

Effects of arousal reappraisal on the anxiety responses to stress

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1 **Running head: Arousal Reappraisal on the Anxiety Responses to Stress**

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

6

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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

Data availability statement: The data that support the findings of this study are available from the corresponding author upon reasonable request.

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

58 Psychological stress has been associated with adverse mental and physical health
59 outcomes across the lifespan (e.g., Epel et al., 2018; McFarlane, 2010; Cohen et al., 2007;
60 Steptoe & Kivimaki, 2012). While short-term responses to acute stress may indeed be
61 adaptive in appropriately mobilizing the resources needed for behavioral responses to
62 actively cope with acute stress (Obrist et al., 1981; Ginty et al., 2017; Gianaros & Jennings,
63 2017; Schneiderman et al., 2005), long term exposure to stress (i.e., chronic stress) can be
64 detrimental through ‘wear and tear’ on physiological systems (Cohen et al., 2007; Cohen et
65 al., 2016) and lead to adverse health outcomes (e.g., Cohen et al., 2007). Indeed, stress is
66 generally viewed as negative with emphasis placed on avoiding or reducing exposure to
67 stress (Souza-Talarico et al., 2016; Rudland et al., 2018; Crum et al., 2013; Richardson et al.,
68 2012). However, eliminating or reducing exposure to stress is not always possible.

69 One way to manage stress is through the use of cognitive reappraisal, which focuses
70 on changing or reinterpreting beliefs of stressful situations (e.g., Gross, 1998; Lazarus &
71 Folkman, 1984; Kross & Ayduk, 2011; Liu et al., 2019) and can help manage negative
72 emotional, cognitive, and physiological responses (Cutuli, 2014; Gross, 1998). Arousal
73 reappraisal may be viewed as an extension of the cognitive reappraisal literature, which
74 specifically emphasizes altering the appraisals of physiological arousal that occur during
75 acute stress from harmful to helpful, enhancing, or facilitative for performance (Beltzer et al.,
76 2014; Lindquist & Barrett, 2008; Lindquist et al., 2011). Laboratory studies suggest that
77 using arousal reappraisal to manipulate stress appraisals directly improves acute stress
78 responses and can result in more positive stress related outcomes (e.g., Jamieson et al., 2010;
79 Jamieson et al., 2012; John-Henderson et al., 2015; Jamieson et al., 2016; Jamieson et al.,
80 2018; Moore et al., 2015; Crum et al., 2020).

81 A stress related outcome which can be improved by arousal reappraisal is anxiety. In
82 the broadest sense, stress is anything that alters the equilibrium of the individual (Selye,
83 1936). Anxiety is a state that includes behavioral, affective, and cognitive changes in
84 response to stressor or a potential stressor as an effort to avoid or reduce the impact of the
85 threat (Grupe & Nitschke, 2013). Often, anxiety includes feelings of worry and concern and
86 increases in physiological activity (i.e., increased heart rate; Buss et al., 1955). Research
87 demonstrates that while there are individual differences in the intensity of anxiety
88 experienced, acute psychological stress often elicits feelings of anxiety both in anticipation of
89 and during stressful scenarios (Hofmann et al., 2009; Jamieson et al., 2016; Trotman et al.,
90 2018; Williams et al., 2017). Anxiety is typically regarded as ‘negative,’ however, evidence
91 suggests anxiety can be perceived by the individual as debilitating (i.e., harmful) or
92 facilitative (i.e., helpful; Jones & Hanton, 1996).

93 Arousal reappraisal is beneficial in reducing the intensity of anxiety experienced in
94 response to stress. In experimental studies, arousal reappraisal has been associated with lower
95 levels of self-report or experimenter observed anxiety across a range of tasks: Graduate
96 Research Examinations (Jamieson et al., 2010), socially evaluative speech (Beltzer et al.,
97 2014; Hofman et al., 2009; Jamieson et al., 2013), and math examinations (Jamieson et al.,
98 2016). While the majority of work has focused on the impact of arousal reappraisal on
99 anxiety intensity, one study examined if arousal reappraisal altered the directional
100 interpretation (i.e., if the individual saw the anxiety as facilitative or debilitating) of the
101 anxiety experienced. In a study of 50 participants randomly assigned to arousal reappraisal or
102 control, Moore et al. (2015) demonstrated that those in the arousal reappraisal group had
103 more facilitative interpretations of their somatic anxiety levels (referred to in the manuscript
104 as physiological arousal) in anticipation of the task compared to the control group. Taken
105 together, this body of research suggests arousal reappraisal is beneficial in reducing levels of

106 anxiety and assisting with more positive interpretations of anxiety. However, the exact
107 psychological mechanisms through which arousal reappraisal is having these benefits remain
108 largely unknown, as does the impact of arousal reappraisal on cognitive anxiety
109 interpretation.

