ABSTRACT

Title of dissertation: EXAMINATION OF THE BRAIN PROCESSES UNDERLYING EMOTION REGULATION WITHIN A STRESS RESILIENT POPULATION

Michelle E. Costanzo, Doctor of Philosophy, 2011

Dissertation directed by: Dr. Bradley D. Hatfield, Ph.D., FACSM, FAAKPE
Neuroscience and Cognitive Sciences Program

Emotion robustly affects the quality of cognitive-motor performance under conditions of mental stress. As such, the regulation of emotion is critical to successful execution of motor skills during emotional challenge. Previous investigations of the stress-performance relationship have typically focused on behavioral outcomes, however, few have adopted a cognitive neuroscience approach to examine the involved mechanisms underlying this relationship. Furthermore, it is unclear if individuals who have a history of superior performance under stress (stress resilient population) exhibit brain responses characterized by an efficiency of neural processing and an adaptive emotion regulatory strategy. Using functional magnetic resonance imaging (fMRI), the present study examined activation in critical brain regions during affective challenge (i.e., presentation of International Affective Picture System negative images and Sport-Specific negative images) in 13 elite athletes (intercollegiate football players who have demonstrated successful execution of cognitive-motor skills under mental stress) relative to an age-matched control group

(n=12). The present dissertation is organized into three main sections. The first report, entitled Brain Processes during Motor Performance under Psychological Stress, an Independent Component Analysis of EEG, is an examination of brain processes during competitive stress. This study revealed non-essential neuromotor cerebral cortical noise with a quantified increase in complexity during a cognitive-motor task. The second report is entitled Efficiency of Affective Brain Processes in Expert Cognitive-Motor Performers during Emotional Challenge. This fMRI examination of elite athletes revealed processing economy in brain regions critical to self regulation, management of emotional impulses and social cognition. The third report, entitled The Specificity of Neural Regulatory Processes during Emotional Challenge in a Stress Resilient Population, examined with fMRI if elite athletes spontaneously engage in cognitive reappraisal during the presentation of arousing sport-specific images. Results suggest that elite athletes process sports-relevant affective information in an automatic manner, congruent with a cognitive reappraisal strategy, which neutralized the negative impact of the scenes. In conclusion, the results suggest that elite performers are important models of stress resilience and respond not only in an efficient manner to stressful events, but demonstrate an adaptive regulatory response when challenged within their domain of experience.

EXAMINATION OF THE BRAIN PROCESSES UNDERLYING EMOTION REGULATION WITHIN A STRESS RESILIENT POPULATION

by

Michelle Elizabeth Costanzo

Dissertation submitted to the Faculty of the Graduate School of the
University of Maryland, College Park in partial fulfillment
of the requirements for the degree of
Doctor of Philosophy
2011

Advisory Committee:

Dr. Bradley D. Hatfield, Ph.D., FACSM, FAAKPE (Chair)
Dr. Allen R. Braun, M.D.
Dr. José L. Contreras-Vidal, Ph.D.
Dr. Nathan A. Fox, Ph.D.
Dr. John VanMeter, Ph.D.

Acknowledgements

Dissertation Committee:
Brad Hatfield, Allen Braun, Jose Contreras-Vidal, Nathan Fox & John Van Meter

University of Maryland:
Trent Bradberry, Ron Goodman, Amy Haufler, Li-Chuan Lo, Matt Miller, Hyuk Oh, Jessica Oldham, Jeremy Rietschel, Bart Russell, Mark Saffer

University of Florida:
Chris Janelle

Special Thanks:
Rodolphe Gentili
Denise Costanzo
Mike Costanzo
Annie & Count
University of Maryland Football Team
Ralph & Gloria Friedgen
Dwight Galt
Banke Adeyemo, Andrew Breeden
Gabriella Hancock, Garrett Beatty, Bradley Fawver
Dr. Kathy Levit
Dr. Kateri McRae

Support:
Graduate Student Summer Research Fellowship
Department of Kinesiology Graduate Research Initiative Project (GRIP) Award
William Hodos Dissertation Research Assistantship

Table of Contents

List of Tables. i

List of Figures. ii

List of Abbreviations. iv

Chapter 1: General Introduction: The Fundamental Stress and Cognitive-Motor Performance Relationship and the Relevance of Emotion Regulation 1

Chapter 2: Brief Review of Psychological Stress and Cognitive Motor Performance 8

Psychological Stress 8

Stress and the Motor Hierarchy 9

Cognitive-Motor Performance under Stress: Neuromotor Noise 10

Competition as a Stress Manipulation 12

Chapter 3: Brain Processes during Motor Performance under Psychological Stress during Motor Performance, an Independent Component Analysis of EEG 14

Introduction 14

Methods 18

Participants 18

Task 18

Measures 19

Arousal 19

Cardiovascular and skin conductance 19

Psychoendocrine 19

Self-reported arousal assessment 20

Visual analog scale 20

State anxiety inventory 21

Brain - EEG 21

Motor behavior 22

Procedure (Manipulations) 22

Day 1 - orientation 23

Day 2: performance alone and competition 24

Performance alone 25

Competition 26

Signal Processing and Data Analysis 27

Arousal 27
Heart rate and heart rate variability 27
Skin conductance 28
Psychoendocrine 29
Brain - EEG 29
Independent Component Analysis (ICA)...29
Standardized Low Resolution Brain Electromagnetic Tomography (sLORETA) 32
Motor behavior 33
Statistical Design 34
Arousal 34
Cardiovascular and skin conductance 34
Psychoendocrine 34
Self-reported arousal assessment 34
Brain - ICA 35
Motor behavior 35
Results 35
Arousal...36
Cardiovascular and skin conductance..36
Self-reported arousal assessment...36
Psychoendocrine..37
Brain 38
ICA 38
sLORETA..39
Motor behavior 41
Discussion 42
Chapter 4: Examination of Expert Groups to Understand Stress Resilience 48
Chapter 5: Efficiency of Affective Brain Processes in Expert Cognitive-Motor Performers during Emotional Challenge..52
Introduction 52
Methods...57
Subjects...57
Procedure 58
Stimuli...58

Task..59
Prior to data collection..60
Imaging parameters..62
Dependent Measures..63
Psychometric inventories: to characterize population 63
Performance Failure Appraisal Inventory (PFAI) 63
State-Trait Anxiety Inventory (STAI) 64
Dispositional Resilience Scale (DRS) 64
Sport Competition Anxiety Test (SCAT) 64
Beck Depression Inventory (BDI) 65
Emotion Regulation Questionnaire (ERQ) 65
Physiological measures of arousal 66
Galvanic skin response 66
Heart rate 67
Behavioral measures - affective rating 67
Functional Magnetic Resonance Imaging: BOLD Signal 67
Statistical Analysis...68
Psychometric inventories: to characterize population 68
Physiological measures of arousal 69
Galvanic skin response 69
Heart rate 69
Behavioral measures - affective rating 69
Functional Magnetic Resonance Imaging: BOLD Signal 70
Results 71
Psychometric Inventories to Characterize Population 71
Performance Failure Appraisal Inventory (PFAI) 71
State-Trait Anxiety Inventory (STAI) 72
Dispositional Resilience Scale (DRS) 72
Sport Competition Anxiety Test (SCAT) 72
Beck Depression Inventory (BDI) 73
Emotion Regulation Questionnaire (ERQ) 74
Physiological Measures of Arousal 74
Galvanic skin response 74

Heart rate 75
Behavioral Measures - Affective Rating...76
Functional Magnetic Resonance Imaging: BOLD Response 77
Comparative (Football vs. Control) descriptive pattern of BOLD response during passive viewing of negative Sports-Specific images 78
Football 78
Control 79
Comparative (Football vs. Control) descriptive pattern of BOLD response during passive viewing of negative IAPS images 80
Football 81
Control 81
Comparative (Football vs. Control) descriptive pattern of BOLD response during the cued cognitive reappraisal of negative Sports-Specific images 83
Football 83
Control 84
Comparative (Football vs. Control) descriptive pattern of BOLD response during the cued cognitive reappraisal of negative IAPS images 85
Football 86
Control 86
Direct Comparisons between Group 88
Passive negative SS condition 89
Whole brain CONT-FB 89
ROI CONT-FB 89
Whole brain FB-CONT 90
ROI FB-CONT 90
Passive negative IAPS condition 92
Whole brain CONT-FB 92
ROI CONT-FB 92
Whole brain FB-CONT 92
ROI FB-CONT 93
Cognitive reappraisal SS condition 94
Whole brain CONT-FB 94
ROI CONT-FB 95
Whole brain FB-CONT 95

ROI FB-CONT 95
Cognitive reappraisal IAPS condition 97
Whole brain CONT-FB 97
ROI CONT-FB 97
Whole brain FB-CONT 97
ROI FB-CONT 98
Discussion 99
Direct Group Comparisons 101
Prefrontal Regions of Interest 101
Posterior Regions Revealed from Whole Brain Analysis 104
Subcortical Efficiency 106
Football Group Greater Than Control 107
Summary 108
Chapter 6: Review of the Process Model of Emotion Regulation 112
Chapter 7: Review of the Neuroanatomy Underlying Emotion Regulation 116
Amygdala 117
Insula 118
Prefrontal Cortex 120
Lateral Prefrontal Cortex 120
Medial Prefrontal Cortex 121
Orbitofrontal cortex 122
Chapter 8: The Specificity of Neural Regulatory Processes during Emotional Challenge in a Stress Resilient Population. 125
Introduction 125
Methods 131
Subjects 131
Procedure 133
Stimuli 133
Task 134
Prior to data collection 135
Imaging parameters 137
Dependent Measures 138
Psychometric Inventories to characterize population 138

Performance Failure Appraisal Inventory (PFAI) 138
State-Trait Anxiety Inventory (STAI) 138
Dispositional Resilience Scale (DRS) 139
Sport Competition Anxiety Test (SCAT) 139
Beck Depression Inventory (BDI) 140
Emotion Regulation Questionnaire (ERQ) 140
Physiological measures of arousal 141
Galvanic skin response 141
Heart rate 142
Behavioral Measures - affective rating 142
Functional Magnetic Resonance Imaging: BOLD Signal 142
Statistical Analysis 143
Psychometric inventories to characterize population 143
Physiological measures of arousal 144
Galvanic skin response 144
Heart rate 144
Behavioral measures - affective rating 144
Functional Magnetic Resonance Imaging: BOLD Signal 145
Results 145
Psychometric Inventories: to Characterize Population 145
Performance Failure Appraisal Inventory (PFAI) 145
State-Trait Anxiety Inventory (STAI) 147
Dispositional Resilience Scale (DRS) 147
Sport Competition Anxiety Test (SCAT) 147
Beck Depression Inventory (BDI) 148
Emotion Regulation Questionnaire (ERQ) 148
Physiological Measures of Arousal 149
Galvanic skin response 150
Heart rate 150
Behavioral Measures - Affective Rating 151
Functional Magnetic Resonance Imaging: BOLD Response 153
Direct comparisons between conditions: whole brain and regions of interest 153
FOOTBALL: cognitive reappraisal SS - passive viewing SS 154

FOOTBALL: passive viewing SS- cognitive reappraisal SS 155
FOOTBALL: cognitive reappraisal IAPS - passive viewing IAPS 155
FOOTBALL: passive viewing IAPS – cognitive reappraisal IAPS 156
CONTROL: cognitive reappraisal SS - passive viewing SS 158
CONTROL: passive viewing SS- cognitive reappraisal SS 159
CONTROL: cognitive reappraisal IAPS - passive viewing IAPS 160
CONTROL: passive viewing IAPS – cognitive reappraisal IAPS 160
Condition Region of Interest Analysis 162
Prefrontal Cortex 163
FOOTBALL: cognitive reappraisal Sports-Specific – neutral baseline contrast 163
FOOTBALL: passive negative Sports-Specific – neutral baseline Contrast 163
FOOTBALL: cognitive reappraisal IAPS – neutral baseline contrast ...164
FOOTBALL: passive negative IAPS – neutral baseline contrast...........165
CONTROL: cognitive reappraisal Sports-Specific – neutral baseline contrast 166
CONTROL: passive negative Sports-Specific – neutral baseline contrast 166
CONTROL: cognitive reappraisal IAPS – neutral baseline contrast 167
CONTROL: passive negative IAPS– neutral baseline contrast.............168

Insula and amygdala 169
FOOTBALL: cognitive reappraisal Sports-Specific – neutral baseline contrast 169
FOOTBALL: passive negative Sports-Specific – neutral baseline contrast 169
FOOTBALL: cognitive reappraisal IAPS – neutral baseline contrast ...169
FOOTBALL: passive negative IAPS – neutral baseline contrast...........170
CONTROL: cognitive reappraisal Sports-Specific – neutral baseline contrast 170
CONTROL: passive negative Sports-Specific – neutral baseline contrast 170
CONTROL: cognitive reappraisal IAPS – neutral baseline contrast 170
CONTROL: passive negative IAPS – neutral baseline contrast............171

Discussion 174
Direct Comparisons Cognitive Reappraisal-Passive Negative 176
Football group - Sports-Specific 176
Football group – IAPS: prefrontal cortex 177
Football group – IAPS: regions beyond the prefrontal cortex 178
Control Group- Sports Specific and IAPS 179
Similarities between the Football and Control Group 180
Activations during cognitive reappraisal 180
Deactivation during cognitive reappraisal 181
Condition Region of Interest Analysis 182
Football – Sports-Specific 182
Football – IAPS 183
Control SS and IAPS 185
Summary 187
Chapter 9: General Summary 188
Appendices. **195**
Appendix A: Institutional Review Board Documentation. 195
Appendix B: Data Collection Documents. 212
Appendix C: Task Order and Stimuli. 268
References. **272**

List of Tables

Chapter 3: Brain Processes during Motor Performance under Psychological Stress during Motor Performance, an Independent Component Analysis of EEG

Table 1, sLORETA Results......40

Chapter 5: Efficiency of Affective Brain Processes in Expert Cognitive-Motor Performers during Emotional Challenge

Table 2, Whole Brain results PN SS-NB (Football and Control) 80

Table 3, Whole Brain results PN IAPS-NB (Football and Control)......82

Table 4, Whole Brain results CR SS-NB (Football and Control)......85

Table 5, Whole Brain results CR IAPS-NB (Football and Control)......88

Table 6, Direct Group Comparison results PN SS 91

Table 7, Direct Group Comparison results PN IAPS 94

Table 8, Direct Group Comparison results CR SS 96

Table 9, Direct Group Comparison results CR IAPS 99

Chapter 8: The Specificity of Neural Regulatory Processes during Emotional Challenge in a Stress Resilient Population

Table 10, Direct Comparison between conditions: FOOTBALL 158

Table 11, Direct Comparison between conditions: CONTROL 162

Table 12, ROI results for Sports Specific Conditions: FOOTBALL 172

Table 13, ROI results for IAPS Conditions: FOOTBALL 173

Table 14, ROI results for Sports Specific Conditions: CONTROL 173

Table 15, ROI results for IAPS Conditions: CONTROL 174

List of Figures

Chapter 1: General Introduction: The Fundamental Stress and Cognitive-Motor Performance Relationship and the Relevance of Emotion Regulation

Figure 1, Stress and Performance Relationship 3

Chapter 3: Brain Processes during Motor Performance under Psychological Stress during Motor Performance, an Independent Component Analysis of EEG

Figure 2, Task Protocol 25

Figure 3, Kinematics of Worst Performer 31

Figure 4, Neuromotor Noise Template 31

Figure 5, Self Report Results 37

Figure 6, Cortisol Results 38

Figure 7, Clustering Results 39

Figure 8, sLORETA Results 40

Figure 9, Kinematic Results 41

Chapter 5: Efficiency of Affective Brain Processes in Expert Cognitive-Motor Performers during Emotional Challenge

Figure 10, PFAI Results 71

Figures 11, Psychometric Results 73

Figure 12, HR and GSR Results 75

Figure 13, Affective Self Report Results 77

Figure 14, Whole Brain Results: PN SS -NB (Football and Control) 79

Figure 15, Whole Brain Results: PN IAPS -NB (Football and Control) 82

Figure 16, Whole Brain Results: CR SS -NB (Football and Control) 84

Figure 17, Whole Brain Results: CR IAPS -NB (Football and Control) 87

Figure 18, Whole Brain Direct Group Comparison Results: PN SS 91

Figure 19, Whole Brain Direct Group Comparison Results: PN IAPS 93

Figure 20, Whole Brain Direct Group Comparison Results: CR SS 96

Figure 21, Whole Brain Direct Group Comparison Results: CR IAPS 98

Chapter 8: The Specificity of Neural Regulatory Processes during Emotional Challenge in a Stress Resilient Population

Figure 22 (same as Figure 10), PFAI Results 146

Figure 23 (same as Figures 11), Psychometric Results.......................................149

Figure 24 (same as Figure 12), HR and GSR Results 151

Figure 25 (same as Figure 13), Affective Self Report Results 153

Figure 26, Whole Brain Direct Comparison between conditions: FOOTBALL SS 155
Figure 27, Whole Brain Direct Comparison between conditions: FOOTBALL IAPS 157
Figure 28, Whole Brain Direct Comparison between conditions: CONTROL SS 159
Figure 29, Whole Brain Direct Comparison between conditions: CONTROL IAPS 161
Figure 30, Prefrontal CR SS –NB & PN SS – NB: FOOTBALL 164
Figure 31, Prefrontal CR IAPS –NB & PN IAPS – NB: FOOTBALL 165
Figure 32, Prefrontal CR SS –NB & PN SS – NB: CONTROL 167
Figure 33, Prefrontal CR IAPS –NB & PN IAPS – NB: CONTROL 168
Figure 34, Insula CR SS –NB , PN SS – NB, CR IAPS –NB & PN IAPS – NB: CONTROL & FOOTBALL 171
Figure 35, Amygdala CR SS –NB , PN SS – NB, CR IAPS –NB & PN IAPS – NB: CONTROL & FOOTBALL 172

List of Abbreviations

Abbreviation	Region
ACC	Anterior Cingulate Cortex
DLPFC	Dorsolateral Prefrontal Cortex
DMPFC	Dorsomedial Prefrontal Cortex
IFG	Inferior Frontal Gyrus
IOG	Inferior Occipital Gyrus
ITG	Inferior Temporal Gyrus
LOFC	lateral Orbitofrontal Cortex
MOFC	medial Orbitofrontal Cortex
MOG	Middle Occipital Gyrus
MTG	Middle Temporal Gyrus
PCC	Posterior Cingulate Cortex
SMA	Supplementary Motor Area
SOG	Superior Occipital Gyrus
SPL	Superior Parietal Lobule
STG	Superior Temporal Gyrus
VLPFC	Ventrolateral Prefrontal Cortex
VMPFC	Ventromedial Prefrontal Cortex

Chapter 1: General Introduction -- The Fundamental Stress and Cognitive-Motor Performance Relationship and the Relevance of Emotion Regulation

Converging neuroimaging data suggest that experts require less neuronal resources compared to novices to accomplish the same task in their domain of expertise, and that this cortical refinement can be characterized as psychomotor efficiency (Hatfield & Hillman, 2001; Hatfield & Kerick, 2007). Thus, one of the hallmarks of highly skilled individuals is the ability to perform using minimal effort and refined cortical processing specific to the action demands (Del Percio et al., 2008; Del Percio et al., 2009; Hatfield & Hillman, 2001). Many investigators have employed precision aiming tasks (shooting tasks) to explore this notion of efficiency since these kinds of tasks involve control of movement, and the advantage of ecological validity, because the study participants are critically involved with the task while motionless, allowing for artifact-free neuroimaging (electroencephalography, EEG) (e.g. Del Percio et al., 2009; Deeny, Haufler, Saffer, & Hatfield, 2009; Haufler, Hatfield, Spalding & Santa-Maria, 2000). This research has consistently revealed that the cerebral cortex decreases in activity during task execution, particularly in the left temporal region (associated with verbal analysis), is indicative of an automaticity of motor control (Hatfield et al., 1984; Haufler, Hatfield, Spalding & Santa-Maria, 2000). In addition, recent studies have suggested that expert precision aiming performance requires a selective engagement of thalamocortical and cortico-cortical oscillatory networks for successful task execution (Del Percio et al., 2009). Collectively, these findings imply a refined recruitment of the essential neural networks required for skilled performance. But critical for the present dissertation, is when the efficiency of brain dynamics is disrupted by mental stress leading to performance decline under pressure (Beilock, 2010; Beilock & Carr, 2001).

Traditionally, the relationship between stress and performance can be characterized by the organizing principle of the inverted-U, termed the Yerkes-Dodson law (Hancock & Szalma, 2008). According to this model, performance varies as a function of the stress activation continuum: with an under-aroused-state resulting in sub-optimal performance (in part due to decrements in attention & lack of engagement); a central zone or maximal adaptability zone where stress levels are consistent with behavioral adaptability, optimal performance and psychomotor efficiency (Hancock & Szalma, 2008; Hatfield & Kerick, 2007); extreme excitation, which can become manifested as anxiety, also resulting in performance decline (Yerkes & Dodson, 1908) (see Figure 1).

As such, the management of high levels of arousal is critical to the performance of tasks under conditions of mental stress. State anxiety is characterized by negative valence expressed by apprehension and threat, resulting in a heighted stage of arousal. Anxiety-induced disruption of the central zone of optimal arousal may act to perturb the refined process associated with psychomotor efficiency (Hancock & Szalma 2008). Such negative appraisal accompanied by elevated arousal, is typically coupled with increased amygdala activity, which, in turn, influences the thalamus, hypothalamus, striatum, and brainstem areas in addition to numerous sensory and association cortical areas (Haines, 2006) creating neuromotor noise. Thus the regulation of emotion (which can be manifested as anxiety), is critical in determining the quality of cognitive-motor performance (Figure 1).

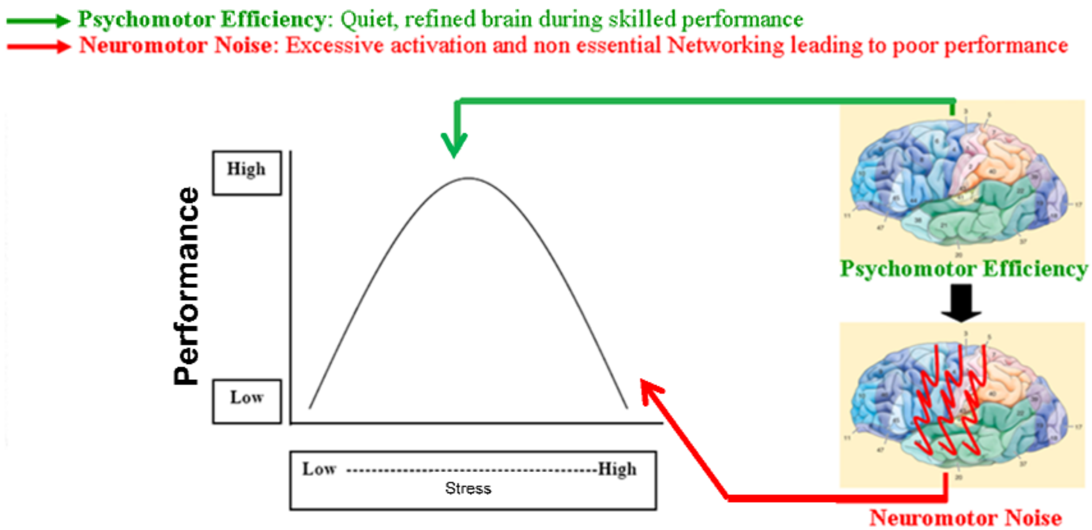


Figure 1. Relationship between stress and performance indicating the range during which performance decline is observed (adapted from Hancock & Szalma 2008).

