +3 *(very facilitative/positive)*. The IAMS provides definitions to ensure individuals fully understand the meaning of each construct and has been identified as a valid and reliable measure to assess state anxiety (Thomas et al., 2002) and is frequently used to assess state anxiety in laboratory-based stress studies (Moore et al., 2012; Quinton et al., 2019; Trotman et al., 2018).

Stress Task

The 4-minute version of the Paced Auditory Serial Addition Test (PASAT; Gronwall, 1977) was used to elicit psychological stress. The PASAT has been extensively used as an acute psychological stress task in research settings (e.g., Veldhuijzen van Zanten et al., 2004; Trotman et al., 2019; Ginty et al., 2012; Ginty et al., 2020) and demonstrates good test-retest reliability (Willemsen et al., 1998). Participants were presented with a series of numbers (ranging between 1-9) and asked to add each consecutive number to the number they just heard from the recording, rather than the number they had just said out loud. The interval between the numbers was 2.4 s for the first minute of the task and decreased by 0.4 s each minute until the completion of the task. Elements of self-evaluation, social evaluation, and competition were added to the task paradigm to increase feelings of stressfulness (Veldhuijzen van Zanten et al., 2004). Participants were told they would lose 5 points for every incorrect answer or omission. They were also informed they were in direct competition with their peers and a “leader board” was prominently displayed in the laboratory. Throughout the duration of the task, a research assistant stood approximately 0.25 meters away to observe and score the participants. Additionally, participants were informed they would hear a loud, aversive noise every time they give an incorrect answer, stuttered, mumbled, or hesitated. In actuality, participants heard the noise at standardized times throughout the protocol. Participants were videotaped throughout the task and told the video tape would be analyzed by “body language experts.” In reality, the video camera was not recording. Lastly, participants were required to look at themselves in a mirror positioned approximately 0.5 meters in front of them throughout the duration of the task.

Procedures

Upon arrival at the laboratory, participants were asked to provide informed consent. Participants then sat quietly for a 10 min adaptation phase, followed by a formal 10 min resting baseline. Participants were then read the instructions for the PASAT and completed a brief practice to ensure they understood the task. Immediately after completing the practice version of the test, but prior to completing the full PASAT, participants were asked to self-report intensity and interpretation of physiological arousal, cognitive anxiety, and somatic anxiety. Participants then completed the 4 min PASAT (i.e., the acute stress phase).

Data Reduction and Analysis

All data analyses were conducted in SPSS and AMOS version 26. Data were first screened and cleaned for missing values and outliers in accordance with recommendations by

Tabachnick and Fidell (2013). Four participants were missing questionnaire data. Given these four participants accounted for less than 1% of the sample they were removed from the analysis. Histograms and skewness and kurtosis values for all outcome variables were examined, which ranged between -.44 to .56 for skewness and -.91 to .06 for kurtosis. Multivariate normality was determined in AMOS by examining Mardia's coefficient, with a value of 40.31. Consequently, bootstrapping of 2000 samples was employed for all SEM analyses to generate 95% confidence intervals. This approach was enabled to create multiple subsamples from the original data and examine parameter distributions related to each of these samples (Byrne, 2010).

Means and standard deviations were calculated for all variables of interested (i.e., physiological arousal intensity, physiological arousal interpretation, cognitive and somatic anxiety intensities, and cognitive and somatic anxiety interpretations). The hypothesized model was then tested in AMOS using path analysis. Goodness of model fit was examined using the chi-square statistic (χ^2) as well as the root mean square error of approximation (RMSEA) and the standardized root mean square residual (SRMR) to indicate absolute fit (values of .06 and $\leq$.08 respectively indicating adequate fit), and the comparative fit index (CFI) and Tucker-Lewis Index (TLI) to indicate incremental fit (values >.90 indicate adequate fit and >.95 indicating excellent model fit; Hu & Bentler, 1999). Mediation analysis as recommended by (Hayes, 2018) was used to explore indirect effects of physiological arousal intensity on cognitive and somatic anxiety via the interpretations of physiological arousal using the bootstrapping technique employed. Gender and age were controlled for in all analyses and standardized regression weightings were reported along with the 95% confidence intervals.

Results

Sample Characteristics

The final sample consisted of 455 participants (M (SD) age = 19.49 (1.26), 62.0% female, 66.6% White, 17.8% Hispanic). Demographic variables are reported in Table 1. Means and standard deviations for physiological arousal intensity, physiological arousal interpretation, cognitive anxiety intensity, cognitive anxiety interpretation, somatic anxiety intensity, and somatic anxiety interpretation are reported in Table 2.