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

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

126 **Study 1**

127 **Aims and Hypotheses**

128 The aim of Study 1 was to formally test pathways between a stressful situation and
129 emotion outcomes proposed by Jamieson et al. (2013). Specifically, Study 1 examined the
130 association between physiological arousal intensity, interpretation of the physiological

131 arousal, and emotions experienced (i.e., anxiety intensity and direction interpretation). Based
132 on Jamieson et al. (2013)'s model, it was hypothesized that during acute psychological stress,
133 higher levels of perceived physiological arousal would be associated with greater negative
134 perceptions of arousal and that these perceptions would be related to greater levels of anxiety
135 and more negative interpretations of these symptoms. The hypothesized model is displayed in
136 Figure 1.

137 **Method**

138 *Participants*

139 Four hundred and fifty-nine young adults were recruited using the first authors
140 university's online SONA psychology subject pool. A minimum sample size was determined
141 using the 15 participants per parameter as an upper limit recommendation by Tabachnick
142 and Fidell (2013). We had 9 primary effects of interest. Thus, our minimum sample size was
143 $N = 135$ for this study. To maximize precision in our estimates, we continued to collect as
144 many data points as possible until resources were expended. Exclusion criteria included: a
145 current illness or infection or a history of cardiovascular disease at the time of partaking in
146 the study. Participants were asked to refrain from the following before their laboratory visit:
147 engaging in vigorous exercise or consuming alcohol 12 h prior, consuming food or any
148 beverage other than water 2 h prior to testing. Participants received 2 h SONA research
149 credits for their participation. All participants provided informed consent prior to the start of
150 the study. The study was conducted in accordance with the Declaration of Helsinki and the
151 study was approved by the first author's university's institutional review board.

152 *Measures*

153 **Perceived physiological arousal intensity and interpretation.** Separate items were
154 employed to assess the extent to which participants perceived themselves to be experiencing
155 physiological arousal (i.e., intensity), as well as the extent to which participants viewed these

156 symptoms as being facilitative or debilitating towards upcoming performance (i.e., direction
157 interpretation). Intensity ratings were made on a 7-point Likert-type scale from 1 (*not at all*)
158 to 7 (*extremely*) while direction interpretation ratings were made on a 7-point Likert-type
159 scale from -3 (*very debilitating/negative*) to +3 (*very facilitative/positive*).

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

173 ***Stress Task***

174 The 4-minute version of the Paced Auditory Serial Addition Test (PASAT; Gronwall,
175 1977) was used to elicit psychological stress. The PASAT has been extensively used as an
176 acute psychological stress task in research settings (e.g., Veldhuijzen van Zanten et al., 2004;
177 Trotman et al., 2019; Ginty et al., 2012; Ginty et al., 2020) and demonstrates good test-retest
178 reliability (Willemsen et al., 1998). Participants were presented with a series of numbers
179 (ranging between 1-9) and asked to add each consecutive number to the number they just
180 heard from the recording, rather than the number they had just said out loud. The interval

181 between the numbers was 2.4 s for the first minute of the task and decreased by 0.4 s each
182 minute until the completion of the task. Elements of self-evaluation, social evaluation, and
183 competition were added to the task paradigm to increase feelings of stressfulness
184 (Veldhuijzen van Zanten et al., 2004). Participants were told they would lose 5 points for
185 every incorrect answer or omission. They were also informed they were in direct competition
186 with their peers and a “leader board” was prominently displayed in the laboratory.
187 Throughout the duration of the task, a research assistant stood approximately 0.25 meters
188 away to observe and score the participants. Additionally, participants were informed they
189 would hear a loud, aversive noise every time they give an incorrect answer, stuttered,
190 mumbled, or hesitated. In actuality, participants heard the noise at standardized times
191 throughout the protocol. Participants were videotaped throughout the task and told the video
192 tape would be analyzed by “body language experts.” In reality, the video camera was not
193 recording. Lastly, participants were required to look at themselves in a mirror positioned
194 approximately 0.5 meters in front of them throughout the duration of the task.