Nonetheless, some individuals are able to maintain a high level of performance during stressful events and, therefore, demonstrate qualities of stress resilience. Stress resiliency encompasses the ability to adaptively cope with adversity and can be examined at behavioral, psychological, and neural levels (Feder et al., 2009). For the purpose of the dissertation we define our stress resilient population as individuals who have a history of successful performance (1) senior varsity athletes 2) letter award winners 3) typically play a starting role on the team 4) on a partial or full athletic scholarship) under conditions of emotional challenge (high-level competition). Examination of elite performers (intercollegiate athletes) holds promise for understanding the neural basis for such abilities to adaptively cope with stressful events, and more specifically, elite athletes may be uniquely resilient to stress perturbation through the ability to regulate their emotions.

There are numerous strategies through which to engage emotion regulatory brain networks, but one strategy, cognitive reappraisal, is a particularly adaptive means of emotion regulation (based on behavioral comparisons (Gross & Thompson, 2007) and neuroimaging comparisons with other emotion regulation techniques ((e.g., expressive suppression (Goldin, McRae, Ramel, & Gross, 2008), distraction (McRae, et al., 2010), cognitive load (Van Dillen, Heslenfeld, & Koole, 2009)). Cognitive Reappraisal is a "cognitive-linguistic strategy that alters the trajectory of emotional responses by reformulating the meaning of a situation" p 1, (Goldin, et al., 2008) and this results in a decrease in the reported negative emotion (Wager, Davidson, Hughes, Lindquist, & Ochsner, 2008). In other words, the result of cognitive reappraisal is that it attenuates negative emotional experience resulting in an enhancement in cognitive control of emotion. This implies it is important to consider not only the stressful event, but the individual's perception of the stressor, to understand how skilled performers maintain consistency under various challenges and during mental stress.

In support of this notion, the dynamics between stress (i.e. state anxiety) and performance can be further characterized by the transactional model described by Staal (2004). Specifically, stress is conceived as the aggregate result of the interpretation of the environmental challenge, as well as the objective challenge. In particular, this model integrates human performance and information processing capacity with the notion of appraisal of threat, controllability, and predictability for understanding how stress affects performance. As such, a key element is the individual's appraisal of the situation. This implies that a great deal of individual variation in the response to the stressor may be a consequence of the perception of the event rather than the actual environmental stressor. Therefore, the perception of the stimulus is essential rather than the objective stimulus and, furthermore, the perception may be highly related the individual's experience (i.e. domain specific). Consequently, elite athletes may have developed a domain specific reaction to stressful challenge, which through experience and training, allows them to endogenously regulate their affective response to known stressors and efficiently respond to affective challenge.

In summary, the present work examined the neuropsychological processes that promote psychomotor efficiency under stress. Using elite athletes as a model for a stress resilience population this study attempted to provide insight into the mental approach these individuals employ to maintain stability as they engage in sports-specific challenges. A model of stress resiliency is proposed which is characterized by an economy of affective neural processing and an experience-dependent automaticity of neural processes associated with cognitive reappraisal.

The present dissertation is organized into three empirical papers accompanied by relevant literature reviews and discussion sections. The chapter 2 of the dissertation will provide a brief review of psychological stress and cognitive-motor performance to set a context for the first paper (chapter 3), entitled Brain Processes during Motor Performance under Psychological Stress, an Independent Component Analysis of EEG. The goal of this paper is to focus on the effect of mental stress on human performance, discussing results from a study in which electrocortical dynamics were examined during competitive precision aiming (target shooting) performance. This paper serves an important role in developing the background and motivation for the subsequent empirical papers since it examines the relationship between mental stress, brain dynamics and human performance in a non-expert group. Importantly, the deleterious effects of stress noted in this paper were likely due to non-expert status of the group. This paper is followed by a rationale for examining expert groups (such as elite athletes) in order to understand the unique features that enable them to adaptively deal with stress (chapter 4). This section is followed by the second empirical report (chapter 5), entitled Efficiency of Affective Brain Processes in Expert Cognitive-Motor Performers during Emotional Challenge. This paper reports that compared to age-matched controls, elite athletes demonstrate an economy of neural processing in the affective domain, which parallels findings in the literature for the cognitive motor domain. This paper serves to underscore the adaptive nature of neural processing efficiency and suggests this type of response may be characteristic of a stress resilience population. The next chapter (7) provides a literature review on various emotion regulation approaches and the critical brain regions involved in emotion regulation. This, in turn, leads to the third and final empirical paper (chapter 8) entitled, The Specificity of Neural Regulatory Processes during Emotional Challenge in a Stress Resilient Population. This paper reports an automaticity of cognitive reappraisal in elite athletes within their domain of expertise. This finding provides further understanding of the role of experience-dependent/adaptive coping in individuals who a have history of high performance under competitive stress. Lastly, the dissertation concludes (chapter 9) with an overall summary, with the goal of linking the three papers to develop a model of stress resiliency.

Chapter 2: Brief Review of Psychological Stress and Cognitive Motor Performance

Psychological Stress

The biological consequence of the affective stress response is the activation of both the endocrine system and autonomic nervous system (ANS). The following physiological details illustrate the changes in the body related to the emotional state. The endocrine system acts through the hypothalamus, anterior pituitary, adrenal cortex system or HPA axis. Through a biochemical cascade, the hypothalamus releases corticotropin-releasing hormone (CRH) which travels through the median eminence to the anterior pituitary. The anterior pituitary releases AdrenoCorticoTrophic Hormone (ACTH) which targets the cortex of the adrenal gland, which releases glucocorticoids (eg, cortisol). Cortisol acts catabolically in the muscles to synthesize new glucose thus providing more energy for aerobic and anaerobic action. Lastly, the ANS response to stress acts primarily through the sympathetic nervous system which results in increased cardiovascular output to muscle, decreased immune response, and inhibition of growth, digestion, tissue repair, and reproduction (Fox, 2008). The change in physiology during stress illustrate the importance of emotion regulation in orchestrating the quality of motor performance. If unregulated, these systems initiated by stress response can introduce non-essential elements into the action and disrupt the automaticity associated with skilled motor performance.

Stress and the Motor Hierarchy

Poor performance may thus be caused by increased noise from mental stress adding unwanted complexity to the motor hierarchary. Thus stress-related non-essential activity may directly affect the tactical level of the motor loop which is part of the motor hierarchy consisting of the 1) strategic level 2) tactical level 3) implementation level (Bear, Connor, & Paradiso, 1996). The tactical level is responsible for the execution and planning of the action. The primary neural substrates are the motor areas (area 6, 4) with input from the cerebellum to construct the appropriate coordinative structure.

Stress also acts to disrupt motor performance at the strategic and implementation levels of the motor hierarchy. At the strategic level, behavioral regulation and action identification are mediated through the prefrontal cortex and the posterior parietal cortex areas. In particular the prefrontal cortex (PFC) is a key region sensitive to stress (Arnsten, 2009). Succinctly, converging evidence indicates that stress exposure impairs prefrontal function involved in cognitively complex behaviors that require flexible thinking, and coordination of action (Arnsten, 2009). Thus without effective emotion regulation, the impairment of PFC function (such as working memory and attentional control) is coupled with amygdala (a critical emotion center of the brain) activation of stress pathways thus representing a shift from a cognitively controlled state to an affectively mediated state (Arnsten, 2009) (Figure 3). What is particularly interesting is in the affective state, simple movements such as reaction time are unimpaired or actually better (Arnsten, 2009; Hancock &

Szalma, 2008). This type of task requires very little information integration, memory demands or manipulation and is related to the basal ganglia, another motor region involved in the strategic level (Hancock & Szalma, 2008). But complex motor tasks suffer performance decrements without emotional control. Thus under conditions of stress the amygdala acts to direct action towards habitual responses that are rapid rather than maintaining flexible and adaptive prefrontally mediate action coordination (Arnsten, 2009).

The remaining level of the motor hierarchy, the implementation level, reflects the quality of output from the motor loop and thus may also be modulated by the stress response. This would result in changes in task execution mediated by brainstem structures (postural adjustments) and the spinal cord (reflexes). In summary, from the tactical level increased noise can be manifested in the periphery through loss of reciprocal inhibition leading to co-contraction of agonist and agontagonist muscles (Hatfield & Kerick, 2007). At the strategic level a loss of prefrontal coordination (regulation of goal directed action) increases variability (dysfluency) in performance and represents a shift from adaptive flexibility behavior to habitual action thus resulting in performance decline under pressure. In this manner effective emotion regulation could decrease the likelihood of such a negative performance state.

Cognitive-Motor Performance under Stress: Neuromotor Noise

As stated earlier, skilled motor execution requires essential cortical networks, leading to greater coordination and a more direct mapping between intended and realized action (Hatfield & Hillman, 2001). But under pressure, some individuals may experience increased input from limbic sources (i.e., the amygdala), in addition to recruitment of associative areas leading to "neuromotor noise." Van Galen & van Huygevoort (2000) defined this concept of neuromotor noise as the primary source of human error under workload and time pressure conditions (i.e., mental stress) (van Galen & van Huygevoort, 2000). These authors argued that such noise reflects a mismatch between an intended movement and the outcome of that movement. In particular the authors attempt to make a connection between functional neural activity and the way in which this information processing is disrupted by neuromotor noise. They suggest that motor performance is inherently noisy due to the degrees of freedom in behavioral repertoire, but psychological and physical stress result in, "…non-specific neural activation spreading" (van Galen & van Huygevoort, 2000). This increased neuromotor noise results in heighted probability in the action error.

Thus, anxiety induced activity, possibility originating from the amygdala, would result in hyperactivity of non-essential associative areas leading to neuromotor noise in the motor system during task execution (Hatfield et al., 2010; van Galen & van Huygevoort, 2000). The behavioral consequence of neuromotor noise derived from the psychological stress, may result in directing deliberate attention and control to well learned motor skills (reinvestment), which results in performance degradation (Beilock & Carr, 2001).

This injection of neuromotor noise acts to interfere with the refinement of skilled action, representing a reversion to earlier stages of motor learning. Consequently the performer reverts from the stage of automaticity (advanced) returning to effortful analysis (beginning) (Fitts & Posner, 1967). Thus, unless the performer can manage their emotion, they regress in their performance abilities.

Competition as a Stress Manipulation

Recent work from our laboratory supports the model of increased neuromotor noise during stressful challenge. University of Maryland Reserve Officers' Training Corps (ROTC) members engaged in a self-paced shooting task where they performed alone and under conditions of competition. Using this competitive shooting paradigm as a proxy for stress manipulation, we successfully increased arousal in a laboratory setting, as indicated by objective self report, heart rate, skin conductance and salivary cortisol (Hatfield et al., 2010). Recent work from Cerin and Barnett (2009) has supported this notion that competition is a significant and stressful event and affects the performer's emotional state (Cerin & Barnett, 2009). The authors reported that competition related concerns resulted in high self reported fear compared to competition extraneous concerns and can be characterized a threatening and challenging event.

From a neural perspective our work supports these data. Relative to performance alone, competition resulted in an increase in attentional engagement (indexed by high alpha desychrony) and increased cortical networking (indexed by frontal and central to Fz increased theta and alpha coherence) (Hatfield et al., 2010). The results suggest that increases in psychological stress and the consequential neuromotor noise are reflected not only physiologically and behaviorally but in the cortical dynamics recruited during task execution. In particular, the coherence results, which demonstrate networking with a premotor site (Fz), suggest that neuromotor noise targets regions associated with the tactical level of the motor hierarchy. What we see is a loss of psychomotor efficiency during stressful challenge.

The next section of the dissertation is a paper entitled Brain Processes during Motor Performance under Psychological Stress, an Independent Component Analysis of EEG. This paper seeks to provide additional evidence of the disruption of psychomotor efficiency under mental stress. Such a finding further supports the importance of emotion regulation for the management of physiological arousal to maintain motor performance under pressure.

Chapter 3: Brain Processes during Motor Performance under Psychological Stress, an Independent Component Analysis of EEG

Introduction

Classically, the relationship between mental stress and behavioral performance is explained by the organizing principle of the inverted-U, termed the Yerkes-Dodson law (Yerkes & Dodson, 1908). Accordingly stress is a dimension of activation across a continuum, with an under-aroused state resulting in sub-optimal performance (in part due to decrements in attention & lack of engagement), to the zone of optimal performance (see (Rietschel, et al., 2010), and finally, to an extreme excitation state resulting in anxious arousal and leading to performance decline (Hatfield & Brody, 2008; Staal, 2004). Although this arousal-performance relationship is useful, few investigators have offered mechanisms to explain the phenomenon. One promising explanation is the direction of explicit attention and control to well learned motor skills during stress exposure, which, in turn, results in performance degradation (Beilock & Carr, 2001; Chell, Graydon, Crowley, & Child, 2003; Kinrade, Jackson, & Ashford, 2010; Maxwell, Masters, & Poolton, 2006). Consequently, the performer reverts from the advanced stage of automaticity to effortful analysis (Fitts & Posner, 1967). Thus the confluence of increased state anxiety and explicit self monitoring leads to a conscious control of essential motor control processes (Masters, 1992; Masters & Maxwell, 2008). The result is a maladaptive regulatory response by which performers 'reinvest' in control strategies associated with early explicit stages of learning leading to performance decline under pressure in a number of tasks (beyond the shooting task described above) (Jackson, Ashford, & Nosworthy, 2006; Lam, Maxwell, & Masters, 2009; Wan & Huon, 2005). Although promising, this explanation is also incomplete in terms of offering an underlying mechanism.

In attempt to address this limitation, we examined the manner by which mental stress alters the performers neural state during stressed conditions. During skilled motor execution, expert performers demonstrate psychomotor efficiency, relying on essential brain networks in a focused and efficient manner leading to greater skeletal muscle coordination and a more direct mapping between intended and realized cognitive motor action (Baumeister, Reinecke, Liesen, & Weiss, 2008; Del Percio, et al., 2007; Hatfield, Haufler, Hung, & Spalding, 2004; Hatfield & Hillman, 2001). Precision aiming tasks such as pistol shooting have been employed to explore the notion of efficiency during motor performance since they require visual-spatial processing, planning, and perceived control of movement. Such tasks hold the advantage of ecological validity since participants are critically involved and motivated to perform while motionless, allowing for artifact-free psychophysiological recording (Deeny, Haufler, Saffer, & Hatfield, 2009; Del Percio, Babiloni, Bertollo, et al., 2009; Haufler, Spalding, Santa Maria, & Hatfield, 2000). Numerous studies employing electroencephology (EEG) have revealed that the left temporal region (T3), associated with verbal-cognitive analysis, decreases in activity (reflected by T3 EEG alpha synchrony) during the aiming period of expert shooting (Hatfield, Landers, & Ray, 1984; Haufler, et al., 2000; Kerick, et al., 2001; Lawton, Hung, Saarela, & Hatfield, 1998) and that left temporal activity is progressively reduced during learning (Kerick, Douglass, & Hatfield, 2004). In this manner, increased EEG alpha power indexes cortical relaxation, suggesting attenuation of nonessential processes during skilled performance of a motor task thus reflecting the economical automaticity of task-specific functioning (Babiloni, et al., 2008; Babiloni, et al., 2009; Babiloni, et al., 2010; Del Percio, Babiloni, Bertollo, et al., 2009; Del Percio, Babiloni, Marzano, et al., 2009; Del Percio, et al., 2010; Del Percio, et al., 2008). The brain dynamics observed in the left temporal region suggests that experts employ less verbal-analytical processing during the aiming period (possibly due to a shift to reliance on subcortical structure) since it appears to contribute non-essential neural activity or noise, greater complexity and less consistency in motor performance (Hatfield & Brody, 2000).

Importantly, such studies have been conducted under conditions of low stress particularly under non-competitive, non-evaluative conditions, but they do provide a logical framework from which to predict the effects of mental stress on brain dynamics during motor performance. In this manner, if skilled aiming performance depends on relative visuospatial engagement and relative suppression of left hemispheric verbal analytical processes (a sensitive marker of performance outcomes in situations of non-stress (Hatfield & Hillman, 2001)) than it follows that left temporal activation should occur during mental stress. In turn, the efficiency of skilled motor performance may become disrupted under mental stress leading to behavioral changes (i.e. degradation) in task performance. In this manner, stress induced alterations in performance may be caused by increased neuromotor noise from verbal analytical processing adding unwanted complexity to the motor hierarchy, which is similar to the notion of reinvestment from a different level of analysis. Thus, the injection of neuromotor cortical noise acts to interfere with the refinement of skilled action, adding non-essential cortical complexity to the motor task. Therefore the purpose of this study is to examine changes in cortical dynamics associated with mental stress specifically by examination of left temporal region in order to understand how stress affects brain dynamics during motor performance.

To achieve this end, we used competition as a stress manipulation. Participants engaged in a self-paced precision aiming target shooting task during which they performed alone and under conditions of competition. Altering the social environment we attempted to enhance mental stress while measuring EEG to examine the brain dynamics during action execution under pressure. Using a theoretical model that predicts that the left temporal region is sensitive to precision aiming performance (Hatfield & Hillman, 2001), independent component analysis (ICA) was used to identify a functional cortical component that represents non-essential activity in the left temporal region (associated with elevated linguistic function or self talk utilized during reinvestment). This neural noise component was used as a means to quantify non-essential activity during the stress exposure condition (competition) compared to the reference condition (performance alone). Increased complexity (indexed by increased clustering to noise template) reflects recruitment of non-essential cortical activity during competitive stress. We also examined the neural sources of this functional component by using standardized low-resolution brain electromagnetic tomography (sLORETA) to determine the source of the component. We predict an increase in complexity of cortical dynamics during stress of competition which will translate into increased variability in the activation of motor effectors as expressed by lack of steadiness during aiming movement.

Methods

Participants.

Nineteen participants (2 female) were enrolled from the Reserve Officers' Training Corps (ROTC) program of a large State university. All participants were right-hand dominant (Oldfield, 1971) and ipsilateral-eye dominant. Participants were between the ages of 18-38 (M=22 yrs, SD=4.33) and were screened with a health history questionnaire to ensure that they were free of neurological and psychiatric disorders and psychotropic medications. Lastly, all participants met a performance threshold for study inclusion such that each individual had to place their shot on the target 80% of the time. Prior to testing, all participants provided written informed consent approved by the University Institutional Review Board and were instructed they were free to withdraw from the study at any time.

Task

Participants used their right (dominant) hand to complete a dryfire, pistol shooting task in which the Noptel ST-2000 was used to monitor shooting performance (shot placement on the target). Participants stood 5 m from the target to complete the task. Accordingly the target was scaled down to maintain a proportionate target diameter consistent with that of an official competitive target (i.e., 50 ft, or 15.24 m). Participants assumed a standard shooting posture; feet were positioned approximately shoulder-width apart and nearly perpendicular to the shooting lane to minimize sway. Participants extended the shooting arm while aiming and sighted the target with their right eye, while the left eye was occluded.

Measures.

Arousal.

Cardiovascular and skin conductance.

Autonomic measures were recorded from the left hand, and the chest area about the heart using a Thought Technology Procomp2 system, (encoder model # SA7400). Electrocardiogram (EKG) and Skin Conductance (SC) were collected: EKG was sampled at 256 Hz through a single lead consisting of three electrodes (model # SA9306M), sensor placement consistent with manufacturers recommendations. SC (model #SA9309M) was sampled at 32 Hz; sensors were attached to the 2^{nd} digit of the 2^{nd} and 4^{th} finger.

Psychoendocrine.

Saliva collection (Saliva Oral Swab) tubes were labeled in accordance with sample time. The participants were then instructed to gather saliva in his or her mouth, and place the collector in the middle of the mouth until the pad was saturated. The participant then inserted the Oral Swab into the uncapped tube, recap firmly, and put the tube in the storage tray. The tubes were stored in plastic zipper bags in the freezer. After all other data were collected for this study the frozen tubes were analyzed by Salimetrics (State College, PA) for cortisol assays. All samples were assayed for salivary cortisol in duplicate using a highly sensitive enzyme immunoassay (Salimetrics, State College, PA). The test used 25 μl of saliva per determination, has a lower limit of sensitivity of 0.003 μg/dl, standard curve range from 0.012 μg/dL to 3.0 μg/dL, an average intra-assay coefficient of variation of 3.5% and an average inter-assay coefficient of variation of 5.1%. Method accuracy determined by spike and recovery averaged 100.8% and linearity determined by serial dilution averaged 91.7%. Values from matched serum and saliva samples show the expected strong linear relationship, $r(47)=0.91$, $p < 0.0001$.

Self-reported arousal assessment.

Visual analog scale.

The Visual Analog Scale (VAS) asks participants to draw a vertical line on a 100 mm horizontal line that is anchored by adjectives consistent with the dimensions listed below. The mark represents the degrees of a psychological state. The following questions were posed: VAS 1: How competitive do I feel? (0=not competitive, 100=ultra competitive); VAS 2: How stressed am I? (0=no stress, 100=completely stressed); VAS 3: How confident do I feel? (0=extremely confident, 100=no confidence); VAS 4: How relaxed am I? (0=not relaxed, 100=completely relaxed). The VAS was scored through a measurement of where the participant drew a vertical line on a 100 mm horizontal line that was anchored by adjectives consistent with the dimensions listed above (approach adapted from (Bixby, Spalding, & Hatfield, 2001)).

State anxiety inventory.

The participants were assessed by the State-Trait Anxiety Inventory-State (STAI-S) indicating momentary anxiety (Spielberger, Gorsuch, & Lushene, 1970). The STAI-S consists of a total of 42 items rated on a 4-point Likert-type scale ranging from 'not at all' to 'very much so' in terms of how the participant feels at the moment. The STAI-S score ranges from 20 to 80, with increasing scores reflecting greater anxiety.

***Brain – EEG*.**

Scalp electroencephalographic data were collected using tin electrodes housed within a stretchable lycra cap, (Electro-Cap International, Inc.). Data were acquired from 30 sites referenced to linked earlobes and a common ground (FP2), labeled in accordance with the 10-20 international system (Jasper, 1958). At all sites of interest (FP2, FP3, Fz, F3, F4, C3, C4, P3, P4, T3, T4, O1, O2), impedances were maintained below 10 kΩ. All channels were amplified 500 times using Neuroscan Synamps 1, linked to Neuroscan 4.3.3 acquisition/edit software on a Gateway Pentium computer running Windows XP operating system. Bandpass filters were set at .01-100 Hz with a sampling rate of 1,000 Hz. Electrodes were placed above and below the left eye over the orbicularis oculi muscle (VEOG) and the outer canthi of both eyes (HEOG) to record eyeblinks. An electronic pulse was sent into the EEG by the shooting simulator to mark onset of the trigger pull into the continuous EEG recording.