Hypothesized Model

To test the hypothesized model, a regression path was included from physiological arousal intensity to physiological arousal interpretation, and from physiological arousal interpretation to cognitive and somatic anxiety intensities and directions. Associations between the two anxiety intensities and the two anxiety interpretations were also acknowledged by correlating these error terms similar to previous anxiety models (Williams et al., 2016). The first iteration of the model revealed a poor fit to the data, χ^2 (8) = 328.34, $p < .001$, CFI = .75, TLI = .14, SRMR = .14, RMSEA = .30 (90% CI = .27 – .33). Examining the modification indices suggested including additional paths from physiological arousal intensity to cognitive and somatic anxiety intensity, and from cognitive anxiety intensity to cognitive anxiety interpretation, and from somatic anxiety intensity to somatic anxiety interpretation direction. These pathways were added due to conceptual sense and support in the literature (Trotman et al., 2019; Neil et al., 2012). The second iteration of the model demonstrated a very good fit to the data, χ^2 (4) = 6.25, $p = .097$, CFI = .99, TLI = .98, SRMR = .14, RMSEA = .05 (90% CI = <.001 – .09). All paths within the model were found to be significant (*p's* <.001) indicating that greater physiological arousal was associated with a more negative interpretation of these symptoms which in turn predicted greater levels of cognitive and somatic anxiety, and more debilitative interpretations of cognitive and somatic anxiety. Greater physiological arousal intensity was also a direct predictor of greater cognitive and somatic anxiety which were in turn associated with more debilitative interpretations of this anxiety. The final model is displayed in Figure 2. Table 3 displays the indirect effects of the model. Physiological arousal intensity was a significant predictor of all four types of anxiety via physiological arousal interpretation. Additionally, physiological arousal interpretation was also an indirect predictor of cognitive and somatic anxiety interpretation via cognitive and somatic anxiety intensity respectively.

Discussion

Results from Study 1 provide support for the model proposed by Jamieson and colleagues (2013). As hypothesized, physiological arousal intensity was a direct predictor of how these symptoms were interpreted which in turn was associated with both the intensity and the interpretation of the anxiety experienced. Specifically, those who perceived themselves to experience greater physiological arousal in response to the stress task, reported their physiological arousal as being more debilitative. Higher levels of debilitative interpretation of physiological arousal was in turn associated with greater levels of cognitive and somatic anxiety as well as more negative interpretations of this anxiety. In addition to directly predicting cognitive and somatic anxiety interpretation, the additional paths from anxiety intensities to their respective interpretations demonstrating that physiological arousal interpretation also indirectly predicted anxiety interpretations via their anxiety intensities. A second alteration of the hypothesized model was the direct pathways from physiological arousal intensity to both cognitive and somatic anxiety intensities, demonstrating that perceived physiological arousal intensity is associated with greater feelings of cognitive and somatic anxiety. The later finding supports a recent study reporting that perceived heart rate, a form of physiological arousal, was positively associated with both cognitive and somatic anxiety intensity and suggests that the direct relationship between perceived physiological arousal and the intensity of emotions experienced should be accounted for when investigating the effects of arousal intensity and interpretation on emotions and cognitions (Trotman et al., 2019). Irrespective of these direct paths, perceived physiological arousal still predicted both the intensity and interpretation of anxiety via the interpretation of this physiological arousal which supports the hypotheses in Jamieson et al.'s (2013) proposed model. To our knowledge, this is the first study to formally test the affective (i.e., anxiety) outcomes of this proposal model using a large sample and standardized acute psychological stress task.

Study 2

Arousal reappraisal is a technique proposed to be able to "break" the connection (or association) between greater perceived physiological arousal and more negative interpretations (Jamieson et al., 2013).

Aims and Hypotheses

The aim of Study 2 was to examine the extent to which an arousal reappraisal intervention could predict the interpretation of perceived physiological arousal in response to a psychological stress above and beyond that predicted by perceived physiological intensity. If the hypotheses proposed by Jamieson et al. (2013) are correct in that arousal reappraisal interventions can "break" the connection between the intensity and interpretation of physiological arousal, then an intervention condition (i.e., intervention vs no intervention) should be a stronger predictor of perceived physiological arousal than the perceived intensity of the physiological arousal, with individuals in the intervention group perceiving their arousal to be less debilitative and/or more facilitative than the control group.

An independent sample of participants were recruited and completed the same acute psychological stress paradigm to that employed in Study 1. Prior to the stress task, half the sample were randomly assigned to an arousal reappraisal intervention and the other half a control condition (no intervention). In response to the stress task, it was hypothesized that while both groups would display similar levels of perceived physiological arousal intensity, compared to the control group, the arousal reappraisal group would report more positive interpretations of their physiological arousal, lower levels of cognitive and somatic anxiety, and more positive interpretations of these anxiety symptoms. Consequently, when testing a similar model to Study 1, it was hypothesized that the intervention condition would be a significant predictor of physiological arousal interpretation whereas physiological arousal intensity would no longer be a significant predictor. The hypothesized model is displayed in Figure 3.

Method

Participants

One hundred and fifty-five young adults (M (SD) age = 19.48 (0.93) years, 63.8% female, 58% White, 26.5% Hispanic), all independent from participants in Study 1, were recruited using the first author's university's online SONA subject pool. A minimum sample size was determined using the 15 participants per parameter as an upper limit recommendation by Tabachnick and Fidell (2013). We had 10 primary effects of interest. Thus, our minimum sample size was N = 150. Exclusion criteria, pre-visit instructions, and participant compensation were the same as Study 1. All participants provided informed consent prior to the start of the study. The study was conducted in accordance with the Declaration of Helsinki and the study was approved by the first author's university's institutional review board.