195 *Procedures*

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

203 *Data Reduction and Analysis*

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

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

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

229 **Results**

230 *Sample Characteristics*

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

236 ***Hypothesized Model***

237 To test the hypothesized model, a regression path was included from physiological
238 arousal intensity to physiological arousal interpretation, and from physiological arousal
239 interpretation to cognitive and somatic anxiety intensities and directions. Associations
240 between the two anxiety intensities and the two anxiety interpretations were also
241 acknowledged by correlating these error terms similar to previous anxiety models (Williams
242 et al., 2016). The first iteration of the model revealed a poor fit to the data, $\chi^2 (8) = 328.34, p$
243 $< .001$, CFI = .75, TLI = .14, SRMR = .14, RMSEA = .30 (90% CI = .27 – .33). Examining
244 the modification indices suggested including additional paths from physiological arousal
245 intensity to cognitive and somatic anxiety intensity, and from cognitive anxiety intensity to
246 cognitive anxiety interpretation, and from somatic anxiety intensity to somatic anxiety
247 interpretation direction. These pathways were added due to conceptual sense and support in
248 the literature (Trotman et al., 2019; Neil et al., 2012). The second iteration of the model
249 demonstrated a very good fit to the data, $\chi^2 (4) = 6.25, p = .097$, CFI = .99, TLI = .98, SRMR
250 = .14, RMSEA = .05 (90% CI = $<.001$ – .09). All paths within the model were found to be
251 significant (p 's $<.001$) indicating that greater physiological arousal was associated with a
252 more negative interpretation of these symptoms which in turn predicted greater levels of
253 cognitive and somatic anxiety, and more debilitating interpretations of cognitive and somatic
254 anxiety. Greater physiological arousal intensity was also a direct predictor of greater
255 cognitive and somatic anxiety which were in turn associated with more debilitating

256 interpretations of this anxiety. The final model is displayed in Figure 2. Table 3 displays the
257 indirect effects of the model. Physiological arousal intensity was a significant predictor of all
258 four types of anxiety via physiological arousal interpretation. Additionally, physiological
259 arousal interpretation was also an indirect predictor of cognitive and somatic anxiety
260 interpretation via cognitive and somatic anxiety intensity respectively.

261 **Discussion**

262 Results from Study 1 provide support for the model proposed by Jamieson and
263 colleagues (2013). As hypothesized, physiological arousal intensity was a direct predictor of
264 how these symptoms were interpreted which in turn was associated with both the intensity
265 and the interpretation of the anxiety experienced. Specifically, those who perceived
266 themselves to experience greater physiological arousal in response to the stress task, reported
267 their physiological arousal as being more debilitating. Higher levels of debilitating
268 interpretation of physiological arousal was in turn associated with greater levels of cognitive
269 and somatic anxiety as well as more negative interpretations of this anxiety. In addition to
270 directly predicting cognitive and somatic anxiety interpretation, the additional paths from
271 anxiety intensities to their respective interpretations demonstrating that physiological arousal
272 interpretation also indirectly predicted anxiety interpretations via their anxiety intensities. A
273 second alteration of the hypothesized model was the direct pathways from physiological
274 arousal intensity to both cognitive and somatic anxiety intensities, demonstrating that
275 perceived physiological arousal intensity is associated with greater feelings of cognitive and
276 somatic anxiety. The later finding supports a recent study reporting that perceived heart rate,
277 a form of physiological arousal, was positively associated with both cognitive and somatic
278 anxiety intensity and suggests that the direct relationship between perceived physiological
279 arousal and the intensity of emotions experienced should be accounted for when investigating
280 the effects of arousal intensity and interpretation on emotions and cognitions (Trotman et al.,

281 2019). Irrespective of these direct paths, perceived physiological arousal still predicted both
282 the intensity and interpretation of anxiety via the interpretation of this physiological arousal
283 which supports the hypotheses in Jamieson et al.'s (2013) proposed model. To our
284 knowledge, this is the first study to formally test the affective (i.e., anxiety) outcomes of this
285 proposal model using a large sample and standardized acute psychological stress task.

286 **Study 2**

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

290 **Aims and Hypotheses**

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

300 An independent sample of participants were recruited and completed the same acute
301 psychological stress paradigm to that employed in Study 1. Prior to the stress task, half the
302 sample were randomly assigned to an arousal reappraisal intervention and the other half a
303 control condition (no intervention). In response to the stress task, it was hypothesized that
304 while both groups would display similar levels of perceived physiological arousal intensity,
305 compared to the control group, the arousal reappraisal group would report more positive

306 interpretations of their physiological arousal, lower levels of cognitive and somatic anxiety,
307 and more positive interpretations of these anxiety symptoms. Consequently, when testing a
308 similar model to Study 1, it was hypothesized that the intervention condition would be a
309 significant predictor of physiological arousal interpretation whereas physiological arousal
310 intensity would no longer be a significant predictor. The hypothesized model is displayed in
311 Figure 3.

312 **Method**

313 *Participants*

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

324 *Measures*

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

329 *Arousal Reappraisal*

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

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

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

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

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

352 ***Stress Task***

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

355 ***Procedures***

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

362 ***Data Reduction and Analysis***

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

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

377 Next, the hypothesized model was tested in AMOS using path analysis using the same
378 model fit indices and examination of indirect effects as that employed in Study 1. Gender and

379 age were controlled for in all analyses and standardized regression weightings were reported
380 along with the 95% confidence intervals.