Motor behavior.

The Noptel simulator system was used to measure shooting score and motor performance. This system is an optical reflection unit (light emitting and receiving unit), which is attached to the barrel of the pistol. During the aiming period, a light was emitted from the unit and subsequently reflected from the target through reflecting crystals surrounding the target. The reflected light was then captured by the optical unit and transmitted to an analog-to-digital conversion device at a rate of 66 Hz. The actual shot location was recorded as the position of the aiming point on the target at the time of the trigger pull. Feedback was provided for all trials (shots) in the form of a shooting score and a "clock face" reference to identify the position on the target. All scoring was consistent with competitive shooting scoring metric of Bulls eye=10, outermost ring=1. All participants shot from a standing position.

Procedure (Manipulations).

The study required that participants to complete three testing sessions, orientation, practice-alone and competition, over a two-day period.

Day 1 – orientation.

The purpose of the orientation was to familiarize the participants with the procedure of the study and to measure that all of them met the performance threshold of hitting the target 80% of the time. Upon arrival at the laboratory, participants were informed of the requirements of the experiment and provided an opportunity to ask questions before they signed the consent form. A health history questionnaire was given to ensure all participants were free from neurological abnormalities and handedness was assessed. In order to reduce any novelty effect that might be observed on the actual testing day, the electroencephalographic and autonomic nervous system (heart rate (HR), and skin conductance (SC)) monitors were placed on the participants for familiarization, and they completed the behavioral assessments (VAS, State Spielberger Self-Evaluation Questionnaire), and were instructed on the acquisition of salivary cortisol (i.e., oral swab). Participants viewed a videotape made by a National Collegiate Athletic Association Division I pistol shooting coach in which instructions about shooting position and pistol safety were provided. Participants were then asked to begin a shooting practice session of three blocks of 20 trials (shoots) each for a total of 60 practice trials. The first block was considered "warm up" and did not contribute to the study selection criteria. Selection criteria for participation in the rest of the study required that 80% of their shots during blocks 2 and 3 of the orientation practice sessions must "hit" inside the outermost ring of the target. This performance criterion was established to assure that study participants were relatively similar in their ability to complete the shooting task successfully. Participants were also informed of the two testing conditions: performance alone (PA) and competition (C)

Day 2: performance alone and competition.

Participants were asked to refrain from consuming any alcoholic or caffeinated beverages on the day of testing and asked to get 7-8 hours of sleep the prior night. Upon arrival the participants were provided with a brief review of the instructional video and were refamiliarized with the tasks associated with the two testing phases (PA and C) (see Figure 2). Participants were prepared for electroencephalographic as well as autonomic nervous system (HR and SC) monitoring. The testing sessions were counter-balanced for testing order such that half of the participants engaged in performance alone first, followed by competition and the other half of the participants completed competition first and then performance alone with rest periods in between. Participants were allowed 10 sighting shots prior to each of their Day 2 testing sessions. For both PA and C, feedback was provided after every shot in the form of their score and a "clock face" reference to indicate shot placement. Prior to both conditions, cortisol, VAS, STAI-S behavioral questionnaires and baselines (1 minute standing in shooting position without pistol) were collected prior to session commencement. In between PA and C there was an approximately 15 minute rest period. Within a testing sessions the subjects were standing continuously thus these periods were when subjects were considered 'engaged' in relation to the baseline period.

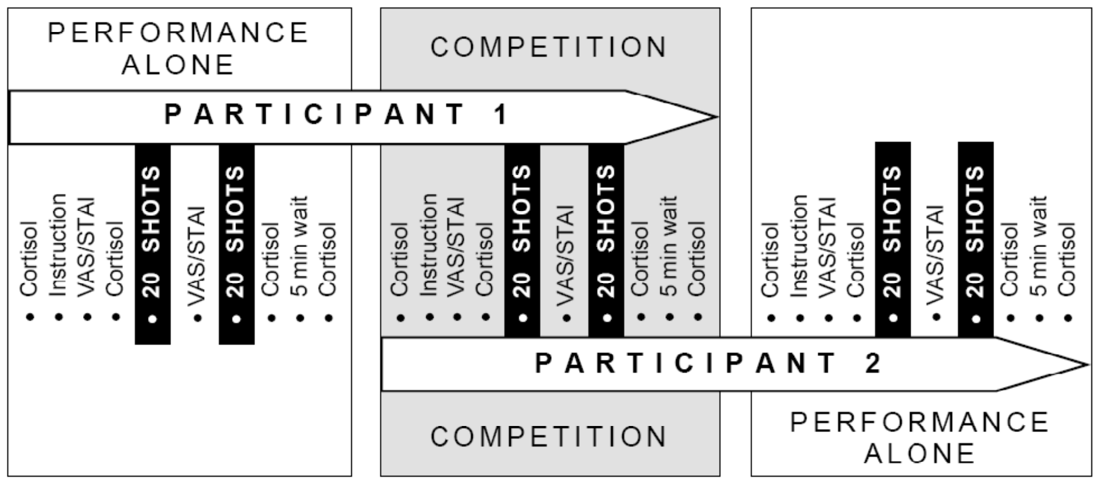


Figure 2. Schematic illustration of task protocol. Participant 1 arrived prior to the competition for his/her performance alone session whereas participant 2 executed his/her performance alone after the competition.

Performance alone.

The performance alone session was executed in a quiet environment. Participants were informed that their score in the performance alone session had no impact on the competition and they were instructed to remain focused and relaxed during this period. Following the baseline measures and the sighting shots, a second cortisol sample was collected just prior to the first 20 test shots. After shooting, the participants received approximately a 5 minute break during which they completed a second battery of VAS and STAI behavioral assessments. The final 20 test shots were then executed followed by a third cortisol sample. After an additional 5-minute delay, the final cortisol sample was obtained for that session.

Competition.

The competition session (C) involved the same order of measurements, but included shooting against another study participant. During the competition, participants took turns shooting and alternated between shooting order such that in one trial, shooter A shot first followed by shooter B, but the next trial shooter B shot first, etc. Participants were instructed to set the gun down between each shot and to remain standing throughout the shooting session. After each trial scores were presented to the competitors and a winner of that trial was declared. During competition the following psychological pressures - in addition to peer-competition - were imposed on the subjects: 1) social evaluation by a superior officer who conspicuously took notes and evaluated participants' shooting stance and accuracy; 2) financial loss or gain of 50 cents per round, from a starting sum of $20 (in the case of equal scores, the sum at stake carried over to the next shot), a dollar bonus for a bull's-eye and a dollar loss for missing the target completely; 3) a 30 second time constraint for each shot, beginning when the subject grasped the pistol; 4) video camera recording; and 5) participants were placed on teams such that their score contributed to overall team score, both of which were displayed outside the ROTC field house. Participants were informed of all of these pressures during the instructional period prior to task execution and were told to attempt to "beat" their competitors' score.

Signal Processing and Data Analysis.

All data were co-registered such that trials were only included if cardiovascular, SC, motor behavior and EEG data were artifact free. Arousal measures were analyzed during the PA and C conditions and by block (first 20 shots, second 20 shots). EEG was measured according to condition PA and C, four seconds prior to trigger pull. EEG spectral and coherence results will be presented in companion manuscript.

Arousal.

Heart rate and heart rate variability.

The first and last 10% of each EKG time series was discarded in order to remove transient portion associated with beginning and end of a block. The remaining 80% of EKG represented a stable measure of cardiac activity during a particular level of engagement (competition and performance alone). The inter-beat-interval (ibi), defined as the time in ms between positive peaks of the QRS complex in the EKG signal, was determined using customized software written for Matlab (Mathworks). HR in beats per minute (bpm) was computed from the average ibi. The respiratory sinus arrhythmia (RSA) was computed from the ibi using MXedit software. RSA is an index of vagal influence with higher values of RSA associated with an increase in vagal influence. The same analysis was performed on the 1-minute standing baseline EKG time series.

Skin conductance.

The first and last 10% of each signal was discarded in order to remove transient portion associated with beginning and end of a block. The remaining 80% of signal represented a stable measure of SC during a particular level of engagement (C and PA). Tonic skin conductance (SC-t) was computed as the average SC across this interval. Phasic skin conductance (SC-ph) measures the amount of fluctuation of SC in a given time period. It is computed by calculating the area between the SC signal and a straight line connecting the initial and ending value of SC for the defined time period regardless of direction, positive or negative (Senior, Russell, & Gazzaniga, 2006). The time window used to examine phasic SC was determined by computing the dynamic change in SC-ph. The dynamics of SC-ph for both competition and performance alone were computed using a 5s moving window from 10s before the trigger pull to 5s after. The dynamics for each condition were averaged across shots for each subject and then across subjects. The difference between the dynamics of SC-ph during competition and performance alone was examined to find the maximum difference. The maximum difference was used as the center of a time window between 1.5s prior to trigger pull and 3.5s after. In order to determine the nature of the difference in SC-ph between performance alone and competition, the percentage of negative deflection in SC-ph was computed. A negative deflection represents a decrease in SC. The phasic SC was determined for the 1-minute standing baseline as the average of the phasic SC computed with a 5s moving window across the entire minute.

Psychoendocrine

The salivary cortisol levels were computed for each sample time (1, 2, 3, 4) for each condition (PA and C). A first order polynomial was fit to the slope of the values of the cortisol over the sample times (1, 2, 3, 4) for each testing session (PA and C).

Brain – EEG.

In order to reduce the influence of eye blinks on the EEG data an ocular artifact reduction filter was applied (Semlish et al., 1986). The 4-s period of continuous data prior to the completion of each shot was then partitioned into four successive 1-s epochs. The termination of the final epoch was coincident with the trigger pull (i.e., the numbering of epochs was based on a temporal sequence during the aiming period so that Epoch 4 represented the initial 1-s period preceding sequentially Epoch 3, Epoch 2, Epoch 1, and the shot). The data were then baseline corrected and linear detrended. A final visual inspection of all sweeps was performed to remove any epochs that still contained artifact.

Independent Component Analysis (ICA).

ICA (Bell & Sejnowski, 1995) using an extended infomax algorithm (Lee, Girolami, & Sejnowski, 1999) of artifact-free EEG time series was executed on both conditions. The data was epoched 2 seconds prior to trigger pull and 3 sequential trials were concatenated to produce a time series 6 seconds in length. Twenty eight independent components (IC) were generated for each 6 seconds (2 second epoch, three trials) concatenated time series and from the artifact-free EEG.

For selection of the neuromotor noise template, the worst performer, who showed degradation of motor performance under psychological stress, was determined by kinematic analysis of the shot score (C 5.20, PA 4.59) and shot standard deviation (C 2.60, PA 2.48) (see Figure 3). Also critical to this selection process was the participant's behavioral self report which reveal for the VAS1 scale (How competitive do I feel? (0=not competitive, 100=ultra competitive)) a score for PA of 89.5 and for C of 99.5; VAS2 scale (How stressed am I? (0=no stress, 100=completely stressed)) a score for PA of 65 and for C of 82; VAS3 (How relaxed am I? (0=not relaxed, 100=completely relaxed)) a score for PA of 58.5 and for C of 18.5. For the STAI state (20-80, low to high) questionnaire he reported a score of 36.5 for PA and 68 for C. These metrics indicated both psychometrically and behaviorally that this individual found the stress of competition maladaptive.

Visual inspection of the independent components from this poor performer resulted in the selection of the neuromotor noise template based on our conceptual model (Figure 4, left panel). Power spectral density (PSD) plots of the time series associated with the neuromotor noise component illustrated the frequency domain characteristics of the cortical network spatially represented by the ICA scalp map. The PSD of the noise component shows desynchrony of alpha power and increased power in both beta (~15Hz-25Hz) and gamma (36Hz-44Hz) bands indicative of increased activation in the left lateralized cortical network (see Figure 6, right panel).

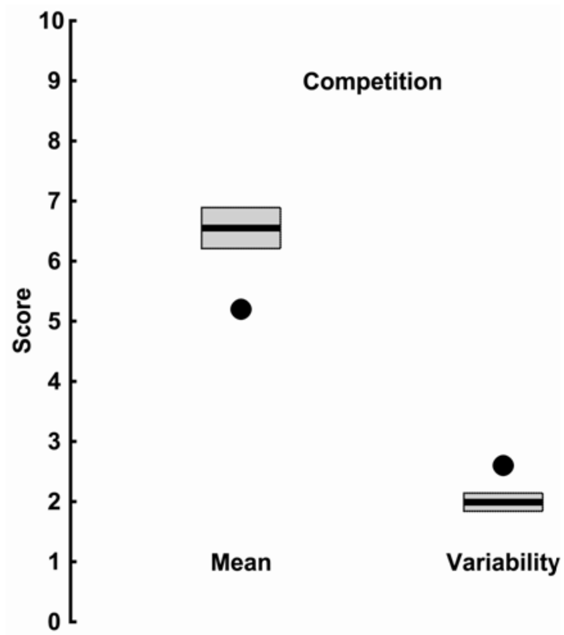


Figure 3. Illustration of the worst performer based on the kinematic parameters of the mean score and variability during the competition. The data point representing the worst performer illustrates his mean scores relative to the group mean (lower score) and the variability relative to the group mean (higher variability).

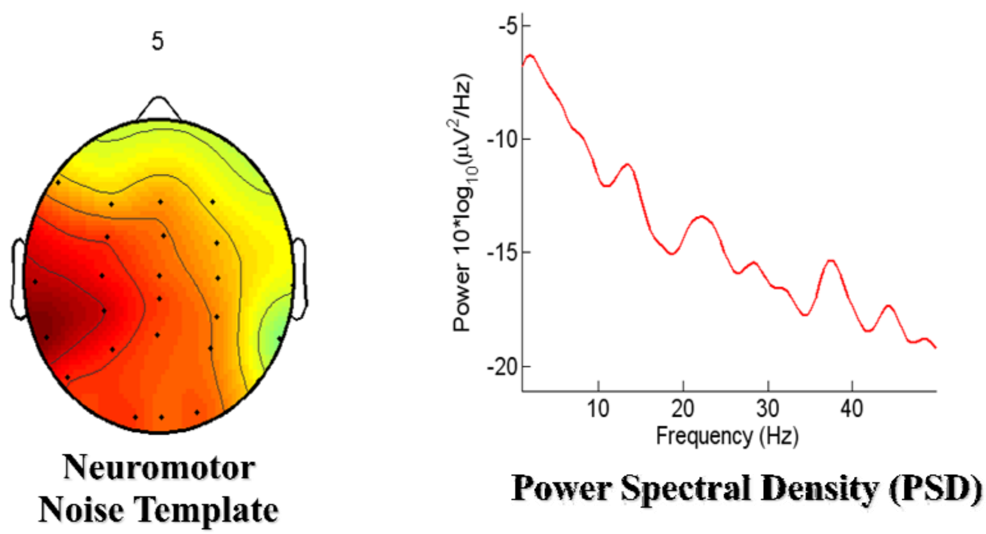


Figure 4. The IC, characterized as the neuromotor noise template that was selected from the worst performer. The neuromotor noise template was identified to act as an exemplar based on our theoretical model (Hatfield & Kerick, 2007) that predicts that non-essential activity, especially in the left lateralized temporal lobe (associated with linguistic function or more generally involved feature detection of details), interferes with optimal engagement of brain areas vital for task completion. To the right is the PSD of the noise component, which shows desynchrony of alpha power and increased

power in both beta and gamma bands indicative of increased activation in the left lateralized cortical network.

Next four feature values of the ICs were investigated to isolate the neuromotor noise component across the population using threshold based clustering algorithm (Rong & Contreras-Vidal, 2006): topographic distance, activation entropy, kurtosis, and spectral distance of the independent components. Threshold selection was identified by plotting entropy and kurtosis compared to the spectral and spatial features of all the independent components of three randomly selected subjects. In the feature plots, each threshold was approximately ranged from 2.80 to 2.81 for entropy, 5.0 for kurtosis, 0.5 to 1.5 for spatial distance, and 0.22 to 0.4 for spectral distance. This threshold was applied across all subjects in both conditions to serve as a quantitative means of assessing cortical complexity.

Standardized Low Resolution Brain Electromagnetic Tomography (sLORETA).

To estimate the sources of the neuromotor noise IC time series, we used standardized low-resolution brain electromagnetic tomography (sLORETA) (Pascual-Marqui, 2002) in a fashion similar to (Bradberry, Gentili, & Contreras-Vidal, 2010). First, preprocessed EEG signals from all channels were fed to sLORETA to estimate current sources. Second, Pearson's correlation coefficients (*r* values) were computed between the squared time series of each of the preprocessed EEG signals and the 6239 time series from the sLORETA solution. Third, the mean of the |*r* values| multiplied by the |IC weights| of their associated sensors was assigned to each voxel (where | | means absolute value). Fourth, for visualization purposes, the upper 15% of voxels were set to the value one, and the rest of the *r* values were set to zero. Finally these binary-thresholded *r* values were plotted onto a surface model of the brain.

Motor behavior.

Mean score was computed based on distance from center target. All scoring was consistent with competitive shooting scoring metric of Bulls eye=10, outermost ring=1. The aiming point trajectory on the target in mm was sampled at 66Hz. The tangential displacement with respect to shot was computed for the 3s period prior to trigger pull. Variability was computed as the standard deviation of the tangential displacement with respect to shot. In addition normalize jerk was computed since it is a unitless measure of the dysfluency based on the third derivative of position (or the rate of change in acceleration). The dynamic change in normalized jerk was computed using a 1s moving window. The dynamics for each condition were averaged across shots for each subject and fitted with a first order polynomial to determine slope. Normalized jerk was also examined for the final second prior to trigger pull.

Statistical Design.

Arousal

Cardiovascular and skin conductance.

Arousal measures, HR, RSA and SC were statistically analyzed as a 2 x 2 x 2 (Condition x Order x Block) repeated measures ANOVA.

Psychoendocrine.

Cortisol sample values were statistically analyzed with a 2 x 2 x 4 ANOVA (Condition x Order x Sample). A first order polynomial was fit to the slope of each line (PA and C) and these slopes were tested by employing a 2 x 2 (Condition x Order) ANOVA.

Self-reported arousal assessment (visual analog scale and state-trait anxiety inventory).

The VAS scores were statistically analyzed as a 2 x 2 x 2 (Condition x Order x Block) repeated measures ANOVA. The STAI-S inventory scores were statistically analyzed as a 2 x 2 x 2 (Condition x Order x Block) repeated measures ANOVA.

Brain – Independent Component Analysis (ICA).

The number of components clustering to the noise template were entered into a 2 x 2 (Order x Condition) ANOVA.

Motor behavior.

Both score and variability were subjected to a 2 x 2 (Condition x Order) ANOVA. A 2 x 2 (Condition x Order) ANOVA was executed for both the normalized jerk value at the final second prior to trigger pull and normalized jerk slope three seconds prior to trigger pull.

Results

The study design included order and condition factors. All participants completed both the performance-alone and competitive conditions and the order was counterbalanced. For the purpose of this report, all observed interactions of condition and order were characterized by a difference in magnitude. There were no directional differences due to order. We will highlight the findings for the order that best illustrates the given prediction.

Arousal.

Cardiovascular and skin conductance.

The HR during competition (M=90.46 (SEM+/- 3.29)) is significantly higher performance alone (M=86.18 (SEM+/- 2.65)). The RSA ANOVA revealed no significant differences between performance alone (M=5.88 (SEM+/- 0.20)) and competition (M=5.87 (SEM+/- 0.24)). An Engagement x Condition (interaction $F(1,15)=30.401$, $p<0.001$ indicates that SC-ph is significantly higher when engaged in task performance compared to baseline for whether performance alone (effect size (ES)=4.0196) or during competition (ES=1.1796).

Self-reported arousal assessment.

Behavioral measures provide evidence of successful manipulation. The VAS measures reveal a robust elevation in self-reported competitiveness ($F(1,16)=8.869$, $p=0.009$, ES=0.67). Participants additionally reported that competition was accompanied by an increase in perceived stress ($F(1,16)=7.715$, $p=0.013$, ES=0.39). In addition state anxiety was elevated during Competition (M=34.62 (SEM+/- 1.9)) relative to the Performance-Alone (M=32.35 (SEM+/- 1.972) (approached significance, two tailed, $F(1,16)=4.177$, $p=0.058$, ES=0.246). No difference between competition and performance alone was found for confidence and relaxation (see Figure 5).

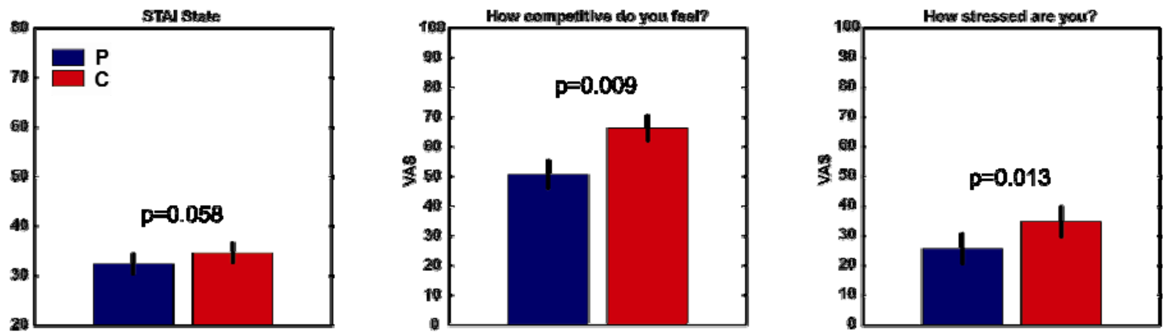


Figure 5. Self report findings indicating that during competition state anxiety, feeling of competitiveness and stress were significantly higher.

Psychoendocrine

Post hoc comparisons from the 2 x 2 x 4 (Order x Condition x Sample) ANOVA indicate a significant difference between the competition and performance alone across samples (see Figure 6, top panel) (Condition x Sample $F(3,39)=4.150$ $p=0.048$, $\varepsilon=0.436$ Greenhouse-Geiser). Further examine of the first order polynomial that was fit to the slope of each line (PA and C) 2 x 2 (Order x Condition) ANOVA indicates a significant main effect for condition $F(1,13)=5.062$; $p=0.042$ ES=0.18. This indicates that during performance alone there is a reduction in cortisol and during the competition the cortisol levels are relatively stable (see Figure 6, bottom panel).