Measures

The same measures used in Study 1 to assess perceived physiological arousal intensity, physiological arousal interpretation, cognitive anxiety intensity, cognitive anxiety interpretation, somatic anxiety intensity, and somatic anxiety interpretation were employed in Study 2.

Arousal Reappraisal

Participants were given instructions based on those used in previous arousal reappraisal studies (e.g., Jamieson et al., 2010, John-Henderson et al., 2015). More specifically, all participants were told:

> "*The goal of this research is to examine how physiological arousal during a math test correlates with performance. Because it is normal for people to feel stressed or anxious during standardized tests, the equipment will measure cardiovascular changes that indicate your current physiological arousal."*

For those in the control condition, that was the end of the instructions. Participants in the arousal reappraisal condition then received the following additional information:

> "*Interestingly, people think that physiological arousal during a standardized math test will negatively impact their performance. However, recent research suggest that physiological arousal does not hurt performance on standardized tests and can even help performance. People who feel aroused an anxious during a math test might actually do better! This means you shouldn't feel concerned if you feel aroused or anxious while performing today's math test. If you find yourself, feeling anxious, simply remind yourself that your arousal could be helping you do well."*

Instructions were audio recorded using the same voice and played to participants as the task instructions. After the instructions, participants in the arousal reappraisal group were asked to verbally summarize what they were supposed to do during the stress task (e.g., reinterpret arousal as helpful for performance) to the research assistant. The research assistant listened and recorded the participant's statement to ensure they listened and understood the instructions.

Stress Task

The PASAT stress task employed in Study 1 was used in Study 2, however, in the present study the 10-minute version of the task was used (Ginty et al., 2012).

Procedures

The procedures were identical to Study 1 with the exception that upon arrival to the laboratory, participants were randomly assigned, using a random number generator with gender stratification, to either the arousal reappraisal group or a control group and that immediately prior to completion of the pre-task questionnaires, participants experienced the specific arousal reappraisal instructions described above based on which group they were assigned to.

Data Reduction and Analysis

All data reduction was conducted in SPSS version 26 and data analyses were conducted in SPSS and AMOS version 26. Data were screened and cleaned for missing values and outliers in accordance with recommendations by Tabachnick and Fidell (2013). There were no missing data. Histograms and skewness and kurtosis values for all outcome variables were examined. Skewness ranged between -.166 to .373 and kurtosis ranged between -.959 to -.373. Multivariate normality was determined using the same methods as Study 1. Although the Mardia coefficient value was 1.92, similar to study 1, bootstrapping was employed to examine indirect effects of the hypothesized model.

Chi-square and one-way ANOVAs were conducted to examine any group differences in race, ethnicity, gender, and age. Means and standard deviations were first calculated for all variables of interested (i.e., physiological arousal intensity, physiological arousal interpretation, cognitive and somatic anxiety intensities, and cognitive and somatic anxiety interpretations) for both groups and one-way ANOVAs were used to examine any group differences. Partial eta squared (η_p^2) was reported as the effect size.

Next, the hypothesized model was tested in AMOS using path analysis using the same model fit indices and examination of indirect effects as that employed in Study 1. Gender and age were controlled for in all analyses and standardized regression weightings were reported along with the 95% confidence intervals.

Results

Group Differences

There were 80 participants in the arousal reappraisal group and 75 participants in the control group. There were no statistically significant differences in groups in age, gender, ethnicity, or race (*p*'s > .488). Demographic variables are reported in Table 4. Means and standard deviations for physiological arousal intensity, physiological arousal interpretation, cognitive anxiety intensity, cognitive anxiety interpretation, somatic anxiety intensity, and somatic anxiety interpretation are reported in Table 5. A one-way ANOVA showed no significant difference between groups in physiological arousal intensity, $F(1, 153) = 0.11$, $p = .745$, $\eta_p^2 = .001$. There was, however, a significant difference in physiological arousal interpretation, $F(1, 153) = 10.74$, $p = 001$, $\eta_p^2 = .066$, with the arousal reappraisal group perceiving their arousal to be significantly more facilitative towards performance of the task. There were no statistically significant group differences in cognitive ($F[1, 153] = 3.35$, $p = .069$, $\eta_p^2 = .021$) and somatic ($F[1, 153] = 0.00$, $p = 1.00$, $\eta_p^2 < .001$) anxiety intensities, but the arousal reappraisal group perceived their cognitive (F[1, 153] = 8.11, $p = .005$, $\eta_p^2 = .050$) and somatic ($F[1, 153] = 7.04$, $p = .009$, $\eta_p^2 = .044$) anxiety to be significantly more facilitative towards performance.