381 **Results**

382 *Group Differences*

383 There were 80 participants in the arousal reappraisal group and 75 participants in the
384 control group. There were no statistically significant differences in groups in age, gender,
385 ethnicity, or race (p 's > .488). Demographic variables are reported in Table 4. Means and
386 standard deviations for physiological arousal intensity, physiological arousal interpretation,
387 cognitive anxiety intensity, cognitive anxiety interpretation, somatic anxiety intensity, and
388 somatic anxiety interpretation are reported in Table 5. A one-way ANOVA showed no
389 significant difference between groups in physiological arousal intensity, $F(1, 153) = 0.11, p =$
390 $.745, \eta_p^2 = .001$. There was, however, a significant difference in physiological arousal
391 interpretation, $F(1, 153) = 10.74, p = .001, \eta_p^2 = .066$, with the arousal reappraisal group
392 perceiving their arousal to be significantly more facilitative towards performance of the task.
393 There were no statistically significant group differences in cognitive ($F[1, 153] = 3.35, p =$
394 $.069, \eta_p^2 = .021$) and somatic ($F[1, 153] = 0.00, p = 1.00, \eta_p^2 < .001$) anxiety intensities, but
395 the arousal reappraisal group perceived their cognitive ($F[1, 153] = 8.11, p = .005, \eta_p^2 = .050$)
396 and somatic ($F[1, 153] = 7.04, p = .009, \eta_p^2 = .044$) anxiety to be significantly more
397 facilitative towards performance.

398 *Hypothesized Model*

399 To test the hypothesized model, regression paths were inserted from physiological
400 arousal intensity and experimental group (coded 0 = control group, 1 = arousal reappraisal
401 group) to physiological arousal interpretation, and from physiological arousal interpretation
402 to cognitive and somatic anxiety intensities and directions, and associations between the two

403 anxiety intensities and the two anxiety interpretations were also acknowledged by correlating
404 these error terms. Based on the results of Study 1, paths were also included from
405 physiological arousal intensity to cognitive and somatic anxiety intensity, and from cognitive
406 and somatic anxieties to their respective interpretations. The tested model demonstrated a
407 very good fit to the data, $\chi^2(10) = 10.29, p < .416, CFI = .99, TLI = .99, SRMR = .04,$
408 $RMSEA = .01$ (90% CI = $<.001 - .09$). The standardized estimates showed that while
409 experimental condition significantly and positively predicted physiological arousal
410 interpretation (i.e., the arousal reappraisal group was associated with a more facilitative
411 interpretation of physiological arousal), unlike Study 1, arousal intensity was a non-
412 significant predictor ($p = .613$) of physiological arousal interpretation. Physiological arousal
413 interpretation was a significant positive predictor of cognitive and somatic anxiety
414 interpretation and a significant negative predictor of cognitive anxiety intensity so that more
415 positive interpretations of physiological arousal were associated with more positive
416 interpretations of cognitive and somatic anxiety, and lower levels of cognitive anxiety. Unlike
417 Study 1, physiological arousal interpretation was a non-significant direct predictor of somatic
418 anxiety intensity ($p = .269$). Greater physiological arousal intensity was also a direct predictor
419 of greater cognitive and somatic anxiety which were in turn associated with more debilitating
420 interpretations of this anxiety. The final model is displayed in Figure 4. Table 2 displays the
421 indirect effects of the model. Experimental condition was a significant predictor of cognitive
422 and somatic anxiety interpretation via physiological arousal interpretation. Additionally,
423 physiological arousal interpretation was an indirect predictor of cognitive anxiety
424 interpretation via cognitive anxiety intensity. Physiological arousal intensity also indirectly
425 predicted cognitive and somatic anxiety interpretation via their respective intensities.

426 **Discussion**

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

438 **General Discussion**

439 Despite arousal reappraisal demonstrating substantial benefits for stress-related
440 anxiety (Jamieson et al., 2010; Beltzer et al., 2014; Hofmann et al., 2009; Jamieson et al.,
441 2013; Jamieson et al., 2016), no study to date has thoroughly examined the potential
442 psychological mechanisms through which arousal reappraisal may operate. The present two
443 study paper aimed to test a model proposed by Jamieson et al. (2013) hypothesizing a
444 pathway through which physiological arousal may lead to negative emotional outcomes and a
445 second model hypothesizing ‘how’ arousal reappraisal may alter these pathways (i.e., by
446 altering interpretations of physiological arousal) using a large cross-sectional laboratory
447 approach (Study 1) and an experimental design where participants were assigned to a brief
448 arousal reappraisal or control (Study 2) group. Study 1 confirmed the pathway between
449 physiological arousal intensity to negative interpretations of physiological arousal to higher
450 levels of anxiety proposed by Jamieson et al. (2013). Study 2 further supported the hypothesis
451 of Jamieson et al. (2013) by demonstrating that using arousal reappraisal “breaks” the

452 connection between physiological arousal intensity and interpretation. Taken together, the
453 two studies in the present manuscript provide confirmatory evidence that physiological
454 arousal interpretation is an important construct in the relationship between a stressor and the
455 experience of anxiety.