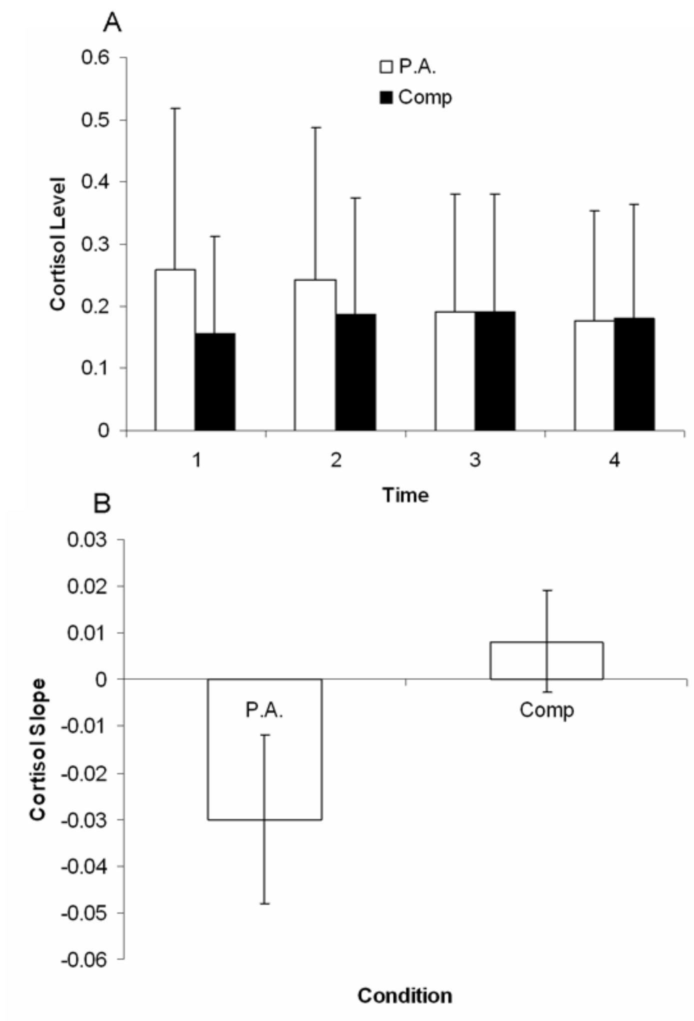


Figure 6 Cortisol results. Panel A indicates the relative stability of the cortisol levels across the competition whereas for the performance alone cortisol levels are progressively reduced over time. Panel B plots the slope of the cortisol samples over time, illustrating the negative slope during performance alone and the stable positive slope during competition**.**

Brain.

Independent Component Analysis (ICA).

During Performance Alone, 122.23 (SEM+/- 12.799) components across all subjects clustered to the neuromotor noise template. During competition, 135.03

(SEM+/- 11.416) clustered across all subjects. A 2 x 2 (Order x Condition) ANOVA was computed revealing a significant main effect for Condition $F(1,17)=5.705$; $p=0.029$ (see Figure 7).

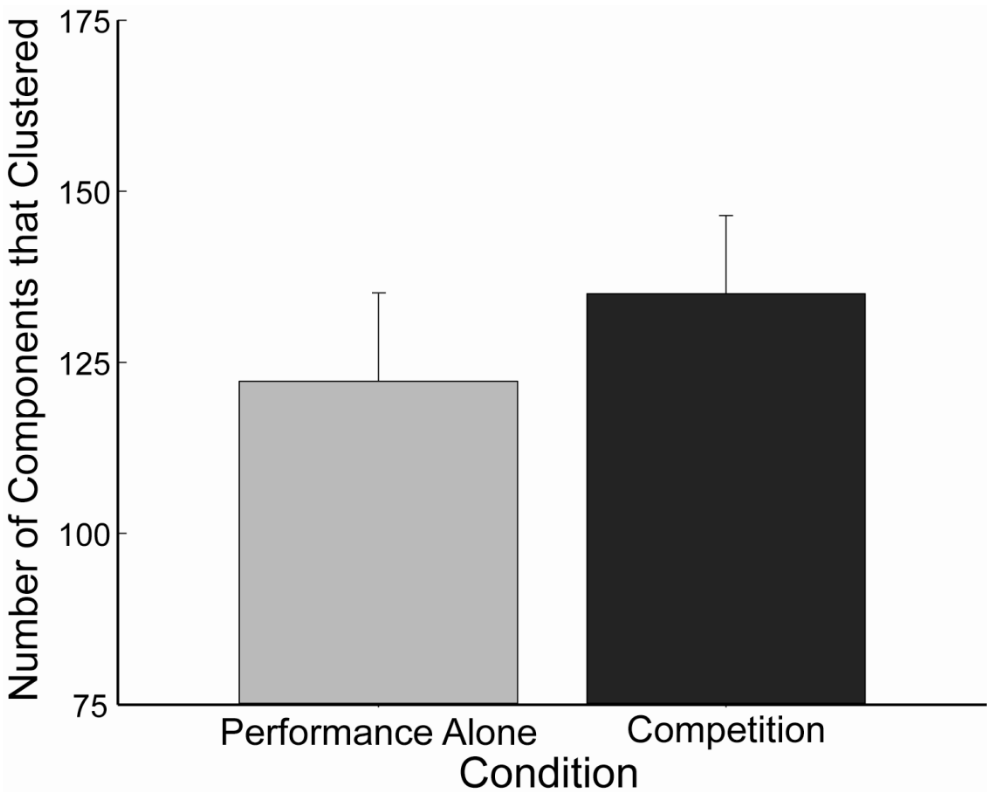


Figure 7. Neuromotor noise components clustered to the template significantly more during competition compared to performance alone. This suggests heighted frequency of maladaptive networking present during competitive stress.

Standardized Low Resolution Brain Electromagnetic Tomography (sLORETA).

The sLORETA analysis revealed primarily left lateralized function activity. In the frontal lobe the premotor cortex (BA6) was active. The temporal lobe showed left inferior temporal (BA22/37), middle temporal (BA39), and fusiform gyrus (BA19) activity. The parietal cortex activity was also left lateralized to the angular gyrus (BA39), postcentral gyrus (BA2) and the inferior parietal lobule (BA40). Occipital regions were primarily localized to the left middle occipital gyrus (BA18). Subcortical structures include the left posterior cingulate (BA31) and bilateral parahippocampal gryus/limbic lobe (BA27/30), see Figure 8 and Table 1.

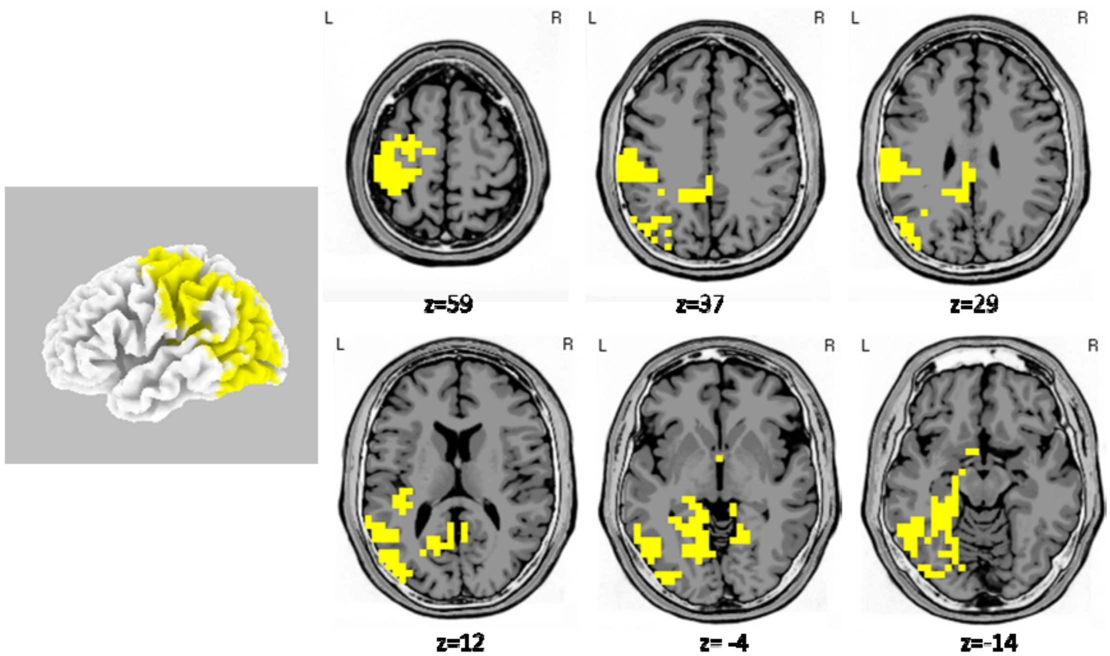


Figure 8. sLORETA source localization results from the neuromotor noise component. Associative, language and affective regions are active.

		Left hemisphere			Right hemisphere		
Region	**Brod. No.**	**x**	**y**	**z**	**x**	**y**	**z**
Precentral Gyrus	BA6	-23	-14	59			
ITG	BA22	-59	-55	12			
MTG	BA39	-50	-71	8			
ITG	BA37	-52	-72	-4			
Fusiform Gyrus	BA19	-25	-57	-14			
Angular Gyrus	BA39	-46	-73	37			
Postcentral Gyrus	BA2	-41	-28	42			
IPL	BA40	-63	-31	29			
MOG	BA18	-35	-89	-4			
Postrior Cingulate	BA31	-7	-44	37			
Parahippocampal Gyrus/Limbic Lobe	BA27/30	-19	-47	-4	10	-36	-4

Table 1: Anatomical regions from the sLORETA source localization of neuromotor noise component.

Motor behavior.

Examination of shot score and variability reveal no significant differences between performance alone and competition. The mean score for performance alone was 6.803 (SEM+/- 0.219) and competition was 6.816 (SEM+/- 0.230), p=0.0941. Variability during performance alone was 0.014 (SEM+/- 0.001) and during competition was 0.014 (SEM+/- 0.001), p=0.0293. A significant increase in aiming dsyfluency was seen during the final second before trigger pull in competition compared to performance alone (Condition F(1,17)=4.886, p=0.041, ES=0.3501). In addition analysis of the slope prior to trigger pull reveal significantly steeper slope in competition compared to performance alone (Condition F(1,17)=12.192, p=0.003, ES=1.0932), see Figure 9.

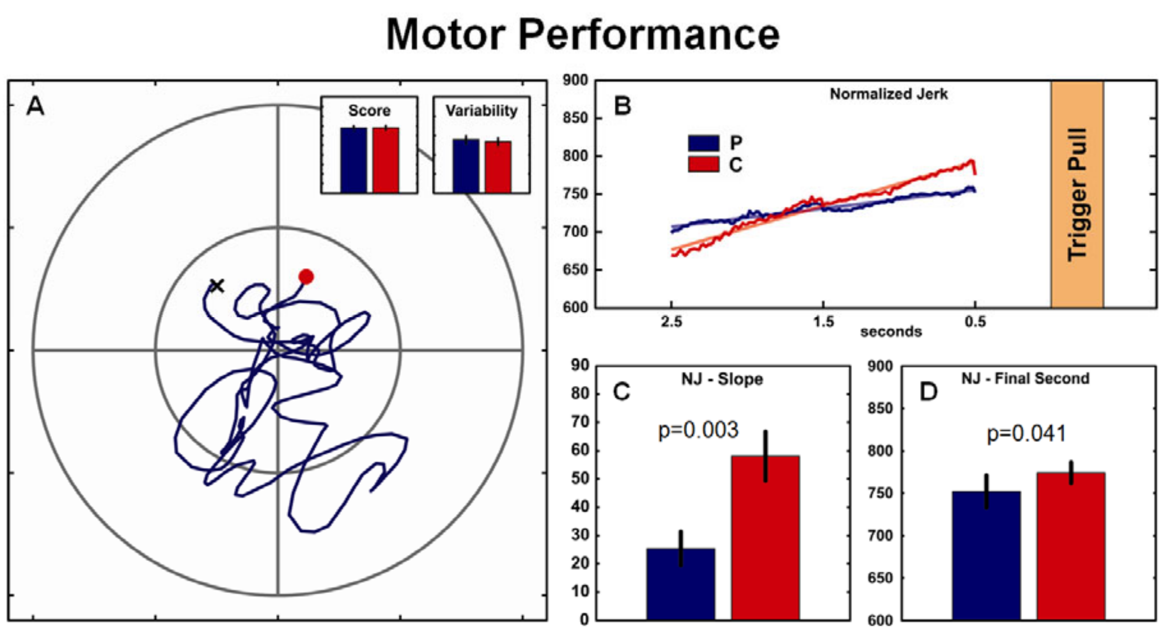


Figure 9. Kinematic results from performance alone and competition. Although score and variability were statistically equivalence (panel A), the normalized jerk slope (panel C) and value (second prior to trigger pull, panel C) indicate greater disfluency during competition relative to performance alone.

Discussion

This study offers a mechanism that attempts to explain a change in motor performance under mental stress. Previous investigations of skilled performance have revealed a psychomotor efficiency of expert task execution. This concept of efficiency is not only reflected in the biochemical, metabolic changes but also in the cortical processing which mediate more consistent motor effectors. During circumstances of low mental stress, left T3 alpha synchrony during expert shooting is a sensitive indicator of skilled action predicated on the notion of a quiescence of cognitive analysis (Hatfield et al., 2004; Kerick et al., 2004). In this study we examined how stress may perturb psychomotor efficiency during a competitive shooting paradigm by capitalizing on the sensitivity of this performance-relevant brain region. Thus we used the left lateralized temporal lobe region (associated with linguistic function or more generally involved feature detection of details) as a means of assessing unwanted complexity in the motor hierarchy during motor performance. The results provided validity for the role of such regional activity in the quality of cognitive motor performance and revealed that increased expression of this component was produced as consequence of competition which in turn translated into the quality of motor processes.

Our results indicate that we successfully increased arousal in a laboratory setting, as signified by objective self report, HR, SC and salivary cortisol. This is consistent with recent work from Cerin & Barnett (2009) who report that competition is a significant and stressful event and affects the performer's emotional state. The authors reported that competition-related concerns resulted in high self-reported fear compared to competition extraneous concerns and the former can be characterized as a threatening and challenging event (Cerin & Barnett, 2009). In addition kinematic comparisons revealed competitive stress exposure produced increased disfluency of action although with this magnitude of stress we saw no difference in variability and score. Thus, the performance outcome was constant across conditions but the quality of the aiming trajectory was compromised during mental stress.

Employing two different analytical tools, ICA and sLORETA, we sought to provide a more complete understanding of how mental stress disrupts motor performances. The ICA results indicated an increase in complexity (indexed by increased clustering to left temporal noise template) in competition compared to performance alone suggesting that a competitive situation introduced nonessential noise into the motor cortical areas. The specific features of the neuromotor noise template indentified here are consistent with the more general concept of neuromotor noise described by (van Galen & van Huygevoort, 2000). Their model identifies neuromotor noise as the primary source of human error under workload and time pressure conditions. These authors argued that such noise reflects a mismatch between an intended movement and the outcome of that movement. They suggest that motor performance is inherently noisy due to the degrees of freedom in behavioral repertoire, but psychological and physical stress result in, "…non-specific neural activation spreading". The increased neuromotor noise resulted in heighted probability in action error thus not only disturbing the refinement of skilled action, but also resulting in performance decline under pressure (van Galen & van

Huygevoort, 2000). Our results indicate that the stress of competition produced behavioral changes in the disfluency of performance, consistent with the neural processing efficiency (Eysenck & Calvo, 1992). While the reduction in efficiency does not always results in performance decline in the short run, it is possible that such attenuated efficiency could translate to performance decline if mental stress is sustained over time. In the present study the reduction of efficiency was manifested by heighted disfluency/jerk indicating a compromised smoothness and economy of motion (Smith, Brandt, & Shadmehr, 2000).

The anatomical specificity revealed by the sLORETA analysis provides insight into the nature of the neuromotor noise represented in this functional component. Left lateralized posterior temporal regions including the middle temporal gyrus, superior temporal gyrus are involved in language processes, specifically the mapping of phonological representation onto semantic representation (Hickok & Poeppel, 2007). In addition, posterior parietal regions and fusiform regions are critical areas in the neural representation of semantic knowledge (Binder, Desai, Graves, & Conant, 2009). In particular the angular gyrus is reported to be involved in information synthesis and conceptual knowledge recall required for language processing (Binder, et al., 2009; Bright, Moss, & Tyler, 2004; Davis, Meunier, & Marslen-Wilson, 2004). The parahippocampal gyrus is reported to be sensitive to negative valence during mental stress exposure (Surguladze, et al., 2006). Lastly the premotor cortex and the supplementary motor area, or SMA are essential in planning of planning of complex, coordinated movements (Bear, Connor, & Paradiso, 1996) suggesting the neuromotor noise extends into motor key element of the motor hierarchy. Thus, the perceived psychological stress produced by competition may elevate input from limbic sources in mesiotemporal regions, which are connected with numerous sensory and association cortical areas leading to a cascade of non-essential activity during motor performance (Haines, 2006). In turn, this stress-induced perturbation to cortical refinement may lead to maladaptive coping strategies such as reinvestment that recruits associative areas (left temporal-parietal activity) which can be characterized as neuromotor noise.

Collectively, the anatomical representations of the neuromotor noise component are consistent with the self-talk described in the reinvestment hypothesis during anxious arousal (Masters, 1992). Self talk is a means of interpreting feelings and perception in an effort to change evaluations of the athletes affective state (Hardy, Hall, & Alexander, 2001). In turn, this self attention may produce a reinvestment of explicit knowledge in an effort to promote controlled processing (Maxwell, Masters, & Eves, 2000). Such control processes implies a regression to a lower stage of skilled motor behavior (Fitts & Posner, 1967). Thus our data support this model of conscious control during performance under pressure as a maladaptive means of self talk. In particular this type of explicit monitoring may be more frequent in complex motor tasks since the training is typically centered on substantial explicit technical instruction (Kinrade, et al., 2010).

However there are circumstances when self talk may promote rather than interfere with motor performance. For example, Gibson reported that motivational thoughts can sustain effort during exertion acute exercise (St Clair Gibson & Foster, 2007). Thus the type of self talk and the nature of situation are critical to influence on behavior. Higher level cognitive linguistic strategies may be adaptive if used as tools to maintain optimal arousal, manage emotion and support task engagement. Global cue words that represent a gestalt of explicit skills reduced reinvestment under pressure and instead produced self-regulatory approaches that do not require explicitly learned attention (Gucciardi & Dimmock, 2008; Jackson & Wilson, 1999). Also an emotion regulation strategy called cognitive reappraisal changes the emotional responses to stressful challenges by verbally reformulating the meaning of a situation (Goldin, McRae, Ramel, & Gross, 2008; Wager, Davidson, Hughes, Lindquist, & Ochsner, 2008). In turn utilizing these approaches when challenged with a stressful event may create an optimal arousal that maintains psychomotor efficiency.

In addition, the neuromotor noise quantified in this task suggests that it may not only be the emergence of counterproductive self talk but also a detrimentally timed cognitive management. The data presented here were extracted from 4 seconds prior to trigger pull thus characterizing non-essential features that interfere with the refinement and efficiency just prior to action execution. In comparison, positive self talk as part of a mental preparation technique prior to motor performance may regulate arousal levels and be adaptive in that is can promote emotion regulatory cognitive linguistic strategies like cognitive reappraisal. Further understanding of different types of self talk and how they may interact with the timing and execution of the motor task requires future studies. Although self talk may be adaptive, we cannot determine from our data whether the individuals where engaged in negative or positive self talk nonetheless, but our results support the notion of a loss of efficiency during stressful challenge. Thus, self talk (independent of type) is extraneous and non-essential to the motor loop 4 second prior to trigger pull and our results indicate that it goes up under the stress of competition leading to neuromotor noise.

In summary the results suggest that a competitive situation introduced non-essential noise resulting in a quantified increase in complexity during a cognitive motor task. Investigation of the neural sources of this neuromotor noise component revealed the anatomical substrates of the neuromotor noise are based in language, affective, and association regions. In addition we found that this loss of psychomotor efficiency translates into the quality of motor behavior resulting in an increase in disfluency during the aiming movement.

Chapter 4: Examination of Expert Groups to Understand Stress Resilience

The findings described in the first paper portray the detrimental effects of stress with a non-expert population. However, experts are generally able to successfully handle stressful events in a manner that does not interfere with performance. Thus, expert groups are informative models for understanding how some individuals are resilient to stress perturbation and have developed adaptive mental approaches to cope with stressful challenge.

This section will focus on the psychological and physiological characteristics of elite performers, highlighting a few example populations. The first example comes from the work of Fenz (1975) who investigated expert parachutists using Galvanic Skin Response (GSR) and Heart Rate (HR) as indicators of arousal (Fenz, 1975). The GSR is an index of sympathetic system activity, which is mediated (via the hypothalamus and brainstem) by brain regions involved in emotional processing and arousal (Driscoll, Tranel, & Anderson, 2009; Patterson, Ungerleider, & Bandettini, 2002) In particular this measure is well suited for evaluating endogenous affect control since the neurobiological regulatory cascade involved in the GSR includes the management of subcortical regions (hypothalamic and brainstem) by the ventromedial prefrontal cortex (vmPFC) and orbitofrontal cortex (OFC) (Patterson, et al., 2002). These prefrontal regions play a critical role in the regulation of emotional processing (described in more depth below). Additionally HR reflects the integration of both branches of the autonomic nervous system and is sensitive to not only arousal but valence (Patterson, et al., 2002).

Thus, utilizing dependent measures sensitive to emotional processing, Fenz's work has the advantage of ecological validity since these measures were recorded in the field during seven intervals prior to jumping from an airplane (Fenz, 1975). The investigators were particularly interested in what they termed "learned control of the involuntary cardiac response" by which experts demonstrated a relationship between arousal and performance that followed an inverted V, with an initial increase in arousal (as measured by HR and skin conductance) followed by a sharp decline prior to the jump (control of emotions). This is consistent with a physical manifestation of a reduced stress response in terms of a relative decrease in sympathetic response (increased vagal tone) and reduction in HR and GSR. The authors found that in experts, certainty and uncertainty (known psychological constructs that manipulate mental stress) were mediating factors in cardiac anticipatory control. They reported that if an experienced parachutist experienced a mishap, these individuals regressed temporary into a GSR pattern that matched novices. Thus with greater uncertainty and threat, the inverted V shape of the expert is lost. Additionally when a subject was told that his parachute would malfunction, therefore requiring him to use the secondary chute, the expert's physiological response was attenuated with greater variability (Fenz, 1975). Moreover, recent accounts that have looked at stress dependent performance decline found stress was attenuated in individuals who had greater perceived controllability of the situation; it was only during uncontrollable stress where prefrontal mediated action were impaired (e.g., coordination of complex motor sequences involving decision making) (Arnsten, 2009). This is consistent with recent work indicating that elite athletes who have greater perceived personal control over the competition showed reduced anger, fear and sadness, in other words, management of negative stress-related emotions (Cerin & Barnett, 2009). Cognitive control may thus be a critical factor in the endogenous emotion regulation of stress resilient elite performers.