Hypothesized Model

To test the hypothesized model, regression paths were inserted from physiological arousal intensity and experimental group (coded 0 = control group, 1 = arousal reappraisal group) to physiological arousal interpretation, and from physiological arousal interpretation to cognitive and somatic anxiety intensities and directions, and associations between the two anxiety intensities and the two anxiety interpretations were also acknowledged by correlating these error terms. Based on the results of Study 1, paths were also included from physiological arousal intensity to cognitive and somatic anxiety intensity, and from cognitive and somatic anxieties to their respective interpretations. The tested model demonstrated a very good fit to the data, χ^2 (10) = 10.29, $p < .416$, CFI = .99, TLI = .99, SRMR = .04, RMSEA = .01 (90% CI = <.001 – .09). The standardized estimates showed that while experimental condition significantly and positively predicted physiological arousal interpretation (i.e., the arousal reappraisal group was associated with a more facilitative interpretation of physiological arousal), unlike Study 1, arousal intensity was a non-significant predictor ($p = .613$) of physiological arousal interpretation. Physiological arousal interpretation was a significant positive predictor of cognitive and somatic anxiety interpretation and a significant negative predictor or cognitive anxiety intensity so that more positive interpretations of physiological arousal were associated with more positive interpretations of cognitive and somatic anxiety, and lower levels of cognitive anxiety. Unlike Study 1, physiological arousal interpretation was a non-significant direct predictor of somatic anxiety intensity ($p = .269$). Greater physiological arousal intensity was also a direct predictor of greater cognitive and somatic anxiety which were in turn associated with more debilitative interpretations of this anxiety. The final model is displayed in Figure 4. Table 2 displays the indirect effects of the model. Experimental condition was a significant predictor of cognitive and somatic anxiety interpretation via physiological arousal interpretation. Additionally, physiological arousal interpretation was an indirect predictor of cognitive anxiety interpretation via cognitive anxiety intensity. Physiological arousal intensity also indirectly predicted cognitive and somatic anxiety interpretation via their respective intensities.

Discussion

In the present experimental design, arousal reappraisal was associated with increased facilitative interpretations of physiological arousal, cognitive anxiety, and somatic anxiety compared to the control group. However, contrary to our hypotheses, there were no statistically significant differences between the arousal reappraisal and control group for cognitive anxiety or somatic anxiety. In analyses examining a model similar to the model in Study 1, but with the addition of experimental group, the experimental group was a statistically significant predictor of physiological arousal interpretation. In the present model, physiological arousal intensity was no longer a significant predictor of physiological arousal interpretation. This supports the hypothesis of Jamieson et al. (2013) stating that arousal reappraisal interventions can "break" the connection between the intensity and interpretation of physiological arousal.

General Discussion

Despite arousal reappraisal demonstrating substantial benefits for stress-related anxiety (Jamieson et al., 2010; Beltzer et al., 2014; Hofmann et al., 2009; Jamieson et al., 2013; Jamieson et al., 2016), no study to date has thoroughly examined the potential psychological mechanisms through which arousal reappraisal may operate. The present two study paper aimed to test a model proposed by Jamieson et al. (2013) hypothesizing a pathway through which physiological arousal may lead to negative emotional outcomes and a second model hypothesizing 'how' arousal reappraisal may alter these pathways (i.e., by altering interpretations of physiological arousal) using a large cross-sectional laboratory approach (Study 1) and an experimental design where participants were assigned to a brief arousal reappraisal or control (Study 2) group. Study 1 confirmed the pathway between physiological arousal intensity to negative interpretations of physiological arousal to higher levels of anxiety proposed by Jamieson et al. (2013). Study 2 further supported the hypothesis of Jamieson et al. (2013) by demonstrating that using arousal reappraisal "breaks" the connection between physiological arousal intensity and interpretation. Taken together, the two studies in the present manuscript provide confirmatory evidence that physiological arousal interpretation is an important construct in the relationship between a stressor and the experience of anxiety.

Contrary to our hypotheses, in Study 2, there were no statistically significant differences between the arousal reappraisal and control group on somatic anxiety intensity or cognitive anxiety intensity. This is somewhat surprising given other work demonstrating arousal reappraisal lowers the level of anxiety experienced during acute stress (Jamieson et al., 2010; Beltzer et al., 2014; Hofmann et al., 2009). However, while the groups did not differ in cognitive or somatic anxiety intensity, they did significantly differ in the interpretation of their anxiety. While unexpected, the absence of differences between groups in anxiety intensity accompanied by the significant group differences in anxiety interpretation align with intervention research utilizing other methods to alter appraisals. For example, in a within group study design, mental imagery designed to highlight positive interpretations of physiological responses to stressful situations (i.e., challenge imagery) elicited more positive interpretations of cognitive and somatic anxiety compared to threat and neutral imagery, but there were no differences between conditions in the anxiety intensities (Williams et al., 2017). Recent theoretical work has proposed that it is the interpretation of the emotion, not the intensity, which is important for more optimal outcomes (Crum et al., 2020).