456 Contrary to our hypotheses, in Study 2, there were no statistically significant
457 differences between the arousal reappraisal and control group on somatic anxiety intensity or
458 cognitive anxiety intensity. This is somewhat surprising given other work demonstrating
459 arousal reappraisal lowers the level of anxiety experienced during acute stress (Jamieson et
460 al., 2010; Beltzer et al., 2014; Hofmann et al., 2009). However, while the groups did not
461 differ in cognitive or somatic anxiety intensity, they did significantly differ in the
462 interpretation of their anxiety. While unexpected, the absence of differences between groups
463 in anxiety intensity accompanied by the significant group differences in anxiety interpretation
464 align with intervention research utilizing other methods to alter appraisals. For example, in a
465 within group study design, mental imagery designed to highlight positive interpretations of
466 physiological responses to stressful situations (i.e., challenge imagery) elicited more positive
467 interpretations of cognitive and somatic anxiety compared to threat and neutral imagery, but
468 there were no differences between conditions in the anxiety intensities (Williams et al.,
469 2017). Recent theoretical work has proposed that it is the interpretation of the emotion, not
470 the intensity, which is important for more optimal outcomes (Crum et al., 2020).

471 Despite there being no significant differences in physiological arousal intensity,
472 cognitive anxiety intensity, or somatic anxiety intensity between the groups, the arousal
473 reappraisal group rated their physiological arousal and anxiety as being more facilitative
474 compared to the control group. These results are in line with a previous study demonstrating
475 arousal reappraisal is associated with more facilitative interpretations of somatic anxiety,
476 referred to as physiological arousal in the study, during a golf putting task (Moore et al.,

477 2015). However, the present results are at odds with a study finding no differences between
478 an arousal reappraisal intervention or control condition in the interpretation of arousal during
479 a dart throwing task (Sammy et al., 2017).

480 How one interprets their anxiety as being helpful or hurtful towards performance has
481 been shown to predict how an individual copes with and performs during stress (Carrier et al.,
482 2014; Chamberlain & Hale, 2007; Jones & Swain, 1995; Swain & Jones, 1996). Specifically,
483 in the sport psychology literature, athletes frequently report that experiencing high levels of
484 anxiety (i.e., anxiety intensity) can be facilitative towards their performance (Hanton &
485 Jones, 1999). Importantly, research has shown that interpreting anxiety symptoms more
486 positively can be a stronger predictor of better outcomes than the intensity of the anxiety
487 symptoms (Chamberlain & Hale, 2007; Neil et al., 2012).

488 While the studies above demonstrate the importance of arousal for performance in
489 everyday tasks for non-clinical samples, the importance of anxiety interpretation also has
490 implications for the treatment of anxiety in clinical samples. Indeed, evidence-based
491 treatments for anxiety, such as Cognitive Behavioral Therapy (CBT), often include
492 educational sections on the adaptive functions of arousal in psychological stress (Craske &
493 Barlow, 2000) and elements of reappraisal to cope with acute stress (for reviews see Barlow,
494 2004; Smits et al., 2012). With reappraisal training, individuals are taught to change their
495 interpretations of stress to decrease arousal (e.g., mindfulness; Levitt et al., 2004) or accept
496 arousal (e.g., interoceptive exposure; Cincotta et al., 2011). Changing interpretations with
497 arousal reappraisal may, as the work by Jamieson, Nock, and Mendes (2012) suggests,
498 “break” the link between physiological arousal intensity and negative interpretations of
499 physiological arousal to stress (i.e., negative stress to positive stress).

500 The present studies provide evidence for the benefits of arousal reappraisal in the
501 treatment for anxiety. In Study 1, cross-sectional evidence demonstrated that in a large

502 sample, higher levels of physiological arousal were associated with more negative
503 interpretations of this arousal, which was in turn associated with more debilitating and intense
504 ratings of anxiety. This supports clinical work demonstrating interpretations are important in
505 predicting negative emotional outcomes (e.g., Muris & Field, 2008). Study 2 demonstrates
506 that arousal reappraisal, even in a brief format of introducing participants to the concept, has
507 the ability to “break” the link between physiological arousal intensity and negative
508 interpretations of physiological arousal to stress. Further work is needed to examine if this
509 extends to other types of stressful situations (i.e., examinations, speeches, sport performance).