Thus it appears certainty, with “attentive observation of the external environment,” and greater emphasis on task requirements, produces a stabilizing effect on autonomic stress responses and enhances performance (Fenz, 1975). The focus on task-relevant, externally oriented events is, therefore, a hallmark of stress resilience to maintain cognitive-motor performance. Importantly, the Fenz work reported that emotional expression was minimized in expert performers while the narrative from novices illustrates anxious anticipation of the stressful event. This suggests that emotional reactivity can be managed by execution of cognitive control with a subsequent effect of maintained flexible adaptive behavior.

Consistent with this concept, psychological constructs such as resilience, grit and hardiness often characterize elite performers who are resistant to the negative outcomes of stress exposure (Matthews, 2008). Soldiers have been particularly studied with respect to these constructs since they encounter extreme adverse and stressful circumstances with high frequency. Hardiness is reported to protect against the ill effects of stress exposure, while grit is predictive of success in extreme training programs (Matthews, 2008). Athletes also share such psychosocial attributes such as determination, confidence, focus, inspiration and hope (Hanin, 2007). These emerging virtues of character strength have a converging effect of characterizing elite performers as individuals who may be uniquely resilient to stress perturbation.

These unique behavioral and psychophysical characteristics may maintain and promote efficiency in the cognitive-motor domain. But this raises the question as to whether or not this psychomotor efficiency translates into an economy of brain processes in regions sensitive to cognitive control of emotion. The next paper seeks to examine this question by examining the neural response of elite athletes and an age-matched control group to mentally stressfully images.

Chapter 5: Efficiency of Affective Brain Processes in Expert Cognitive-Motor Performers during Emotional Challenge

Introduction

Superior cognitive-motor performance is characterized by an economy of effort (Hatfield & Hillman, 2001). Skilled action is exemplified by remarkable ability in processing speed and accuracy requiring minimal effort and automaticity of execution (Schneider & Chein, 2003). This behavioral efficiency is evident in the form of movement economy, with maximized power output, reduced muscle activation, and greater movement coordination (compared to novices) (Lay, Sparrow, Hughes, & O'Dwyer, 2002). Neurobiological investigations of skilled performance also reveal that efficient nature of brain processes during motor action (Hatfield & Hillman, 2001). In general, neural processing efficiency bears relevance on the relative ease with which an individual executes a particular task. In the motor domain, this concept is understood as psychomotor efficiency, characterized by cortical refinement critical for adaptive engagement of brain areas that are primarily involved in performance (leading to a consistent, stable and refined motor behavior) (Babiloni, et al., 2009; Del Percio, Babiloni, Marzano, et al., 2009; Del Percio, et al., 2008; Hatfield & Hillman, 2001). Thus, individuals who demonstrate low efficiency are characterized by greater mental effort during task execution (Gray, et al., 2005) whereas highly skilled individuals reportedly demonstrate neural efficiency (as evident by reduced neural activity) accompanied by the automaticity of performance (Del Percio, et al., 2010). Neural efficiency is revealed not only with skilled performers engaged in sensorimotor tasks, but also short term memory tasks, IQ scores, intelligence (Haier, Siegel, Tang, Abel, & Buchsbaum, 1992), word fluency, and spatial skills (see (Neubauer & Fink, 2009) for a review). In turn, efficiency of processing appears to be an organizing principle of skill. This suggests that economy in the cognitive-motor domain may extend to efficiency in the emotive domain in individual who consistently performance well under mental stress, in other words, these individuals may be skillful at adaptively processing emotional events.

The interconnectivity of the brain suggests that the quality of brain processes associated with emotion likely influences the ability to maintain psychomotor efficiency. The amygdala, a region heavily involved in emotional processing, influences cortical sites across the brain via the basal forebrain which in turn modulates sensory and motor responses to environmental stimuli (Pessoa, 2010). Consequently, affective attention is critical to the coordination of information (affective salience, significance, ambiguity, unpredictability and overall 'biological value') about an external event to the cerebral cortex, thus influencing action plans and serving as the foundation for the interaction between affective and cognition (Pessoa, 2010; Pessoa & Adolphs, 2010). This suggests that an economy of processing in the amygdala and other regions critical to the assessment of affective information (e.g., parahippocampal gyrus) may be essential to the refinement of brain activity necessary for effective task execution particularly under conditions of stressful challenge (i.e., competition, social evaluation, etc.). Therefore, using functional magnetic resonance imaging (fMRI) this study seeks to examine if individuals who have demonstrated superior cognitive-motor performance under stress expend less brain activity (relative to control comparison) during emotional challenge.

Athletes are individuals who motorically are faster, stronger, accurate, consistent, efficient and automatic in their sport compared to non-athletes (Nakata, Yoshie, Miura, & Kudo, 2010). Practice is an essential mediator of the development of these unique qualities, since it facilitates both explicit and implicit learning, thus leading to neurophysiological changes that produce greater efficiency of movement. From a learning perspective, practice-dependent changes promote 1) the reduction of explicit regulation of performance, 2) changes in attentional strategies (goal oriented) and 3) changes in memory processes (greater reliance on declarative and procedural knowledge are gained as a result of practice) (Kerick et al., 2004). The consequence is a more automatic performance of task with a reduction in effort and an economy of neural processing (Chein & Schneider, 2005). Although this principle of efficiency is a general feature of practice-related cognitive-motor adaptation (Gentili, Bradberry, Oh, Hatfield, & Contreras Vidal, 2010), neuroscientific investigations of elite athletes are ideal for examining principles of psychomotor efficiency.

Neuroimaging investigations have consistently revealed that physical training has produced adaptive changes in neural circuits of elite athletes including faster motor-related cortical potentials (MRCPs) (increased motor readiness), increased positive of slow potentials (indicative of an inhibition of neuromuscular activity and reduce neural activity), structural differences (i.e., larger vermian lobules in human cerebellum), greater event related alpha synchrony (reduced neural activity), early P300 latencies (faster speed of stimulus classification), and greater motor planning efficiency (fMRI) compared to non-athletes (for a complete review see (Nakata, et al., 2010)). Thus the findings reveal that the athlete's brain demonstrates adaptive changes in functioning and an automaticity of processing making this population an exemplar of psychomotor efficiency.

Athletes are also remarkable in that they have distinguished themselves in situations of competition. Competitive stress has been shown to produce an affective response in performers (Cerin & Barnett, 2009), but the performance abilities of elite athletes suggest that they are resilient to such stress perturbation, enabling them to maintain a high level of motor performance during stressful conditions. In addition, psychological constructs which promote resilience include commitment, patience, optimism and self esteem (Vialou, et al., 2010) are congruent with attributes of top athletes. This suggests that individuals actively involved in high levels of sport are not only exceptional exemplars of psychomotor efficiency but inform understanding of stress resilience since this population is not only highly skilled, but is able to perform at high levels under variable and challenging conditions.

This study will examine elite athletes who have history of high level motor performance. Since the literature supports neural efficiency in skilled performer (Hatfield & Kerick, 2007), by deduction, we assume that these individuals are efficient in cognitive-motor domain. In addition these participants have experience with performing during an emotionally charged context; therefore it seems reasonable that they would also exhibit efficiency in the emotive domain, particularly in light of interconnectivity of affective regions with the cerebral cortex. In summary, these individuals, through their ability to cope the deleterious effects of mental stress, may show specific adaptive changes in the neural circuits that cognitively control fear, emotional reactivity and in turn behavior (Feder, Nestler, & Charney, 2009). Thus, we predict that elite athletes may have developed an economy of neural processing when faced with stressful challenge but this may be specific to their sport. Through experience elite athletes may have developed a neural processing efficiency to sport specific negative events such that overall arousal is efficiently managed promoting a generalized economy of brain activity (Pfaff, Kieffer, & Swanson, 2008). Thus it would be logical that such great athletes would be less perturbed affectively which would help them to be more stable motorically.

In addition, the management of cortical arousal to promote psychomotor efficiency may be the sequelae of a cognitive interpretation of the stressful event. Studies have shown that cognitive control and emotion regulation involve the prefrontal cortical regions (Goldin, et al., 2008; Ochsner, Bunge, Gross, & Gabrieli, 2002), and additionally, the prefrontal cortex is a region particularly sensitive to motor performance efficiency (Rypma, et al., 2006). Thus, we predict that affective economy may be particularly robust in the prefrontal cortex, since this region sensitive to performance efficiency and essential to cognitive control of emotion (Ochsner & Gross, 2008; Rypma, et al., 2006).

Methods

Subjects

Twenty-five male participants between the ages of 18 and 22 were recruited and of these 13 were football athletes (M=21.46 years; SD=0.776) and 12 were non-athletes (M= 21.08 years; SD=2.19). The football athletes were 1) senior varsity athletes 2) letter award winners 3) typically play a starting role on the team 4) on a partial or full athletic scholarship. The non-athletes were healthy subjects who never played football at a college level but reported familiarity with the goal and rules of the sport; this is critical to ensure that all subjects understand the meaning of the negative sport-relevant images. We developed a metric to quantify the football experience of the control subjects (Please select the answer that best describes your football experience : 0=no experience, do not watch or attend games (not a fan); 1=no experience, but watch occasionally (mild fan); 2=no experience, but watch frequently (avid fan); 3= some experience playing and watch frequently (e.g., intramurals); 4=several years experience playing competitively (e.g., high school); 5=currently playing competitively) such that control subjects scored a mean score of 3 (M=3; SD=0.94) for football experience. We additionally characterize their sport experience outside of football with a similar metric; mean score of 4.09 (M=4.09; SD 0.51) for sports experience in general.

Additional selection criteria included that the subjects must have been (a) native English speakers (b) free of current or past diagnosis of neurological or psychiatric disorders, and (c) MRI compatible (e.g., no metal in body, no tattoos on face, no medicine delivery patch). All subjects gave their written informed consent and all experimental procedures were approved by the University of Maryland Institutional Review Board with proper notification IRB of record for Hyman Subject Research Projects performed at the Georgetown University Center for Functional and Molecular Imaging.

Procedure.

Stimuli.

Following the approach developed by (Goldin, et al., 2008; Ochsner, et al., 2004) the fMRI investigation evaluated the BOLD response during negative and neutral visually presented images. The neutral images served to provide a baseline to remove lower-level sensory processing associated with the visual modality and thus isolate affect specific networks. Negative and neutral images were selected from the International Affective Picture System (IAPS) (Lang, Bradley, & Cuthbert, 1999). In addition we developed Sport-Specific (SS) images by searching internet databases (e.g., Google Images) to find images representing unpleasant events experienced during football competition: for example: 1) injuries; 2) embarrassment due to loss (i.e., dejected players); 3) critical coaches.

Undergraduates (n=103) at the University of Florida gave their written consent (approved by the University of Florida Institutional Review Board) and the rated sport pictures (i.e., sport-specific negative images) (31 performance, 39 injury) and 48 negative IAPS images using the IAPS self assessment manikins and IAPS protocol (Lang, Bradley, & Cuthbert, 1999). The top 48 most negative sport images were selected based on valence scores (38 injury, 10 performance) and, for men, the SS images resulted in a valence rating mean of 4.131 and arousal mean rating of 4.824. In turn, IAPS images were selected with matching valence means scores of 4.116 and arousal mean scores of 4.896 to create equivalence between the two image sets. These ranges are consistent with what Patrick and Lavoro (1997) reported as negative for IAPS images: "Slides with mean valence ratings of less than 4.5 out of 9 were classified as unpleasant, those between 4.5 and 5.5 were classified as neutral, and those with mean ratings above 5.5 were classified as pleasant" (Patrick & Lavoro, 1997).

***Task*.**

Each trial was composed of four events: First, instructions (watch or decrease) appeared centrally for 2 seconds. On "decrease" trials, participants were instructed to engage in cognitive reappraisal and on "watch" trials participants will be instructed simply to look at the image and let themselves respond naturally. Second, an aversive or neutral image will appear centrally for 8 seconds. This duration was selected based on a recent meta–analysis by Kalisch (2009) that suggests that 8 second image presentation time ensures examination of one concrete dimension of this psychological construct (implementation of cognitive reappraisal) (Kalisch, 2009). While the image remained on the screen, participants performed the evaluation operations specified by the prior instructional cue. Third, a rating scale will appear immediately after presentation of the image for 4 seconds asking “How negative do you feel” with a rating from 1 to 5 (1 not at all, 3 moderately, 5 extremely). This scale will allow participants to rate with a joystick the current strength of their negative affect and serve as a behavioral index of the success of reappraisal. Fourth, the transition task of fixation cross for 4 seconds in the center of the screen indicating that participants should relax until the next trial. Each subject was cued to passively view or reappraise 48 domain non-specific negative images (24 each) and 48 domain specific negative images (24 each) in addition to the passive viewing of 24 neutral images during randomly intermixed trials over 4 MRI scanning runs. Each image was shown only once for a given participant. Upon completion of the MRI, subjects returned to the Behavioral Testing room to complete questionnaires.

Prior to data collection.

Upon arrival at the Georgetown University Center for Functional and Molecular Imaging, participants were escorted to a Behavioral Testing room were written consent and MRI safety screening were attained. Task instructions consisted of a scripted training manual designed to provide an overall explanation of the goal of study, provide a detailed overview of the trial structure, review the instructional cues and describe the rating approach. During this orientation the investigator read aloud the manual while the participant followed along.

> The subject was instructed that the goal of the study was “We are interested in the biological and brain processes related to mental pressure and toughness. In

order to make sense of the pattern of your brain response we need to have a consistent comparison condition. Thus, I am going to train you on a task which we will use as the comparison state but we are really interested in how you respond naturally to these pictures." Next the subject viewed the trial structure and was read the following description: "You will be given an instructional cue of either "Watch" or "Decrease" (I will describe the instructions in greater depth next). Next you will see a picture. Some of the pictures may prompt emotional experiences; others may seem relatively neutral. You will be asked to rate the image using a joystick (which will also be described next). Lastly you will see a cross in the center of the screen; simply fix your eyes on that cross." Next the rating instructions were given "After viewing a picture we ask that you rate it. You will be asked "how negative do you feel?" and select the numeric value that applies to how you felt when viewing the image. If you felt in between the three descriptors, please select the appropriate intermediate value. There is no right or wrong answers, so simply respond as honestly as you can." Then the subject was introduced to the meaning of the watch instruction and shown a sample trial with a picture of an injured player: "Next, I will review the instructional cues. Below I have included one example trial in which the instruction will be "watch", which means you must simply look at the image and let yourself respond naturally." The decrease instruction was next reviewed (descriptions taken from previous protocols, e.g., (McRae, Ochsner, Mauss, Gabrieli, & Gross, 2008; Ochsner, et al., 2002): "The second instructional cue is "Decrease." What you will do when you see this instruction is transform your response or interpretation of the picture so it's not so negative. There are three ways to do this: 1) Transform the scenario depicted into positive terms; imagine that the situation is not as bad as it appears (e.g., a women crying outside of a church could be interpreted as a woman expressing tears of joy from a wedding ceremony rather than from the sorrow of a funeral); 2) Rationalize or objectify the content of the pictures; view the image from the perspective of a distant, detached observer (e.g., consider a woman with facial bruises could be an actor wearing makeup rather than a victim of domestic abuse); 3) Imagine that things will improve with time (e.g., whatever appears to be bad will resolve over time). This is called cognitive reappraisal. Cognitive means how you think and reappraisal means transforming the meaning." And then the subjects were shown an example trial (IAPS number 6212): "Here's a sample trial, and the implementation of all three strategies with this one image. Again you may choose 1 of the 3 strategies during the image viewing period: all are appropriate. 1) The Soldier is clearly not aiming at the child but at his adversary in the distance. The child is running to the safety of his family where he will avoid any harm; 2) Action movie trailer for the latest Special Forces flick; 3) The village will be safe again after the Soldiers remove the threat."

Next participants sat at a desktop computer to practice the task using a duplicate MRI compatible joystick that matched the device used in the MRI environment. Participants were introduced to all elements of the experimental protocol including the initial instructional prompt of “Remember when cued to ‘watch’ respond naturally and when cued to ‘decrease’ engage in cognitive reappraisal (as practiced).” Next the participant viewed two “watch” trials and executed their rating selection. After that, the participant viewed an investigator demonstration of reappraisal using three negative images and again executed their rating selection. The participant was then instructed to overtly engage in reappraisal during the viewing of 6 negative images (3 IAPS and 3 SS) to ensure proper use of the cognitive reappraisal strategy. All training was scored during these self paced sessions using a categorically scoring metric that included the following categories identified in (McRae, et al., 2008): 1) It is not real (e.g., it is just a scene from a movie, they are just pretending); 2) Things will improve with time (e.g., whatever is going wrong will resolve over time); 3) Things are not as bad as they appear to me (e.g., the situation looks worse than it is, it could be a lot worse, at least it’s not me in that situation); 4) Expressive Suppression/ Attention Modulation; 5) Failure to Reappraise.

All subjects performed at/or better than 90% correct for the initial training session (mean percent correct: 92.14%). The final training session occurred in the MRI during which the subject viewed 6 reappraisal “decrease’ trials which match the exact timing of the experiment. The subjects then retrospectively reported all of their reappraisal strategies such that the training success could be scored based on the categories mentioned above. All subjects performed at/or better than 90% correct for the in scanner training session (mean percent correct: 90.91%).

Imaging parameters.

Functional and structural magnetic imaging data were acquired on a 3T Siemens Magnetom Trio system equipped with gradients suitable for echo-planar imaging sequences. Thirty-eight axial slices (3.2 mm thick in plane) were acquired using an echo planar imaging (EPI) pulse interleaved sequence (TR 2000 ms; FOV

205; TE 30ms). For the possibility of aligning of the functional data to each subject's individual anatomy, anatomical images were obtained: a high resolution T1 3D MPRAGE. Image data were transferred via the network for quantitative analysis and to magnetic tape for backup.

Dependent Measures.

Psychometric inventories: to characterize population.

Performance Failure Appraisal Inventory (PFAI).

This inventory is a multidimensional measure of cognitive-motivational-relational appraisals associated with fear of failure (FF). FF was associated with (a) high levels of worry, somatic anxiety, cognitive disruption, and sport anxiety, and (b) low levels of optimism. General FF was unrelated to either perceived competence or fear of success. This measure consists of five questions examining failure appraisal: 1) When I am failing, I am afraid that I might not have enough talent; 2) When I am failing, it upsets my "plan" for the future; 3) When I am not succeeding, people are less interested in me; 4) When I am failing, important others are disappointed; 5) When I am failing, I worry about what others think about me. Subjects are asked to rate these questions based on the following range: Do Not Believe at All, Believe 50% of the Time, Believe 100% of the Time. To compute the general fear of failure score all 5 item scores are averaged (Conroy, 2001).

State-Trait Anxiety Inventory (STAI).

This is a 40-item self-report index of state and trait anxiety consisting 20 state items and 20 trait items. The STAI-T consists of 20-items rated on a 4-point scale ranging from 'not at all' to 'very much so' in terms of how the participant feels at the moment. The STAI-T score ranges from 20 to 80, with increasing scores reflecting greater trait anxiety (Spielberger, et al., 1970).

Dispositional Resilience Scale (DRS).

This inventory is a hardiness measure with 5 items each to measure the hardiness facets of Commitment, Control, and Challenge. Each question asks how much you think each one is true for you ranging from 0=Not at all true; 1=A little true; 2=Quite true; 3=completely true. Six items are negatively-keyed, which makes this scale quite well-balanced for negative and positive items. Results include raw scores and percentiles for commitment, control, challenge, and total hardiness (Bartone et al., 2008).

Sport Competition Anxiety Test (SCAT).

This is a 15-item questionnaire gauging an individual's tendency to perceive competitive situations as threatening and to respond to these situations with elevated state anxiety. Subjects are asked to indicate how they generally feel when they compete in sports and games and respond to each item using a three-point scale (hardly ever, sometimes and often). Scores on the SCAT range from 10 to 30 (Martens, Vealey, & Burton, 1990).

Beck Depression Inventory (BDI).

This is a 21 item self-report questionnaire evaluating depression symptoms. It is a widely accepted measure consistent with clinician ratings and other depression scales based its comparable internal consistency and validity. Each question consists of 4 statements describing increasing intensities of symptoms of depression. Questions are rated on a scale from 0–3, reflecting how participants have felt over the past week. Possible scores range from 0– 48; higher scores reflect more severe depressive symptomotology. (Beck, Rush, Shaw, & Emery, 1979).

Emotion Regulation Questionnaire (ERQ).

This is a 10-item self-report questionnaire indexing the habitual use of expressive suppression and cognitive reappraisal. This measure consists of 10 questions, 4 measuring suppression (e.g., ‘I keep my emotions to myself’) and 6 measuring reappraisal (e.g., ‘When I want to feel more negative emotion I change what I’m thinking about’). Higher scores indicate more frequent use of each strategy.

Physiological measures of arousal.

Galvanic skin response.

Skin conductance is measured using the Psylab Stand Alone Monitor through the application of a small voltage across two electrodes and in turn measures the current that flows between the electrode locations. Electrode placement is constrained to sites unique to eccrine sweating, which, is related to mental processes and exclusively under sympathetic control. Electrodes were placed on medial phalanges on left index and middle fingers. The skin conductance data were recorded continuously at a rate of 25 samples per second. Off-line analysis of skin conductance response waveforms using a local peak-detection algorithm was used to compute stimulus-related skin conductance responses defined as trough-to-peak conductance differences greater than 3.1 micro Siemens occurring within 100 second windows to minimize transition points. The amplitude of the largest skin conductance response associated with each stimulus (skin conductance response magnitude) was used as an index of the subject's maximum arousal during that stimulus (if no skin conductance response was detected, amplitude was considered to be 0) (Butler, et al., 2007). Skin conductance response were then co-registered with viewing time by examining time windows 0.5 s to 12 s following stimulus onset (Butler, et al., 2007). The skin conductance responses were then averaged within the cognitive reappraisal SS, IAPS, passive negative SS, IAPS, passive neutral conditions for each subject.

Heart rate.

HR was measured using the Invivo cart (3150 MRI) using the 4-in-1 Quadtrode® MRI ECG Electrode placed on the subject's left side, below the left pectoral, on the bottom of the ribcage. As a secondary measure, we used a pulse oximeter on the left thumb of the participant in case the ECG recording became disrupted due to the MRI gradients. HR was then co-registered with viewing time (8 s) and then averaged within the cognitive reappraisal SS, IAPS, passive negative SS, IAPS, passive neutral conditions for each subject.

Behavioral measures - affective rating.

Mean negative affect ratings will be calculated for the passive negative (SS and IAPS), passive neutral, and cognitive reappraisal (SS and IAPS) conditions for "How Negative Do You Feel?" (1= not at all, 3=moderately, 5=extremely).

Functional Magnetic Resonance Imaging: BOLD Signal.