Despite there being no significant differences in physiological arousal intensity, cognitive anxiety intensity, or somatic anxiety intensity between the groups, the arousal reappraisal group rated their physiological arousal and anxiety as being more facilitative compared to the control group. These results are in line with a previous study demonstrating arousal reappraisal is associated with more facilitative interpretations of somatic anxiety, referred to as physiological arousal in the study, during a golf putting task (Moore et al., 2015). However, the present results are at odds with a study finding no differences between an arousal reappraisal intervention or control condition in the interpretation of arousal during a dart throwing task (Sammy et al., 2017).

How one interprets their anxiety as being helpful or hurtful towards performance has been shown to predict how an individual copes with and performs during stress (Carrier et al., 2014; Chamberlain & Hale, 2007; Jones & Swain, 1995; Swain & Jones, 1996). Specifically, in the sport psychology literature, athletes frequently report that experiencing high levels of anxiety (i.e., anxiety intensity) can be facilitative towards their performance (Hanton & Jones, 1999). Importantly, research has shown that interpreting anxiety symptoms more positively can be a stronger predictor of better outcomes than the intensity of the anxiety symptoms (Chamberlain & Hale, 2007; Neil et al., 2012).

While the studies above demonstrate the importance of arousal for performance in everyday tasks for non-clinical samples, the importance of anxiety interpretation also has implications for the treatment of anxiety in clinical samples. Indeed, evidence-based treatments for anxiety, such as Cognitive Behavioral Therapy (CBT), often include educational sections on the adaptive functions of arousal in psychological stress (Craske & Barlow, 2000) and elements of reappraisal to cope with acute stress (for reviews see Barlow, 2004; Smits et al., 2012). With reappraisal training, individuals are taught to change their interpretations of stress to decrease arousal (e.g., mindfulness; Levitt et al., 2004) or accept arousal (e.g., interoceptive exposure; Cincotta et al., 2011). Changing interpretations with arousal reappraisal may, as the work by Jamieson, Nock, and Mendes (2012) suggests, “break” the link between physiological arousal intensity and negative interpretations of physiological arousal to stress (i.e., negative stress to positive stress).

The present studies provide evidence for the benefits of arousal reappraisal in the treatment for anxiety. In Study 1, cross-sectional evidence demonstrated that in a large sample, higher levels of physiological arousal were associated with more negative interpretations of this arousal, which was in turn associated with more debilitative and intense ratings of anxiety. This supports clinical work demonstrating interpretations are important in predicting negative emotional outcomes (e.g., Muris & Field, 2008). Study 2 demonstrates that arousal reappraisal, even in a brief format of introducing participants to the concept, has the ability to “break” the link between physiological arousal intensity and negative interpretations of physiological arousal to stress. Further work is needed to examine if this extends to other types of stressful situations (i.e., examinations, speeches, sport performance).

Recent theoretical advances suggest an approach of “stress optimization” (Crum et al., 2020). This approach proposes that displaying a more stress-is-enhancing mindset (i.e., a belief that stress has enhancing consequences for things such as performance and productivity, health and well-being, and/or learning and growth; Crum et al., 2013) may be effective for most optimally coping with stress (Crum et al., 2020). A stress-is-enhancing mindset may allow individuals to be more likely to engage in reappraising thoughts or cognitive change when faced with a stressor (Crum et al., 2020). Stress optimization highlights the importance of responding to stressors in flexible ways that help achieve more optimal outcomes than outcomes achieved by simply reducing or avoiding stressors. Future research should examine 1) if individuals who view stress as more enhancing naturally use arousal reappraisal when faced with stress and if this reappraisal alters interpretations of stress (i.e., extending study 1) and 2) if an intervention to elicit a stress-is-enhancing mindset increases the likelihood of appraising arousal in response to stress as more facilitative and if this appraisal in turn alters interpretations of stress.

The present study is not without limitations. First, physiological arousal and anxiety were assessed using single item questions. It could be argued that utilizing a single item lacks validity. However, the IAMS has been validated against a longer multi-item questionnaire

(Thomas et al., 2003) and has been utilized in many studies examining responses to acute psychological stress (Trotman et al., 2018; Trotman et al., 2019; Williams et al., 2017). While the measure of physiological arousal has not been validated, the measure was developed based on the IAMS enabling for a consistent scale and definitions provided to participants to minimize confusion. The single item approach was considered important to enable questionnaires to be completed quickly and efficiently to minimize any interruption in terms of how the participants were feeling in anticipation of the stress task. Second, Study 1 is cross-sectional, and determining definite causality is impossible (Christenfeld et al., 2004). However, the use of SEM and the large sample size allow for rigorous testing and the model being tested was testing a previously hypothesized model. Third, the sample demographics may limit the potential generalizability of the research. Recruiting participants from a narrow college student age range may possibly limit conclusions on how arousal reappraisal impacts adolescents and older adults. Similarly, participants were not excluded on the basis of having a current anxiety disorder. It is possible that arousal reappraisal may have a differential impact on individuals with and without an anxiety disorder. Early studies in arousal reappraisal that formed the foundational basis for the hypothesized model were conducted in college age students and did not screen for mental health disorders (Jamieson et al., 2010). Future research should aim to include more diverse age ranges of participants and assess for mental health disorders. Fourth, the study was conducted in a laboratory setting and is therefore limited to laboratory-based outcomes. Fifth, the arousal reappraisal intervention was brief and subtle (*i.e.*, embedded in instructions as part of the task). It is possible that the arousal reappraisal intervention may have been too short and/or was not fully attended to by participants. However, all participants in the arousal reappraisal group were asked to summarize the instructions they had heard and provide an example of the reappraisal audibly to the researchers. In addition, a post-task manipulation check asking what strategy they used to cope with the stressor was employed to check they had used arousal reappraisal. Additionally, the instructions and intervention were based on previous work in this area (*e.g.*, Jamieson et al., 2013; Moore et al., 2015).