510 Recent theoretical advances suggest an approach of “stress optimization” (Crum et al.,
511 2020). This approach proposes that displaying a more stress-is-enhancing mindset (i.e., a
512 belief that stress has enhancing consequences for things such as performance and
513 productivity, health and well-being, and/or learning and growth; Crum et al., 2013) may be
514 effective for most optimally coping with stress (Crum et al., 2020). A stress-is-enhancing
515 mindset may allow individuals to be more likely to engage in reappraising thoughts or
516 cognitive change when faced with a stressor (Crum et al., 2020). Stress optimization
517 highlights the importance of responding to stressors in flexible ways that help achieve more
518 optimal outcomes than outcomes achieved by simply reducing or avoiding stressors. Future
519 research should examine 1) if individuals who view stress as more enhancing naturally use
520 arousal reappraisal when faced with stress and if this reappraisal alters interpretations of
521 stress (i.e., extending study 1) and 2) if an intervention to elicit a stress-is-enhancing mindset
522 increases the likelihood of appraising arousal in response to stress as more facilitative and if
523 this appraisal in turn alters interpretations of stress.

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

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

552 to cope with the stressor was employed to check they had used arousal reappraisal.
553 Additionally, the instructions and intervention were based on previous work in this area (*e.g.*,
554 Jamieson et al., 2013; Moore et al., 2015).

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

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

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

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	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

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

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	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)

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979 **Table 3.** *Study 1 indirect effects of physiological arousal intensity and physiological arousal*
 980 *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]

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

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

988

	Arousal	Control
	Reappraisal Group	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

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

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

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	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)

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

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1003 **Table 6.** *Study 2 indirect effects of experimental group, physiological arousal interpretation,*
 1004 *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]

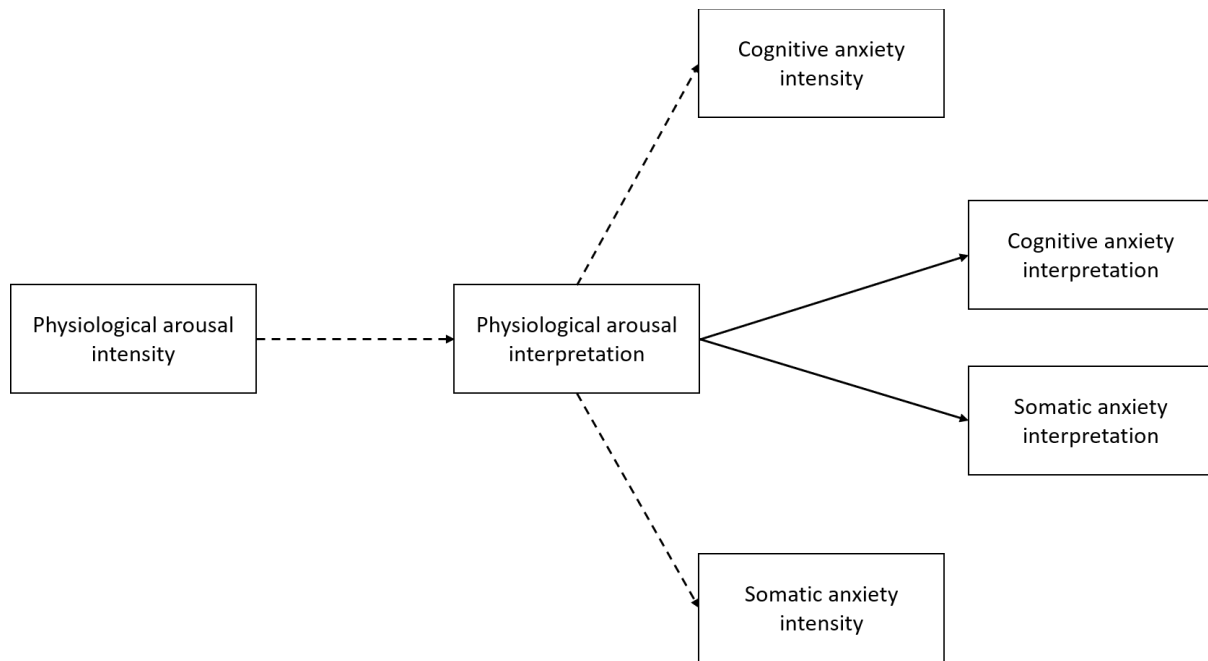
1005 Note. Standardized effects, * $p < .05$, ** $p = .002$, 95% CIs from a bootstrap of 2000 samples

1006 reported in brackets.