The DICOM images were extracted and imported into the signal processing software for preprocessing (e.g., Statistical Parametric Mapping, SPM5). Slice timing correction was followed by correction for head motion during scanning (through the registration of the time series to the reference first scan). The motion parameters were saved for later statistical analysis to be used as regressors in the design matrix. This step was followed by creating binary mask so that voxels outside of the brain are removed. For statistical comparisons to be made across subjects, the data were normalized into MNI format (template EPI.mni) in order to account for variability in brain shape and size. Default SPM5 settings were used to warp volumetric MRIs to fit the standardized template (16 nonlinear iterations), and normalization parameters were applied to subject's functional images. Normalized images were resampled into 2 × 2 × 2 mm voxels. Then, a spatial smoothing of the images was performed by employing a low pass spatial filter which remove high frequency spatial components resulting in the 'blur' of the images (Huettel, Song, & McCarthy, 2003). The Gaussian filter of 6mm (the width is determined by half of the maximum value, Full-Width-Half-Maximum, FWHM) essentially acted to spread the intensity of each voxel in the image to neighboring voxels serving to maximize the signal to noise ratio and reducing false positives in the later statistical analysis (Huettel, et al., 2003).

Statistical Analysis.

Psychometric inventories: to characterize population.

For the PFAI, STAI, DRS, SCA, BDI and ERQ, mean and standard deviations for each item were computed. Group comparisons were tested using a paired t-test.

Physiological measures of arousal.

Galvanic skin response.

Two way ANOVA (2 x 5) Group (control, football) by Condition (cognitive reappraisal SS, passive negative SS, cognitive reappraisal IAPS, passive negative IAPS, passive neutral) was executed. Tukey's post-hoc tests were employed to examine all possible comparisons.

Heart rate.

Two way ANOVA (2 x 5) Group (control, football) by Condition (cognitive reappraisal SS, passive negative SS, cognitive reappraisal IAPS, passive negative IAPS, passive neutral) was executed. Tukey's post-hoc tests were employed to examine all possible comparisons.

Behavioral measures - affective rating.

To examine within group effects one way ANOVAs were executed for each group with Condition as the factor (cognitive reappraisal SS, passive negative SS, cognitive reappraisal IAPS, passive negative IAPS, passive neutral). Tukey's post-hoc tests were employed to examine all possible comparisons.

Functional Magnetic Resonance Imaging: BOLD Signal.

Preprocessed images were entered into a General Linear Model in SPM5 that modeled the canonical hemodynamic response function convolved with an 8-second boxcar representing the picture-viewing period. Motion parameters, the instructional cue period, and the rating period were entered into the model as additional regressors. The General Linear Model (boxcar models representing the picture-viewing period of each condition) was used to create contrasts for each condition, for each subject, for each domain. These individual contrasts were then entered into a Full Factorial design of a 2 x 4 ANOVA Group by Conditions to perform a random-effects group analysis. The Group factor consisted of Football and Control and the Condition factor consisting of Cognitive Reappraisal SS, Passive Negative SS, Cognitive Reappraisal IAPS, and Passive Negative IAPS. Conditions of interests were examined (Cognitive Reappraisal SS, Passive Negative SS, Cognitive Reappraisal IAPS, Passive Negative IAPS) for each group relative to the neutral baseline. Direct contrasts were computed between group were executed within each condition (Cognitive Reappraisal SS, Passive Negative SS, Cognitive Reappraisal IAPS, Passive Negative IAPS). Direct comparisons between groups were reported based on whole brain analysis and a priori region of interest analysis of the prefrontal cortex (BA 8, 9, 10, 11, 45, 46, 47, taken from the Wake Forest Pick Atlas indication of Brodmann Areas). The ROI analysis were FDR corrected for multiple comparisons ($p<0.05$) (marked as *), adjusted for search volume.

Results

Psychometric Inventories to Characterize Population.

Performance Failure Appraisal Inventory (PFAI).

Paired t-test revealed a significant difference between group (p=0.0073) with football group showing less fear of failure (M=-1; SD=0.66) compared to the control group (M=-0.11; SD =0.81). (Figure 10)

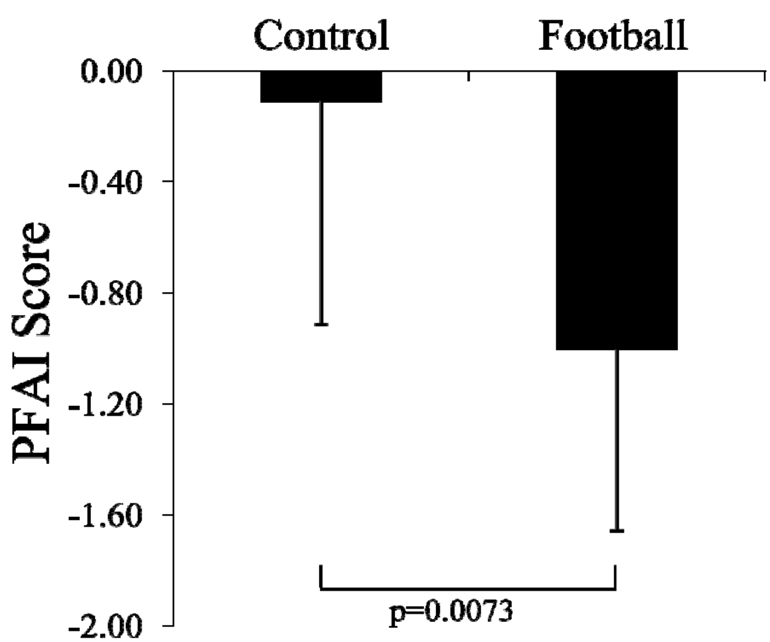


Figure 10. The PFAI revealed that the football group demonstrated significantly less fear of failure compared to the control group.

State-Trait Anxiety Inventory (STAI).

Paired t-test revealed no difference (p=0.9299) in state anxiety between the football group (M=27.5; SD=6.7) and the control group (M=27.3; SD=5.9). Paired t-test also revealed no difference (p=0.2041) between trait anxiety with the football mean of 32.4 (M=32.4; SD=4.2) and the control mean of 35.3 (M=35.3; SD=5.8) (Figure 11).

Dispositional Resiliency Scale (DRS).

The paired t-test revealed no difference (p=0.2851) between the control group (M=34; SD=4) and the football group (M=36; SD=4). The control group was in the 87.7 percentile for total hardiness and the football group was in the 94.2 percentile for total hardiness (Figure 11).

Sports Competition Anxiety Test (SCAT).

The paired t-test revealed no difference (p=0.885) between the groups with the control group mean score of 18 (M=18; SD=4) and the football mean score of 18 (M=18; SD=5) (Figure 11).

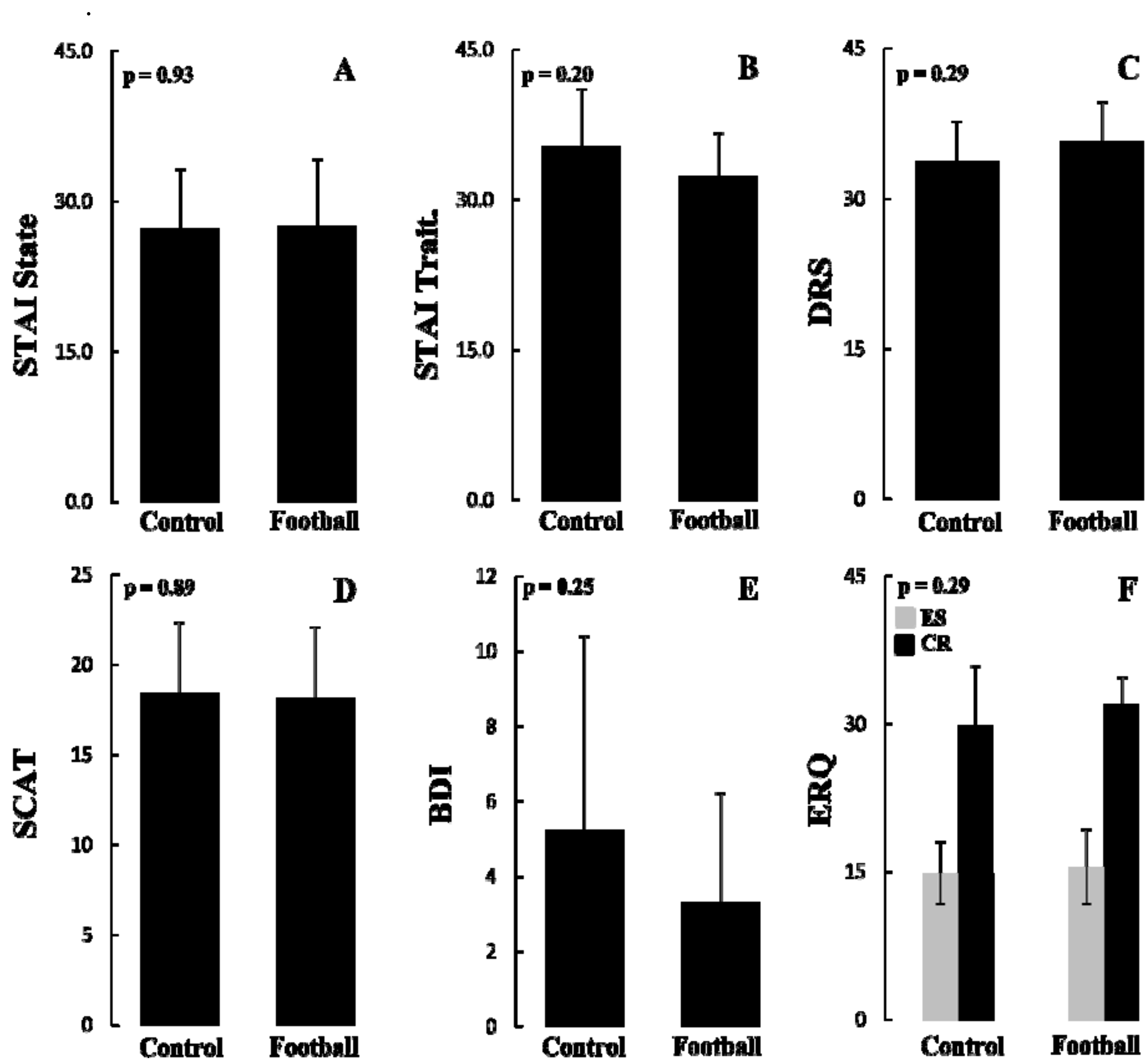


Figure 11. Self report results from psychometric inventories. The control group and football group were statistically equivalent on STAI State (A) STAI Trait (B); DRS (C); SCAT (D); BDI (E); ERQ (F).

Beck Depression Inventory (BDI).

The paired t-test revealed no significant difference between group p=0.2512 with the control group mean of 5 (M=5; SD=5) and the football group mean of 3 (M=3; SD=3) (Figure 11).

Emotion Regulation Questionnaire (ERQ).

Paired t-tests between group revealed no difference (p=0.6793) between expressive suppression (Football: M=14; SD=4. Control M=15; SD=3) and no difference (p=0.2996) between cognitive reappraisal (Football M=32; SD=3. Control M=30; SD=6). Both groups scored higher on cognitive reappraisal compared to expressive suppression (Figure 11).

Physiological Measures of Arousal.

Exploratory results from HR and GSR. Datasets were incomplete due to technical problems with the recording devices (i.e., only 3 control subjects were recorded for HR).

Galvanic skin response.

A two way ANOVA (Group x Condition) revealed no significant difference between group or within condition (Condition main effect p=0.089; Group x Condition interaction p=0.31) (Figure 12).

Heart rate.

A two way ANOVA (Group x Condition) revealed no significant difference between group or within condition (Condition main effect p=0.544; Group x Condition interaction p=0.273) (Figure 12).

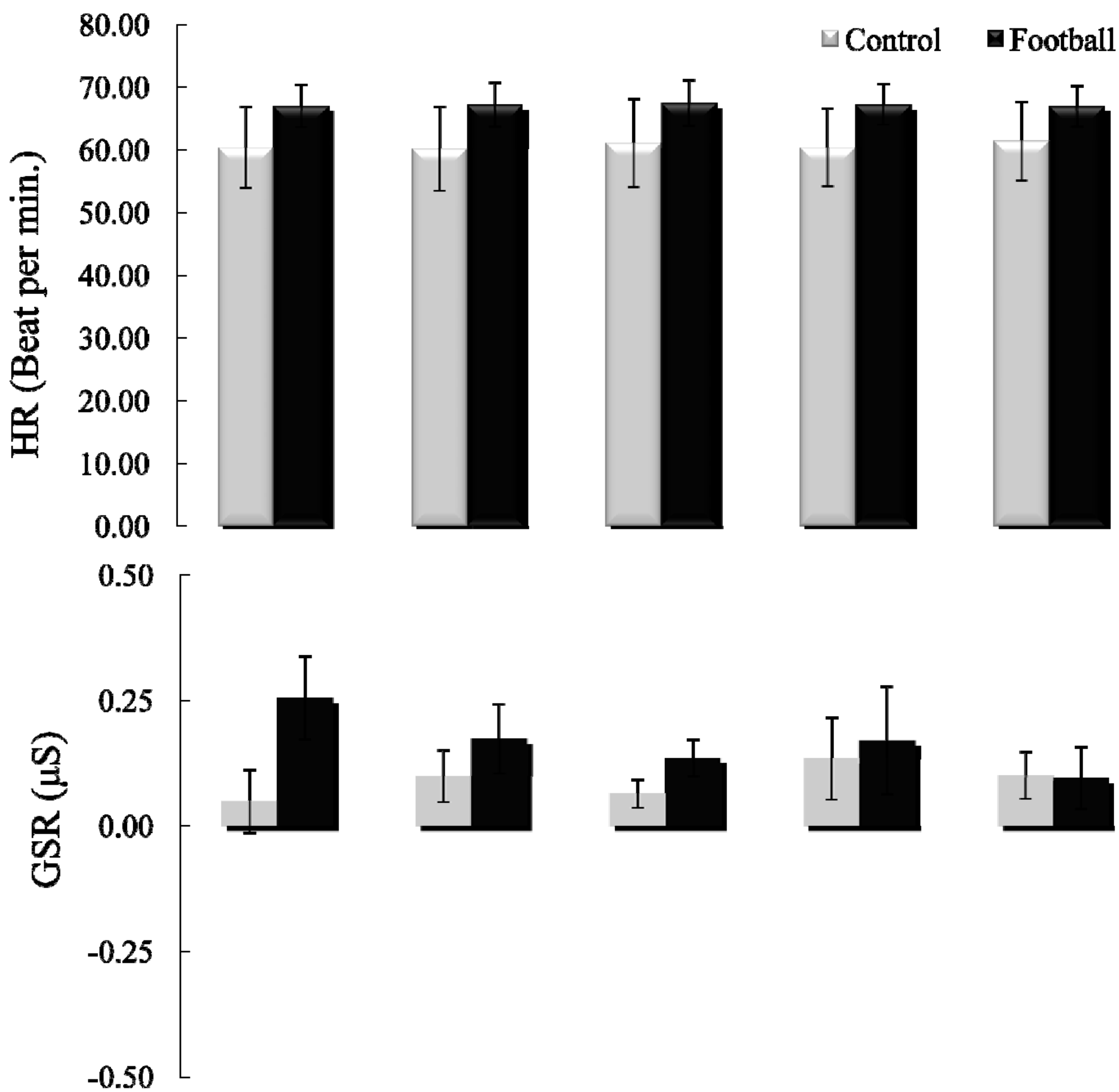


Figure 12. Exploratory results from HR and GSR. Datasets were incomplete due to technical problems with the recording devices (i.e., only 3 control subjects were recorded for HR). Results reveal no significant differences 1) Condition Main Effect: HR: p=0.544; GSR: p=0.089. 2) Group x Condition: HR: p=0.273; GSR: p=0.31.

Behavioral Measures- Affective Rating.

Separate 1 way ANOVAs revealed significant main effects for Condition for each group. The control group ($p<0.001$) Tukey's HSD post-hoc analysis revealed significant differences between all conditions. This indicates that during cued cognitive reappraisal of SS images (M=1.89; SE=0.19) these affective effects were perceived as significantly less negative than during the nature response to SS image (M=2.72; SE=0.25). In addition the cognitive reappraisal of IAPS images (M=1.60; SE=0.17) were perceived less negative compared to the nature response to IAPS images (M= 3.2; SE=0.23). Lastly the neutral images were rated significantly less negative (M=1.42; SE=0.13) compared to the negative IAPS and SS images. The football group ($p=0.001$) Tukey's HSD post-hoc analysis revealed that the passive viewing of negative SS images (M=2.46; SE=0.24) was significantly more negative than viewing neutral images (M=1.28; SE=0.12). In addition the cognitive reappraisal of IAPS images (M=1.65; SE=0.16) was significantly less negative than the passive viewing of IAPS (M=2.69; SE=0.22) images but more negative than viewing the neutral images (M=1.28; SE=0.12). The cognitive reappraisal of SS images (M=1.97; SE=0.19) was rated statistically equal to the natural response of viewing SS negative images (M=2.46; SE=0.24) (Figure 13).

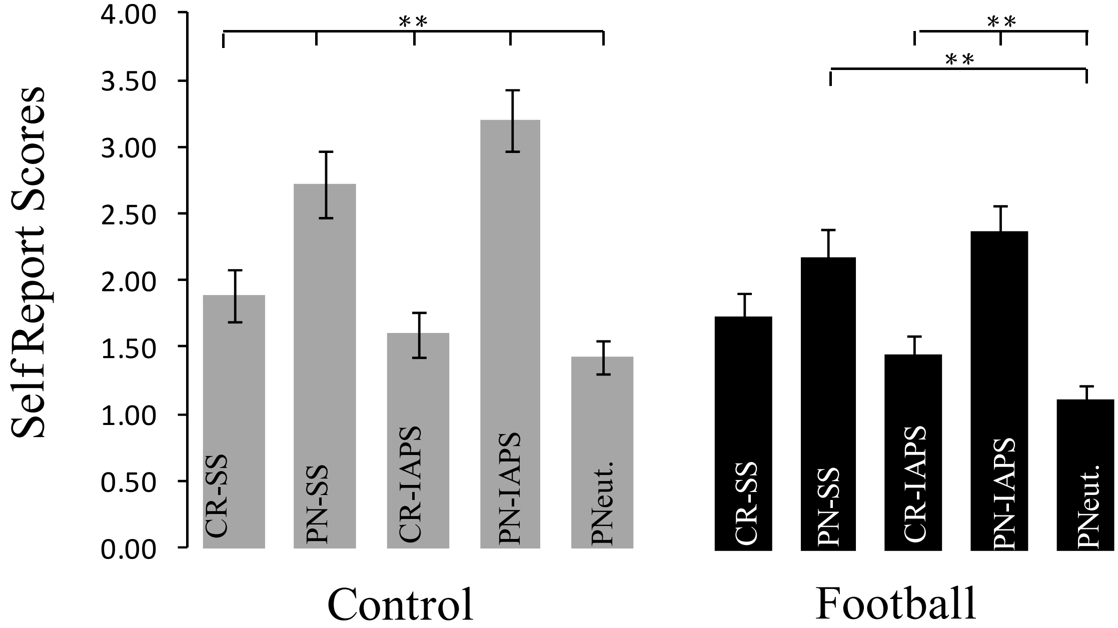


Figure 13. Self report scores from Affective Ratings of "How Negative Do You Feel?" (1=not at all, 3 moderately, 5 extremely) from separate one-way ANOVAs. The control group (left panel) rating of each condition was significantly different. The football group (right panel) rated the cognitive reappraisal of SS images and the passive response to SS images statistically equal, whereas as the generalized images (IAPS) were rated differently. CR-SS: Cognitive Reappraisal of SS Images; PN-SS: Passive (viewing of) Negative of SS Images; CR-IAPS: Cognitive Reappraisal of IAPS Images; PN-IAPS: Passive (viewing of) Negative of IAPS Images; PNEut: Passive (viewing of) Neutral of IAPS Images.

Functional Magnetic Resonance Imaging Results: BOLD Reponses.

The first step of the analysis revealed multiple significant regions in the comparisons of the different conditions relative to the neutral baseline. Multiple comparison corrections of the whole brain analysis were done using Family Wise Error (FWE) thresholded at $p<0.05$ (marked as **) and False Detection Rate (FDR) corrected at $p<0.05$ (marked as *).

Comparative (Football vs. Control) descriptive pattern of BOLD response during passive viewing of negative Sport-Specific images.

Visual inspection of the results during the natural response of the football group and control group to SS negative images revealed less activation in the prefrontal cortex in the elite athlete. Interestingly the efficiency of the football players is not only manifested as reduced activation (relative to the control group) but also different spatial patterns: left IFG (versus bilateral IFG in control), lateral OFC (versus medial OFC in control). Greater efficiency of response was evident in the premotor cortex and temporal regions but was less apparent in the parietal lobe where both groups appeared to show shared and distinct bilateral activation. The occipital areas appeared almost completely overlapped with the football group showing greater activation than the control group in specific regions (Figure 14, Table 2).

Football.

The results indicate that during passive viewing of SS images, the football group showed significant activation in the left DMPFC (BA 8), left insula (BA 13), right lingual gyrus (BA 18), left DLPFC (BA 9), bilateral parahippocampal gyrus (BA 27), left IFG (BA 47), bilateral premotor cortex (BA 6), bilateral SPL/precuneous (BA 7), left postcentral gyrus (BA 2), and left thalamus. In addition, the bilateral ITG (BA 20), the right STG (BA 38), the right lateral OFC (BA11), the left putamen and the bilateral VMPFC (BA 10) were active with a FDR $p<0.05$ threshold (Figure 14, Table 2).

Control.

During the passive viewing of SS images, the control group showed significant activation in the bilateral DLPFC (BA9/46), right IFG (BA 47), left insula (BA 13), right lingual gyrus (BA 18), bilateral parahippocampal gyrus (BA 27), bilateral premotor cortex (BA 6), bilateral SPL (BA 7), left precentral gyrus (BA 2), and left and right lentiform nucleus. In addition the FDR ($p<0.05$) correction also revealed bilateral VMPFC (BA10), left medial OFC (BA11), bilateral STG (BA 38) and left ITG (BA 20) (Figure 14, Table 2).