Findings were relatively consistent across Study 1 and Study 2, with the primary differences concerning the experimental design. Although both studies recruited participants in a manner consistent with the a-priori sample size justification, it is possible that non-significant findings in Study 2 were due to being unpowered. Sensitivity analyses indicated that the sample of 155 used in Study 2 had sufficient power (>80%) to detect all hypothesized effects found in Study 1, with the exception of the direct effects of physiological arousal interpretation on cognitive and somatic anxiety intensity. Future research should consider replicating these results.

In conclusion, the present two studies directly tested a hypothesized model through which physiological arousal intensity and interpretation influence anxiety and then directly tested if arousal reappraisal could improve anxiety outcomes by “breaking” the connection. The study supported both of these hypotheses (Jamieson et al., 2013). Arousal reappraisal may be beneficial on anxiety responses to stress through “breaking” the link between physiological arousal and physiological arousal interpretation. Future research should examine if other factors may be influencing these results such as actual physiological arousal (i.e., cardiovascular reactivity). Additionally, future research should compare the effectiveness of arousal reappraisal to other stress management techniques and look to combine these approaches in search of the most effective intervention strategies to regulate the physiological, psychological, and behavioral responses to stress.

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Table 1. *Demographics for the Study 1 (N = 455) sample.*

	Mean (SD)
Age	19.49 (1.26)
Gender	
Female	282
Male	173
Race	
Black	36
White	303
Asian	83
Mixed	32
Native American	1
Ethnicity	
Hispanic	81
Non-Hispanic	374

Table 2. *Means and standard deviations of physiological arousal intensity, physiological arousal interpretation, cognitive and somatic anxiety intensities, and cognitive and somatic anxiety interpretations for the Study 1 sample.*

	Mean (SD)
Physiological arousal intensity (1 – 7)	3.99 (1.44)
Physiological arousal interpretation (-3 – +3)	-0.07 (1.31)
Cognitive anxiety intensity (1 – 7)	4.32 (1.51)
Somatic anxiety intensity (1 – 7)	3.87 (1.57)
Cognitive anxiety interpretation (-3 – +3)	-0.55 (1.42)
Somatic anxiety interpretation (-3 – +3)	-0.52 (1.32)

Table 3. *Study 1 indirect effects of physiological arousal intensity and physiological arousal interpretation on anxiety variables.*

	Physiological arousal intensity	Physiological arousal interpretation
Cognitive anxiety intensity	.025* [.012 – .048]	
Somatic anxiety intensity	.032* [.017 – .053]	
Cognitive anxiety interpretation	-.193* [-.247 – -.139]	.032* [.016 – .051]
Somatic anxiety interpretation	-.255* [-.321 – -.194]	.045* [.027 – .066]

Note. Standardized effects, **p* < .01, 95% CIs from a bootstrap of 2000 samples reported in brackets.

Table 4. *Demographics for the Study 2 (N = 155, arousal reappraisal n = 80; control n =75) sample.*

	Arousal Reappraisal Group	Control Group
	Mean (SD)	Mean (SD)
Age	19.52(0.99)	19.44 (0.86)
Gender		
Female	50	49
Male	30	26
Race		
Black	4	9
White	52	39
Asian	9	12
Mixed	12	12
Native American	1	1
Native Hawaiian	0	1
Ethnicity		
Hispanic	19	22
Non-Hispanic	59	52

Note. Two participants in the arousal reappraisal and 1 participant in the control group did not report their race or ethnicity. There were no statistically significant differences between groups in age, gender, race, or ethnicity.

Table 5. *Means and standard deviations of physiological arousal intensity, physiological arousal interpretation, cognitive and somatic anxiety intensities, and cognitive and somatic anxiety interpretations for the arousal reappraisal and control groups in Study 2.*

	Arousal Reappraisal Group	Control Group
	Mean (SD)	Mean (SD)
Physiological arousal intensity (1 – 7)	3.74 (1.51)	3.81 (1.38)
Physiological arousal interpretation (-3 – +3)	0.43** (1.36)	-0.25 (1.21)
Cognitive anxiety intensity (1 – 7)	3.84 (1.55)	4.28 (1.46)
Somatic anxiety intensity (1 – 7)	3.50 (1.63)	3.60 (1.60)
Cognitive anxiety interpretation (-3 – +3)	0.30* (1.35)	-0.36 (1.53)
Somatic anxiety interpretation (-3 – +3)	0.18* (1.31)	-0.37 (1.26)

Note. Asterisk indicates a significant difference to the control group *p < .01, **p = .001.