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1011 **Figure 1.** *Study 1 hypothesized model. Note, full lines represent positive predictions and*
1012 *dashed lines represent negative predictions. For visual simplicity, control variables*
1013 *correlations between anxiety intensities and between anxiety interpretations are not*
1014 *displayed.*

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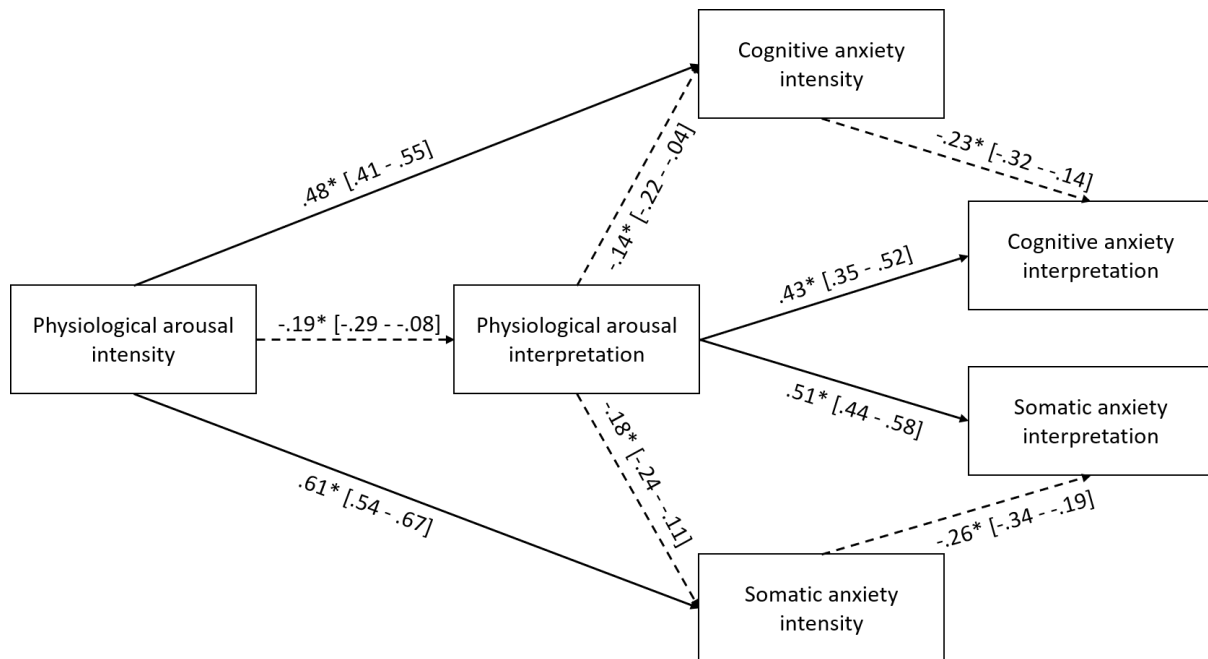
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Arousal Reappraisal on the Anxiety Responses to Stress

1020 **Figure 2.** Study 1 final model. Note, standardized beta weights [95% confidence intervals]
1021 are reported, * $p < .001$. For visual simplicity, control variables and correlations between
1022 anxiety intensities and between anxiety interpretations are not displayed.