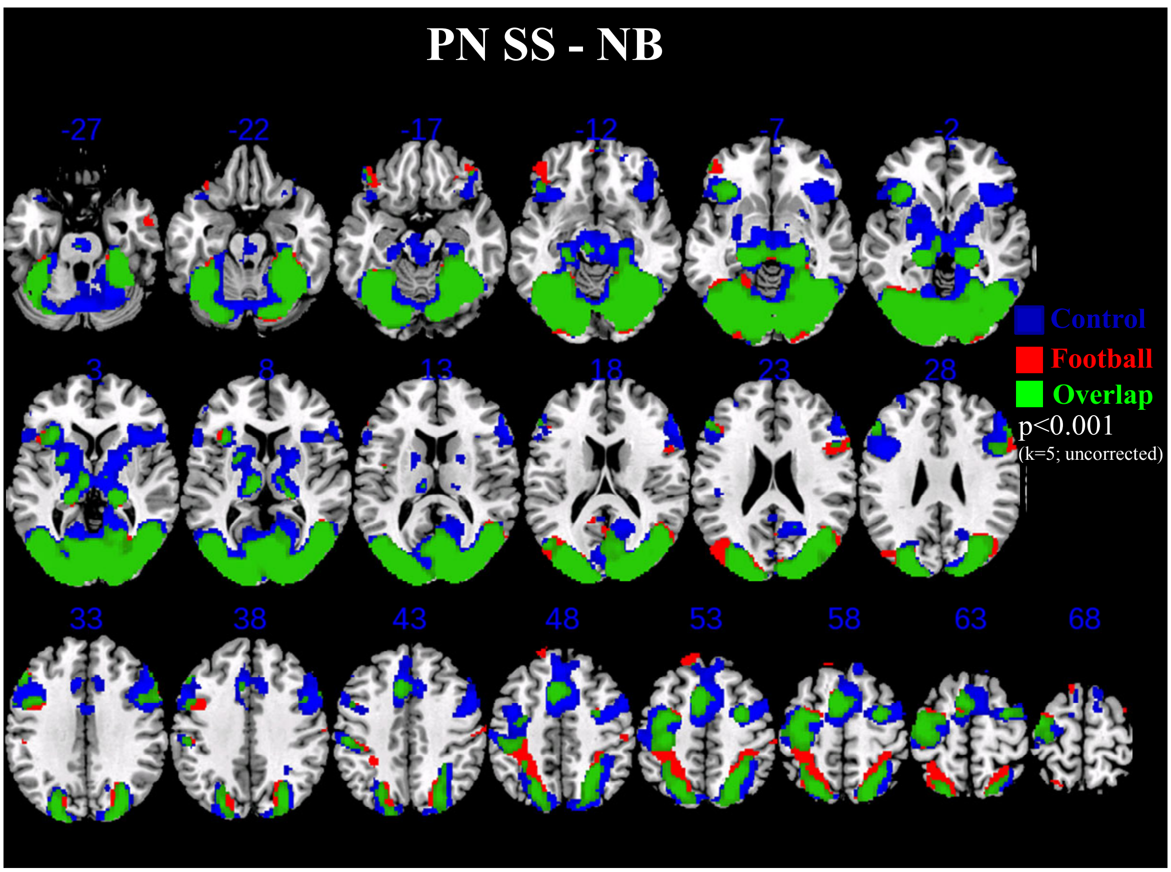


Figure 14. Whole brain axial slice results (inferior-superior) for the passive response to SS negative images (Passive Negative SS (PNSS) – Neutral Baseline (NB)). The red indicates the unique activation for the football group, the blue indicates the unique activation of the control group, and the green indicates regions where both groups showed activation (overlap).

Group	Contrast Conditions	Region	BA	Left			Right		
				Volume in Voxels	MNI coordinates x, y, z	t values	Volume in Voxels	MNI coordinates x, y, z	t values
FOOTBALL	PNSS - NB	DLPFC	9	4	-38 4 36	5.07**			
		DMPFC	8	16	-16 42 54	5.59**			
		VMPFC	10	166	-2 60 -10	3.62*	18	8 68 12	2.66*
		IFG	47	1	-38 22 -2	4.88**			
		LOFC	11				210	44 46 -16	4.65*
		INSULA	13	13	-32 24 -2	5.09**			
		Precentral Gyrus	4	12	-38 -16 60	5.05**			
		Premotor Cortex	6	194	-6 4 58	7.63**	29	30 -6 56	5.71**
		ITG	20	71	-34 -2 -42	3.43*	10	36 -4 -42	2.79*
		STG	38				5	36 6 -44	2.55*
		Postcentral Gyrus	2	1	-50 -26 42	4.91**			
		SPL/precuneous	7	114	-18 -66 52	6.22**	192	26 -54 52	5.85**
		Lingual Gyrus	18				15607	18 -82 -14	16.2**
		Parahippocampal Gyrus	27	199	-20 -30 -2	10.04**	259	20 -32 -2	9.61**
		Putamen	--	376	-26 2 4	4.37*			
		Thalamus	--	11	-8 -20 6	5.07**			
CONTROL	PNSS -NB	DLPFC	46	33	-52 28 28	5.76**	127	58 30 18	6.65**
		DLPFC	9	110	-44 12 32	5.96**	169	48 6 34	6.1**
		VMPFC	10	3	-4 64 30	2.19*	633	4 60 -8	4.14*
		IFG	47				154	40 22 -8	5.49**
		MOFC	11	26	-2 40 -24	3.66*			
		INSULA	13	186	-30 24 2	6.22**			
		Premotor	6	780	-4 6 54	9.38**	221	30 -6 56	6.54**
		STG	38	5	-46 12 -42	2.15*	47	40 16 -38	3.87*
		ITG	20	7	-36 -6 -38	2.24*			
		Postcentral Gyrus	2	20	-52 -26 42	5.5**			
		SPL/precuneous	7	183	-22 -66 56	6.01**	12	14 -82 52	5.29**
		MOG	18				19296	16 -94 20	16.94**
		Lentiform Nucleus	--	14	-16 6 2	5.21**	13	16 -2 0	5.11**
		Parahippocampal Gyrus	27	967	-20 -30 -2	12.76**	832	20 -30 -2	10.96**

Table 2. Whole brain results for the passive response to SS negative images (Passive Negative SS (PNSS) – Neutral Baseline (NB)). Top panel: football group. Bottom panel: control group. Multiple comparison corrections of the whole brain analysis were done using Family Wise Error (FWE) thresholded at $p<0.05$ (marked as **) and False Detection Rate (FDR) corrected at $p<0.05$ (marked as *).

Comparative (Football vs. Control) descriptive pattern of BOLD response during passive viewing of negative IAPS images.

This economy of processing extends to the natural response of the football group to generalized negative images (IAPS). Visual examination of the prefrontal cortex revealed less activation extending from the inferior frontal gyrus to the dorsal prefrontal cortex (both lateral and medial regions) compared to the control group. More posterior patterns of economy were evident to a lesser extent in the premotor cortex, temporal lobe and occipital regions but the magnitude of efficiency was less apparent than in the prefrontal cortex. The parietal cortex revealed more unique patterns for each group, with the football group showing more bilateral activation while the control group appearing primarily left lateralized (Figure 15, Table 3).

Football.

The results revealed that during the natural response of the football group to generalized negative images (IAPS) significant signal change was observed in the bilateral superior parietal lobule (BA 7), right lingual gyrus (BA 18), bilateral parahippocampal gyrus (BA 27), bilateral premotor cortex (BA 6), right cerebellum and right MTG. In addition the left DLPFC (BA 9), left IFG (BA 47), left DMPFC (BA 8), left VLPFC (BA10), bilateral lateral OFC (BA11) and STG (BA 38) were active during the FDR multiple comparison correction ($p<0.05$) (Figure 15, Table 3).

Control.

In the control group significant activation was observed in the bilateral DLPFC (BA 46/9), left DMPFC (BA 8), left IFG (BA 47), right MOG (BA 18), right OFC (BA 11), right ACC (BA 24), bilateral premotor cortex (BA 6), left SPL (BA 7) right lentiform nucleaus and right postcentral gyrus (BA 2). In addition the left VLPFC (BA 10), the left medial OFC (BA 11), the right STG (BA 22), left ITG (BA 20), and right MTG (BA 21) were active under a FDR multiple comparison correction ($p <0.05$) (Figure 15, Table 3).

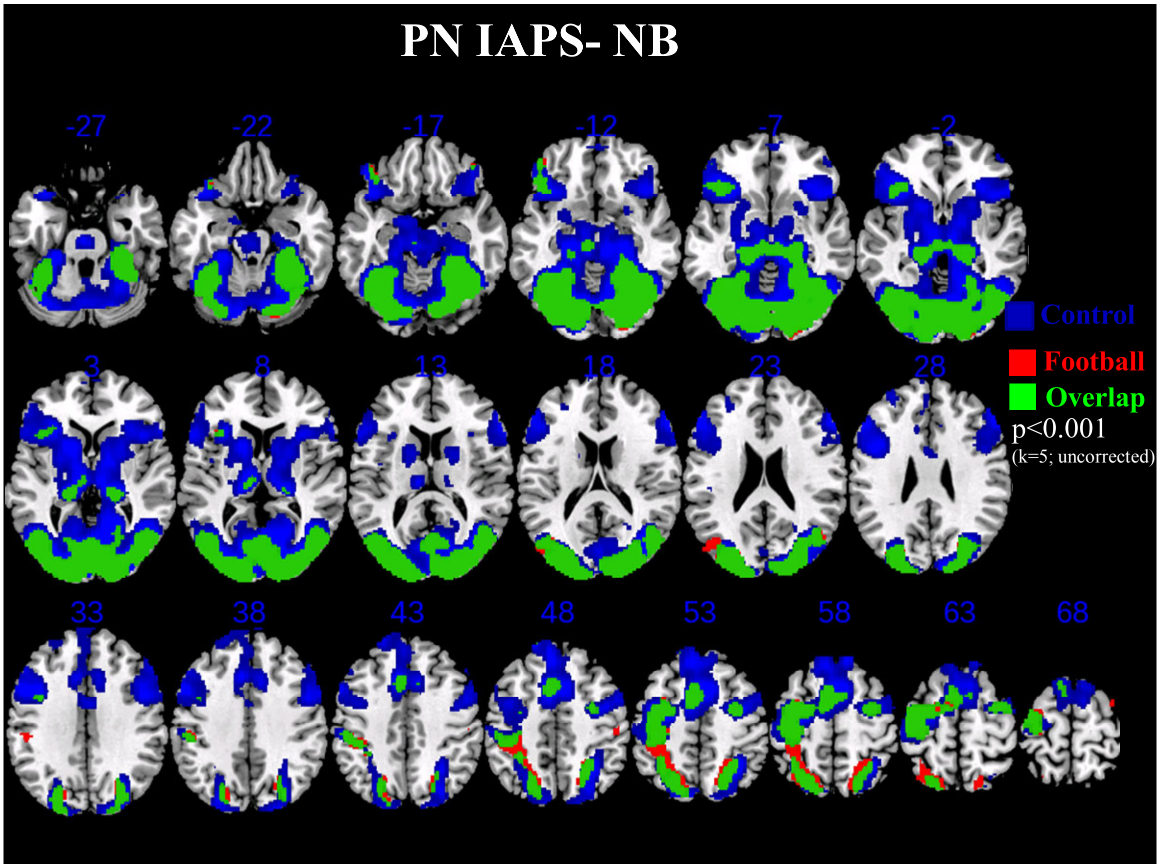


Figure 15. Whole brain axial slice results (inferior-superior) for the passive response to International Affective Picture System negative images (Passive Negative IAPS (PN IAPS) – Neutral Baseline (NB)). The red indicates the unique activation for the football group, the blue indicates the unique activation of the control group, and the green indicates regions where both groups showed activation (overlap).

Group	Contrast Conditions	Region	BA	Left			Right		
				Volume in Voxels	MNI coordinates x, y, z	t values	Volume in Voxels	MNI coordinates x, y, z	t values
FOOTBALL	PN IAPS - NB	DLPFC	9	185	-38 4 36	3.61*			
		DMPFC	8	75	-16 52 46	3.58*			
		VLPFC	10	41	-20 60 -4	3.18*			
		IFG	47	1527	-48 26 -10	4.58*			
		LOFC	11	42	-46 44 -10	4.08*	46	42 42 -18	3.49*
		Premotor Cortex	6	74	-6 4 58	6.89**	8	30 -6 56	5.12**
		MTG	19				40	44 -62 14	5.44**
		STG	38	116	-32 4 -42	3.13*			
		SPL	7	35	-18 -68 54	5.41**	1	18 -66 56	4.9**
		Lingual Gyrus	18				8481	18 -82 -14	11.94**
		Parahippocampal Gyrus	27	131	-20 -30 -2	8.96**	111	20 -30 -4	6.96**
		Cerebellum	--				1	36 -72 -22	5.16**
CONTROL	PN IAPS - NB	DLPFC	46	234	-54 28 24	6.78**	530	58 30 18	6.76**
		DLPFC	9	331	-44 10 32	7.09**	164	48 6 34	6.04**
		DLPFC	8	10	-18 48 48	5.16**			
		DMPFC	8	237	-4 36 50	6.4**			
		VLPFC	10	31	-22 54 -12	3.97*			
		IFG	47	924	-42 28 -6	7.87**			
		LOFC	11				3	40 38 -20	5.18**
		MOFC	11	46	-4 40 -24	3.79*			
		ACC	24				2	6 0 32	4.96**
		Premotor	6	961	-4 6 56	8.87**	186	30 -6 56	6.66**
		ITG	20	19	-36 -6 -36	2.44*			
		MTG	21				3	50 -14 -18	2.21*
		STG	22				15	46 -36 4	2.63*
		Postcentral Gyrus	2	12	-52 -26 42	5.23**			
		SPL	7	119	-22 -66 54	5.77**			
		MOG	18				22511	16 -94 20	15.4**
		Lentiform Nucleus	--				27	24 6 4	5.17**

Table 3. Whole brain results for the passive response to International Affective Picture System negative images (Passive Negative IAPS (PNIAPS) – Neutral Baseline (NB)). Top panel: football group. Bottom panel: control group. Multiple comparison corrections of the whole brain analysis were

done using Family Wise Error (FWE) thresholded at $p<0.05$ (marked as **) and False Detection Rate (FDR) corrected at $p<0.05$ (marked as *).

Comparative (Football vs. Control) descriptive pattern of BOLD response during the cued cognitive reappraisal of negative Sport-Specific images.

Examination of the prefrontal cortex during the cued emotion regulation condition of SS negative events revealed great efficiency in the football group compared to the control. This anterior economy can be seen not only in terms of reduced activation (i.e., DMPFC) but also in terms of different spatial patterns such as the left IFG (compared to bilateral IFG in the control group) and left DLPFC (compared to bilateral DLPFC in the control group). Visual inspection of posterior regions suggest more similar processing in occipital and temporal regions with shared and distinct patterns evident in the posterior parietal regions (Figure 16, Table 4).

Football.

The cued cognitive reappraisal of SS images revealed significant activations in the left DLPFC (BA 9), right lingual gyrus (BA18), bilateral parahippocampal gyrus (BA 27), bilateral premotor cortex (BA 6), and bilateral SPL (BA 7) in the football group. Additionally the FDR correction revealed right lateral OFC (BA 11) and right medial OFC (BA11), left STG (BA 38), left lentiform nucleus, left MTG (BA 21), left cerebellum, left STG (BA 22), left VLPFC (BA 10), left supramarginal gyrus (BA 40), and right postcentral gyrus (BA 3) in the football group (Figure 16, Table 4).

Control.

Activation was observed in the control group in the bilateral DLPFC (BA 46/9), left IFG (BA 47), right cuneus (BA 18), left parahippocampal gyrus, bilateral premotor cortex (BA 6), bilateral SPL (BA7), bilateral lentiform nucleus, bilateral STG (BA 38), right motor cortex (BA 4) and bilateral insula (BA 13) (the right side only survived FDR correction). In addition bilateral medial OFC (BA 11), bilateral VLPFC (BA 10) and right VMPFC (BA 10), left MTG (BA 21), and left posterior cingulate (BA 31) were active during FDR correction ($p<0.05$) in the control group (Figure 16, Table 4).

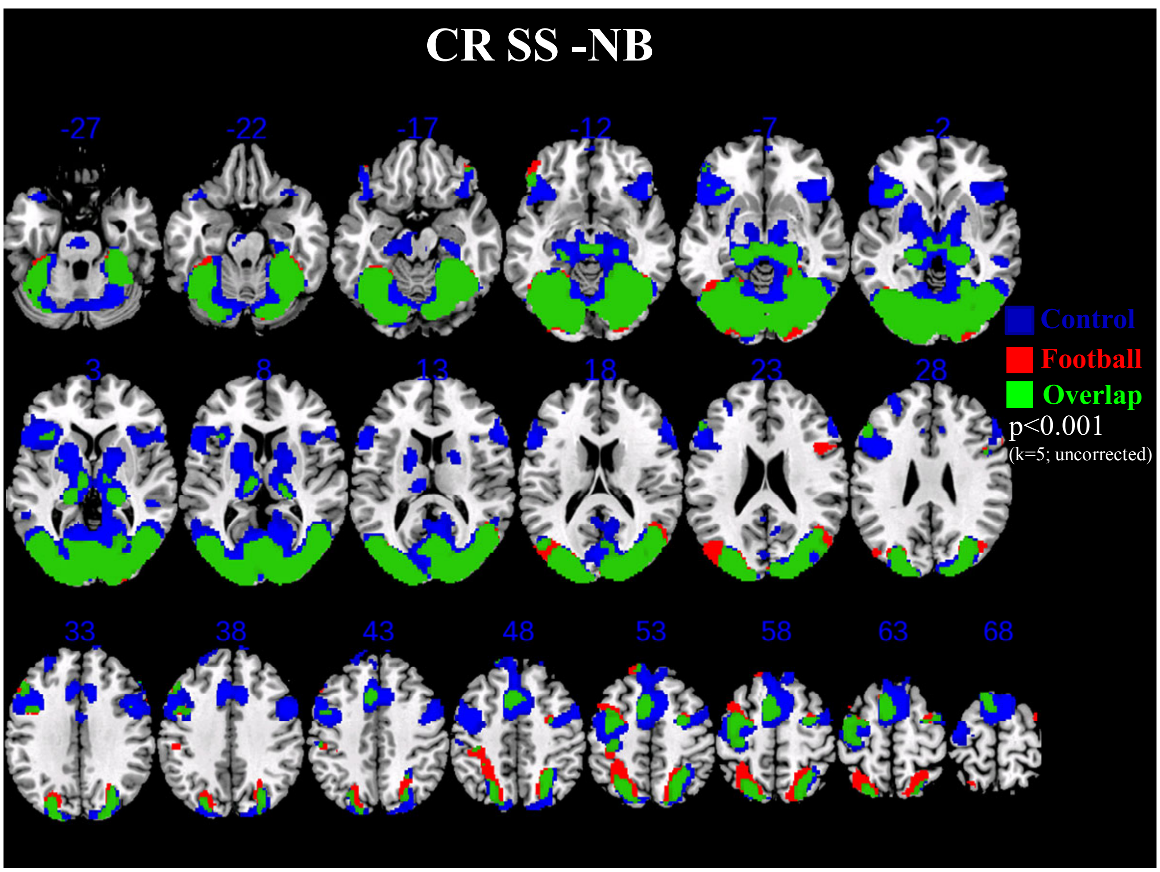


Figure 16. Whole brain axial slice results (inferior-superior) for the cued cognitive reappraisal of SS

negative images (Cognitive Reappraisal SS (CRSS) – Neutral Baseline (NB)). The red indicates the unique activation for the football group, the blue indicates the unique activation of the control group, and the green indicates regions where both groups showed activation (overlap).

Group	Contrast Conditions	Region	BA	Left			Right		
				Volume in Voxels	MNI coordinates x, y, z	t values	Volume in Voxels	MNI coordinates x, y, z	t values
FOOTBALL	CRSS - NB	DLPFC	9	11	-50 26 38	5.66**			
		VLPFC	10	2	-26 54 -12	2.6*			
		LOFC	11				81	44 46 -16	4.02*
		MOFC	11				5	2 60 -12	2.58*
		Premotor Cortex	6	95	-6 6 58	7.13**	11	28 -4 54	5.22**
		MTG	21	35	-50 10 -38	3.07*			
		STG	38	95	-24 18 -26	3.64*			
		STG	22	12	-50 -52 18	2.61*			
		Postcentral Gyrus	3				2	56 -20 38	2.38*
		SPL	7	44	-20 -68 52	5.38**	122	18 -68 56	5.75**
		Supramarginal Gyrus	40	1	-48 -46 30	2.38*			
		Lingual Gyrus	18				12463	18 -82 -14	13.74**
		Lentiform Nucleus	--	172	-28 0 2	3.31*			
		Parahippocampal Gyrus	27	162	-20 -30 -2	9.85**	201	20 -30 -2	9.1**
		Cerebellum	--	5	0 -56 -36	2.72*			
CONTROL	CRSS - NB	DLPFC	46	7	-54 28 26	5.25**	217	58 28 20	6.06**
		DLPFC	9	215	-42 12 32	6.33**	7	50 6 36	4.97**
		VLPFC	10	11	-26 54 -12	3.1*	38	56 2 24	3.26*
		VMPFC	10				9	10 68 10	2.28*
		IFG	47	764	-42 28 -6	7.81**			
		MOFC	11	17	-4 40 -24	2.92*	262	2 60 -10	3.78*
		Insula	13	73	-44 -28 24	2.93*	1	36 18 10	4.95**
		Precentral Gyrus	4	4	-38 -18 62	4.94**			
		Premotor Cortex	6	1356	-4 6 56	10.25**	18	42 -4 46	5.38**
		MTG	21	27	-52 -12 -20	2.64*			
		STG	38	9	-32 18 -28	5.28**	3	48 -36 2	5.06**
		SPL	7	36	-22 -70 60	5.39**	142	30 -54 54	6.35**
		Cuneus	18				17332	14 -94 20	15.58**
		Parahippocampal Gyrus	27	1518	-20 -30 -4	10.45**			
		Posterior Cingulate	31	16	-6 -28 46	2.54*			
		Lentiform Nucleus	--	93	-20 8 2	5.77**	8	16 0 0	4.98**

Table 4. Whole brain results for the cued cognitive reappraisal of SS negative images (Cognitive Reappraisal SS (CRSS) – Neutral Baseline (NB)). Top panel: football group. Bottom panel: control group. Multiple comparison corrections of the whole brain analysis were done using Family Wise Error (FWE) thresholded at $p<0.05$ (marked as **) and False Detection Rate (FDR) corrected at $p<0.05$ (marked as *).

Comparative (Football vs. Control) descriptive pattern of BOLD response during cued cognitive reappraisal of negative IAPS images.

Visual inspection of the responses of the two groups during cued emotion regulation of generalized negative images revealed a similar pattern both anteriorly and posteriorly. This suggests that when elite athletes are asked to cognitively restructure the meaning of a negative event that is outside their area of experience, they rely on similar cortical networks to that utilized by age matched controls (Figure 17, Table 5).

Football.

Cued cognitive reappraisal of generalized negative images (IAPS) resulted in significant activation of the left DLPFC (BA 46/9), right VLPFC (BA 45), bilateral lateral OFC (BA 11), right lingual gyrus (BA 18), bilateral premotor cortex (BA 6), bilateral parahippocampal gyrus (BA 27), left post central gyrus (BA 2), right SPL (BA 7), and left lentiform nucleus in the football group. In addition the FDR correction revealed bilateral VMPFC (BA 10), bilateral ITG (BA 20), bilateral cerebellum, left MTG (BA11), and the left uncus activation in the football group (Figure 17, Table 5).