Table 6. *Study 2 indirect effects of experimental group, physiological arousal interpretation, and physiological arousal intensity on anxiety variables.*

	Experimental group	Physiological arousal interpretation	Physiological arousal intensity
Cognitive anxiety intensity	-.035 [-.092 – .002]		.005 [-.011 – .041]
Somatic anxiety intensity	-.016 [-.055 – .013]		.003 [-.004 – .031]
Cognitive anxiety interpretation	.130** [.051 – .219]	.030* [<.001 – .080]	-.110* [-.216 – -.007]
Somatic anxiety interpretation	.149** [.061 – .248]	.014 [-.009 – .051]	-.163* [-.296 – -.033]

Note. Standardized effects, *$p < .05$, **$p = .002$, 95% CIs from a bootstrap of 2000 samples reported in brackets.

Figure 1. *Study 1 hypothesized model. Note, full lines represent positive predictions and dashed lines represent negative predictions. For visual simplicity, control variables correlations between anxiety intensities and between anxiety interpretations are not displayed.*

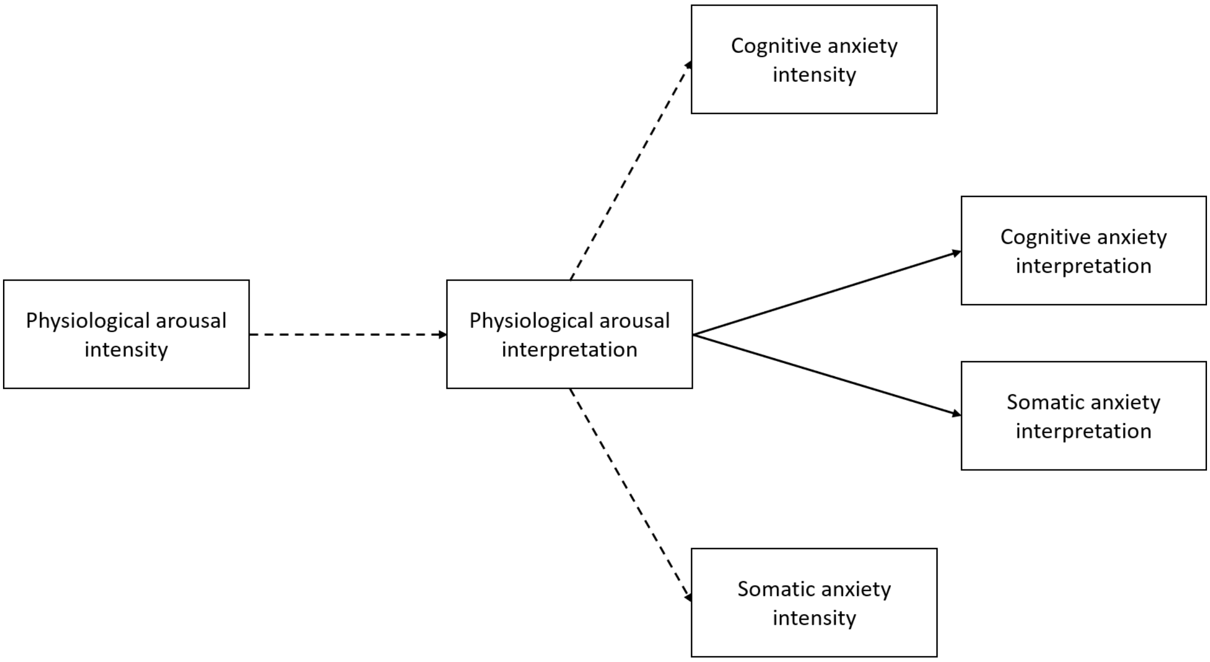

Figure 2. *Study 1 final model. Note, standardized beta weights [95% confidence intervals] are reported, *p < .001. For visual simplicity, control variables and correlations between anxiety intensities and between anxiety interpretations are not displayed.*