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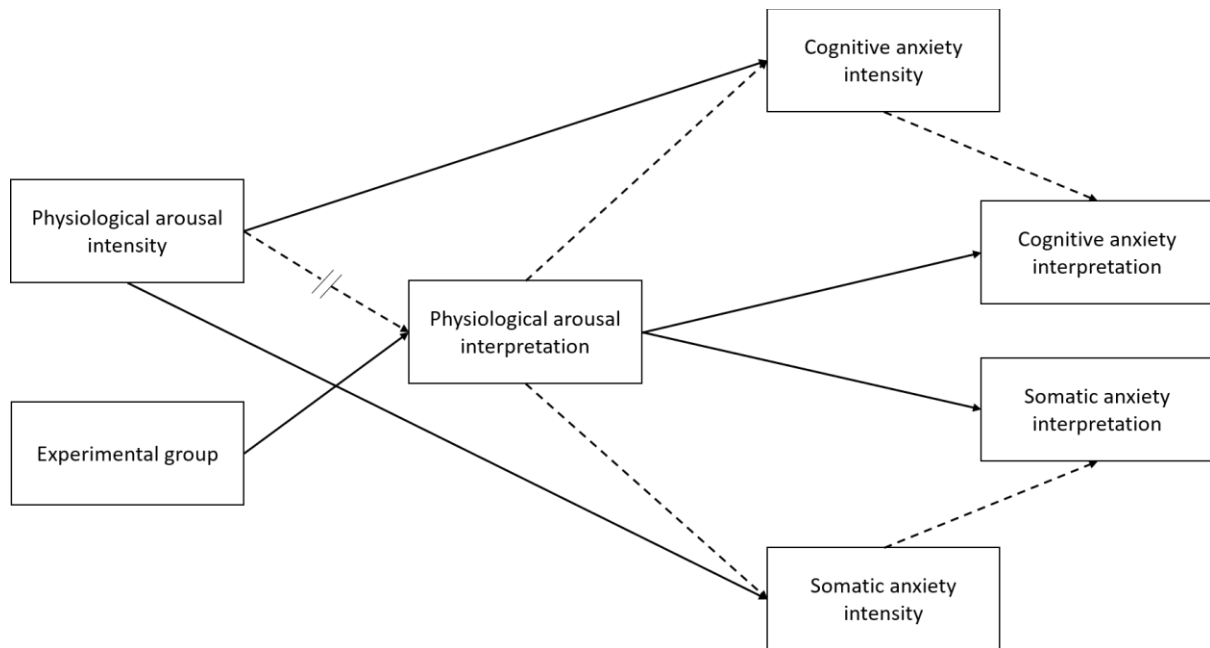
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1031 **Figure 3.** Study 2 hypothesized model. Note, full lines represent positive predictions and
1032 dashed lines represent negative predictions. Non-significant paths are indicated by a double
1033 strikethrough the line. For visual simplicity, control variables and correlations between
1034 anxiety intensities and between anxiety interpretations are not displayed.

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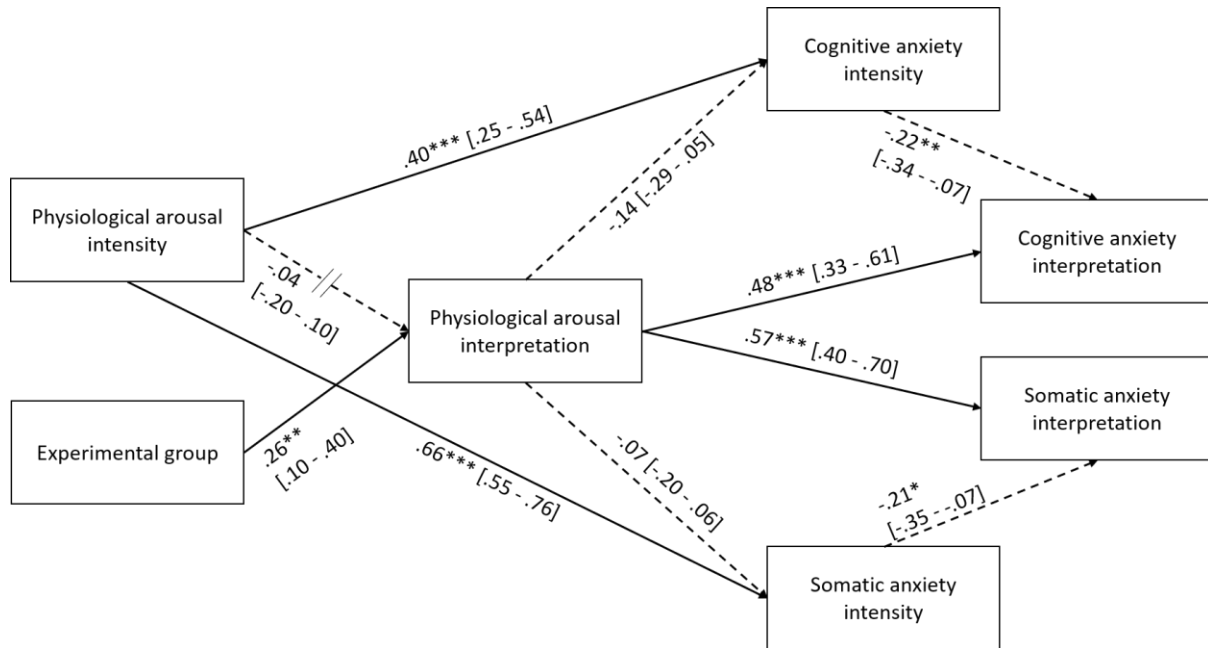
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Arousal Reappraisal on the Anxiety Responses to Stress

1044 **Figure 4.** Study 2 final model. Note, standardized beta weights are reported, * $p = .006$, ** p
 1045 $= .002$, *** $p = .001$. For visual simplicity, control variables and correlations between
 1046 anxiety intensities and between anxiety interpretations are not displayed.
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