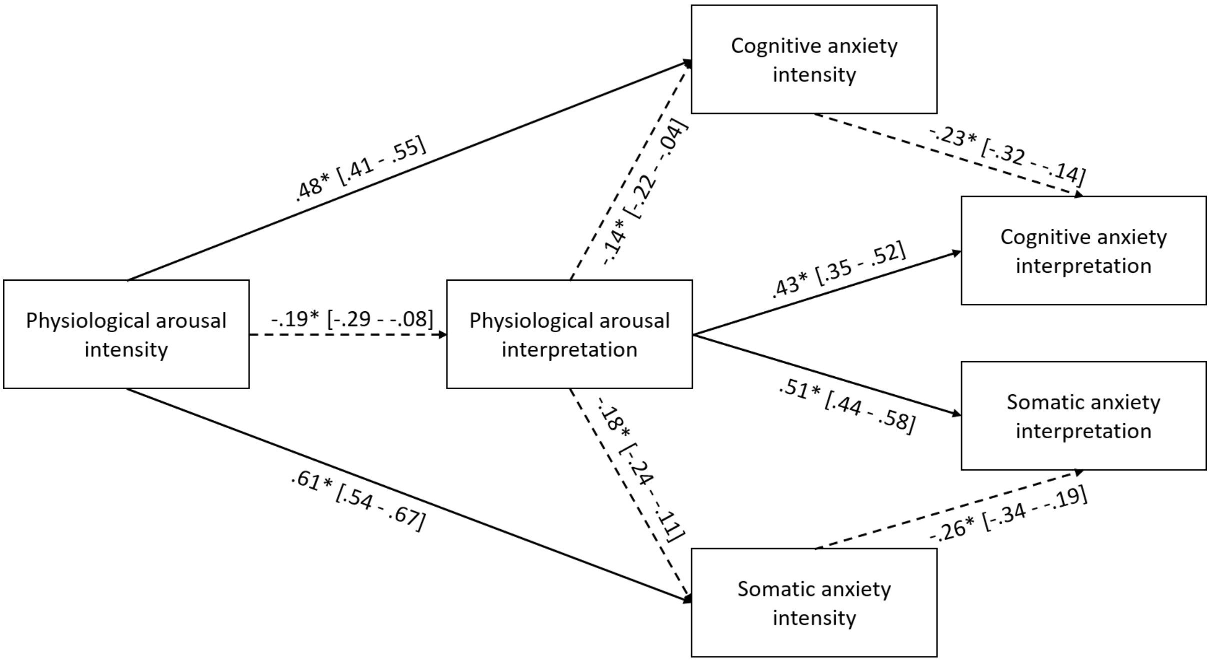

Figure 3. *Study 2 hypothesized model. Note, full lines represent positive predictions and dashed lines represent negative predictions. Non-significant paths are indicated by a double strikethrough the line. For visual simplicity, control variables and correlations between anxiety intensities and between anxiety interpretations are not displayed.*

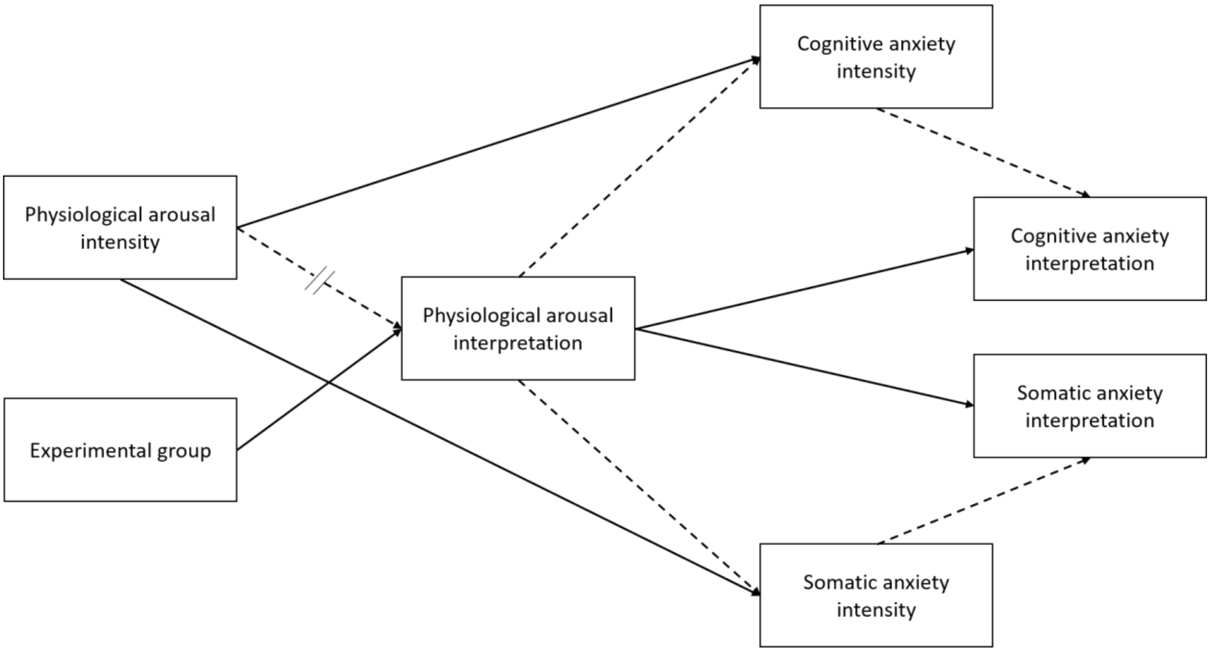

Figure 4. *Study 2 final model. Note, standardized beta weights are reported, *p = .006, **p = .002, ***p = .001. For visual simplicity, control variables and correlations between anxiety intensities and between anxiety interpretations are not displayed.*