Control.

Significant activation in the left DLPFC (BA 9), left DMPFC (BA 8), the right cerebellum, right SPL (BA 7), left amygdala, bilateral IFG (BA 47), right middle occipital gyrus (BA18), and bilateral premotor cortex (BA 6) was observed in the control group during cued reappraisal of IAPS images. In addition bilateral medial OFC (BA 11), left posterior cingulate (BA31), left supramarginal gyrus (BA 40), right STG (BA22) and right ITG (BA 20), and left MTG (BA 21) were active after a FDR correction ($p<0.05$) (Figure 17, Table 5).

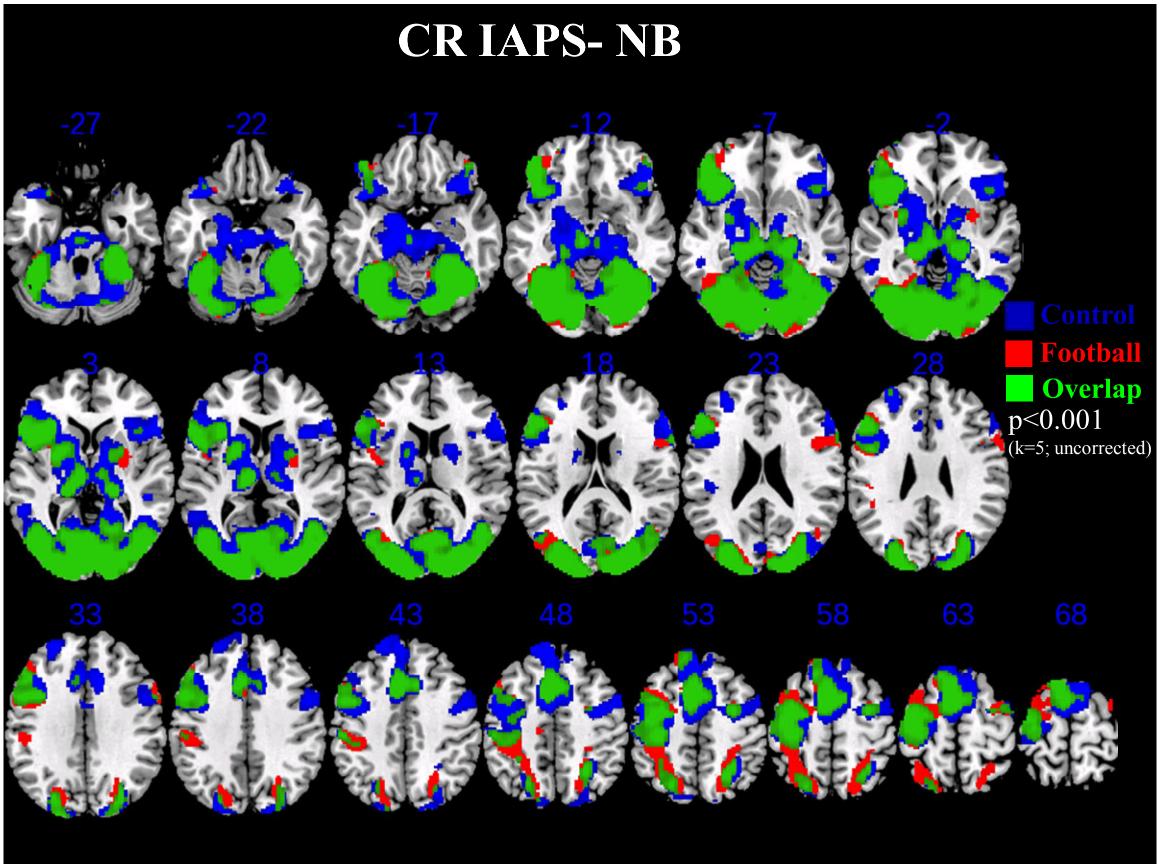


Figure 17. Whole brain axial slice results (inferior-superior) for the cued cognitive reappraisal of International Affective Picture Sysytem negative images (Cognitive Reappraisal International Affective Picture Sysytem (CR IAPS) – Neutral Baseline (NB)). The red indicates the unique activation for the football group, the blue indicates the unique activation of the control group, and the green indicates regions where both groups showed activation (overlap).

Group	Contrast Conditions	Region	BA	Left			Right		
				Volume in Voxels	MNI coordinates x, y, z	t values	Volume in Voxels	MNI coordinates x, y, z	t values
FOOTBALL	CR IAPS - NB	DLPFC	46	245	-54 28 26	6.55**			
		DLPFC	9	62	-36 6 36	5.75**			
		VLPFC	45				2	64 12 20	4.97**
		VMPFC	10	15	-8 66 28	2.83*	36	26 56 -10	3.37*
		LOFC	11	1015	-46 44 -8	6.88**	4	46 44 -16	5.29**
		Premotor Cortex	6	856	-6 6 58	9.59**	12	30 -4 56	5.06**
		ITG	20	35	-34 -6 -38	2.92*	12	36 -4 -42	2.82*
		MTG	22	8	-48 -42 4	2.36*			
		Postcentral Gyrus	2	21	-50 -26 42	5.62**			
		SPL	7				73	20 -66 56	5.46**
		Lingual Gyrus	18				13053	18 -82 -14	13.73**
		Lentiform Nucleus	--	44	-24 2 4	5.38**			
		Parahippocampal Gyrus	27	290	-20 -30 -2	8.96**	138	20 -30 -2	7.74**
		Uncus	--	2	-22 0 -30	2.24*			
		Cerebellum	--	5	-18 -24 -28	2.37*	10	2 -56 -36	2.85*
CONTROL	CR IAPS - NB	DLPFC	9	64	-30 46 26	5.96**			
		DMPFC	8	11	-18 48 44	5.07**			
		IFG	47	3739	-42 30 -6	10.3**	547	48 24 -12	6.77**
		MOFC	11	12	-4 40 -24	2.83*	97	4 60 -10	3.37*
		Premotor	6	2252	-4 6 56	11.43**	28	30 -6 56	5.6**
		ITG	20				1	32 -2 -40	2.1*
		MTG	21	7	-52 -12 -20	2.29*			
		STG	22				276	48 -36 2	4.84*
		SPL	7				104	30 -54 54	6.22**
		Supramarginal gyrus	40	29	-50 -46 28	2.45*			
		MOG	18				18923	16 -94 20	14.7**
		Posterior Cingulate	31		-8 -28 46	2.82*			
		Amygdala	--	32	-20 -4 -18	5.77**			
		Cerebellum	--				3	4 -72 -30	5.02**

Table 5. Whole brain results for the cued cognitive reappraisal to International Affective Picture System negative images (Cognitive Reappraisal IAPS (CRIAPS) – Neutral Baseline (NB)). Top panel: football group. Bottom panel: control group. Multiple comparison corrections of the whole brain analysis were done using Family Wise Error (FWE) thresholded at p<0.05 (marked as **) and False Detection Rate (FDR) corrected at p<0.05 (marked as *).

Direct Comparisons between Groups.

The second step of the analysis determined if the football group demonstrated relative efficiency compared to the control group. Whole brain direct comparisons between the groups within each condition revealed significantly greater signal change in the control compared to the football group. Whole brain analysis was corrected for multiple comparisons using FDR p<0.05 (marked as *) and for exploratory purposes, uncorrected regions (p<0.001, k=5) were also be reported (no star is indicated). In addition a priori region of interest analysis of the prefrontal cortex (BA 8, 9, 10, 11, 45, 46, 47, taken from the Wake Forest Pick Atlas indication of Brodmann Areas) further support the efficiency hypothesis with elite athletes. The ROI analysis were

FDR corrected for multiple comparisons ($p < 0.05$) (marked as *), adjusted for search volume.

Passive negative SS condition.

Whole brain CONT-FB.

The whole brain direct comparisons between the control group minus the football group revealed that for passive viewing of SS negative images, the control group demonstrates greater activation in the right MOG (BA 18), right premotor cortex (BA 6), bilateral cerebellum, bilateral DLPFC (BA9/8), right VLPFC (BA 10), bilateral VMPFC (BA 10), bilateral lingual gyrus, left ACC (BA 24), right insula (BA13), right MTG (BA 21) and right thalamus ($p<0.001$; $k=5$, uncorrected) (Figure 18, Table 6).

ROI CONT-FB.

The ROI analysis revealed bilateral DLPFC (BA 9), bilateral DMPFC (BA 9/8), right VLPFC (BA 10), bilateral VMPFC (BA 10), and right IFG (BA 47) (FDR $p<0.05$ corrected) was significantly more active for the control group compared to the football group (Figure 18, Table 6).

Whole brain FB-CONT.

Whole brain analysis comparing the football group to the control group revealed activation in the right MOG (BA 18) and left MTG (BA 39) at an uncorrected threshold of $p<0.001$ $k=5$ (Figure 18, Table 6).

ROI FB-CONT.

The ROI analysis revealed no significantly greater BOLD signal in the football group compared the control group in the prefrontal cortex (Figure 18, Table 6).

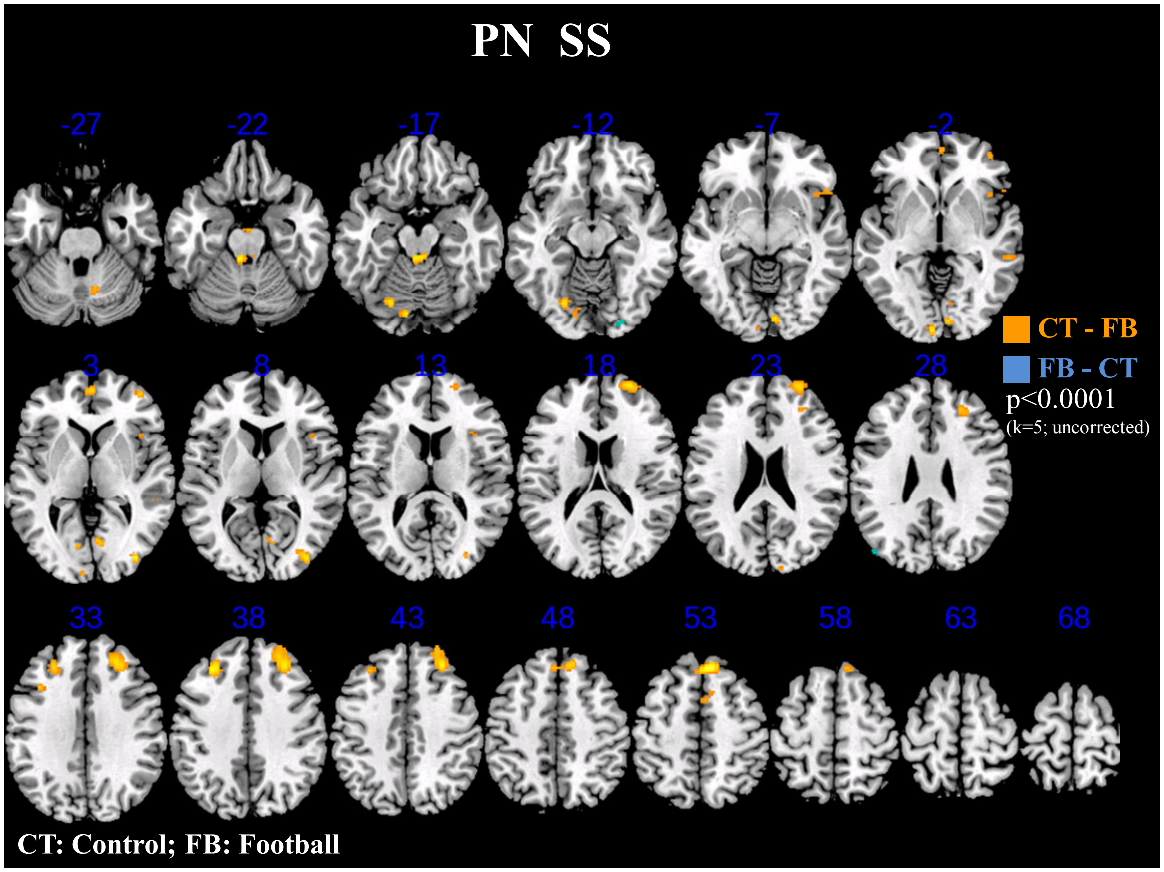


Figure 18. Whole brain axial slice results (inferior-superior) from direct comparisons between groups during the passive response to SS images condition (Passive Negative SS (PNSS)). The orange indicates contrast results from Control – Football (CT-FB). The blue indicates contrasts results from Football- Control (FB-CT).

Contrast Conditions	Region	BA	Left			Right		
			Volume in Voxels	MNI coordinates x, y, z	t values	Volume in Voxels	MNI coordinates x, y, z	t values
PNSS [CONT - FB]	DLPFC	9	29	-28 32 38	4.15*	50	30 36 40	4.19*
	DLPFC	8				14	30 36 44	3.76*
	DMPFC	9	2	-2 44 22	3.25*			
	DMPFC	8	18	-2 34 50	3.67*	52	8 36 52	4.4*
	VLPFC	10				71	28 58 20	4.11*
	VMPFC	10	19	-2 54 4	3.69*	13	2 56 0	3.7*
	IFG	47				14	54 20 -4	3.53*
	DLPFC	9	131	-28 34 38	4.2			
	DLPFC	8				439	30 36 40	4.19
	VLPFC	10				143	28 58 20	4.11
	VMPFC	10	59	0 54 2	3.8			
	ACC	24	11	-2 54 2	3.63			
	Premotor	6				212	8 34 54	4.57
	Insula	13				83	36 20 12	3.58
	MTG	21				25	58 -36 -2	3.46
	Lingual Gyrus	17	43	-6 -96 -2	4.01	61	8 -70 4	3.89
	MOG	18				102	38 -84 4	4.61
	Thalamus	--				5	22 -26 6	3.33
	Cerebellum	--	152	-22 -74 -16	4.55	91	12 -62 -30	4.09
PNSS [FB - CONT]	IOG	18				131	24 -90 -12	4.1
	MTG	39	237	-46 -80 28	3.61			

Table 6. Results from direct comparisons between groups during the passive response to SS images condition (Passive Negative SS (PNSS)). Top panel indicates contrast results from Control – Football (CONT-FB). Bottom panel indicates contrasts results from Football- Control (FB-CONT). Whole brain analysis were corrected for multiple comparisons using FDR $p<0.05$ (marked as *) and for exploratory purposes, uncorrected regions ($p<0.001$, k=5) will also be reported (no star is indicated). Red text signifies results from region of interest analysis (ROI) derived from Wake Forest anatomical

mask. The ROI analysis were FDR corrected for multiple comparisons (p <0.05) (marked as *), adjusted for search volume.

Passive negative IAPS condition.

Whole brain CONT-FB.

The whole brain analysis revealed that the control group demonstrated significantly greater activation in the right premotor cortex (BA 6), bilateral MOG (BA 18), bilateral cerebellum, bilateral DLPFC (BA 9/46), bilateral lingual gyrus (BA 18/17), bilateral STG (BA22/38), bilateral claustrum, right caudate, bilateral ACC, the right insula (uncorrected p<0.001; k=5), left and left parahippocampal gyrus (all regions survive FDR p<0.05 correction unless noted otherwise) (Figure 19, Table 7).

ROI CONT-FB.

The ROI analysis revealed significant activation in the bilateral DLPFC (BA 46/9), bilateral DMPFC (BA 8/9), right VLPFC (BA 10/45), bilateral VMPFC (BA 10), medial OFC (BA 11), and right IFG (BA 47) in the control group compared to the football group (Figure 19, Table 7).

Whole brain FB-CONT.

Whole brain analysis comparing the football group to the control group revealed activation in the left SOG (BA 19) at an uncorrected threshold of p<0.001; k=5 (Figure 19, Table 7).

ROI FB-CONT.

The ROI analysis revealed no significantly greater BOLD signal in the football group compared the control group in the prefrontal cortex (Figure 19, Table 7).

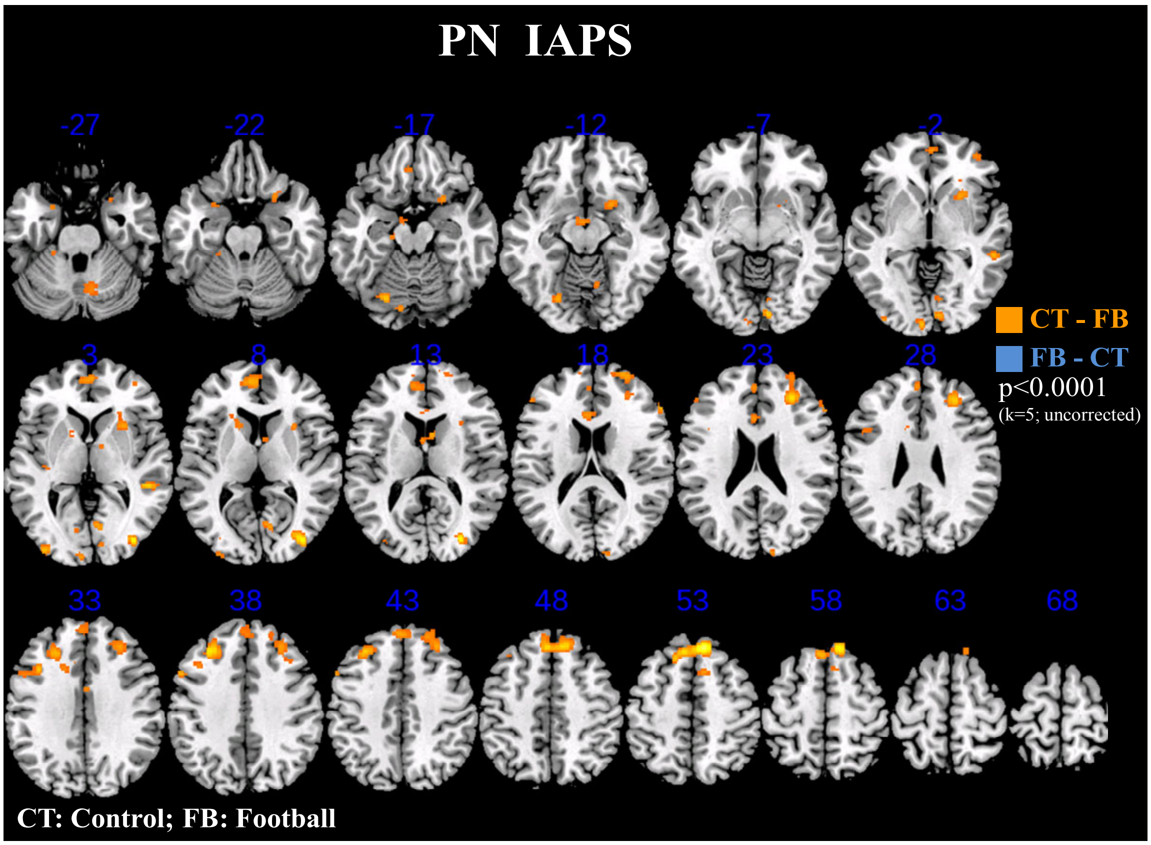


Figure 19. Whole brain axial slice results (inferior-superior) from direct comparisons between groups during the passive response to International Affective Picture System negative images condition (Passive Negative IAPS (PN IAPS)). The orange indicates contrast results from Control – Football (CT-FB). The blue indicates contrasts results from Football- Control (FB-CT).

Contrast Conditions	Region	BA	Left			Right		
			Volume in Voxels	MNI coordinates x, y, z	t values	Volume in Voxels	MNI coordinates x, y, z	t values
PN IAPS [CONT - FB]	DLPFC	46	6	-50 38 20	3.5*	16	58 30 18	3.76*
	DLPFC	9	34	-30 32 38	4.38*	51	30 36 30	3.91*
	DLPFC	8	3	-54 12 42	3.6*	25	30 38 44	3.43*
	DMPFC	9	69	-2 48 24	3.67*	11	4 46 38	3.33*
	DMPFC	8	101	-4 36 50	4.34*	100	8 36 52	4.79*
	VLPFC	10				46	30 56 20	3.79*
	VLPFC	45				4	58 28 20	3.63*
	VMPFC	10	86	-4 54 6	3.92*	23	2 56 4	3.72*
	IFG	47				23	24 12 -18	3.61*
	MOFC	11	10	-4 36 -18	3.43*			
	DLPFC	9	245	-30 32 38	4.38*			
	DLPFC	46	13	-50 38 20	3.5*	35	58 30 18	3.76*
	ACC	--	10	-2 54 2	3.63*	8	2 56 2	3.67*
	ACC	32/24	73	-16 16 32	3.76*	10	2 0 34	3.49*
	Premotor	6				1711	10 36 54	5.07*
	Insula	--				21	30 18 -2	3.52
	STG	22/38	17	-24 6 -24	3.7*	73	48 -36 2	4.15*
	Lingual Gyrus	18/17	49	-6 -96 -2	3.92*	62	8 -86 -6	4.23*
	MOG	18	58	-36 -92 2	3.97*	200	38 -84 4	4.8*
	Caudate	--				83	6 8 14	3.68*
	Claustrum	--	74	-22 22 6	3.55*	230	28 16 0	3.85*
	Parahippocampal Gyrus	28	10	-18 -20 -18	3.4*			
	Cerebellum	--	91	-22 -74 -16	4.44*	17	10 -62 -10	3.49*
PN IAPS [FB - CONT]	SOG	19	298	-44 -80 32	3.07			

Table 7. Results from direct comparisons between groups during the passive response to International Affective Picture System negative images condition (Passive Negative IAPS (PNIAPS)). Top panel indicates contrast results from Control – Football (CONT-FB). Bottom panel indicates contrasts results from Football- Control (FB-CONT). Whole brain analysis were corrected for multiple comparisons using FDR p<0.05 (marked as *) and for exploratory purposes, uncorrected regions (p<0.001, k=5) will also be reported (no star is indicated). Red text signifies results from region of interest analysis (ROI) derived from Wake Forest anatomical mask. The ROI analysis were FDR corrected for multiple comparisons (p<0.05) (marked as *), adjusted for search volume.

Cognitive reappraisal SS conditions.

Whole brain CONT-FB.

The whole brain analysis of cued cognitive reappraisal of SS negative images revealed greater activation in the right MTG (BA 22) (FDR corrected), right premotor cortex (BA 6), left cerebellum, right MOG (BA 19), right insula (BA 13), left lingual gyrus (BA 18), and right lentiform nucleus (p <0.001 uncorrected, k =5) in the control group compared to the football group (Figure 20, Table 8).

ROI CONT-FB.

The ROI analysis revealed significant activation in the bilateral DLPFC (BA 9), bilateral DMPFC (BA 9/8), bilateral VLPFC (BA 10/45) and bilateral IFG (BA 47) in the control group compared to the football group (FDR corrected $p<0.05$) (Figure 20, Table 8).

Whole brain FB-CONT.

Whole brain analysis comparing the football group to the control group revealed activation in the right IOG (BA 18) and left MTG (BA 39) at an uncorrected threshold of $p<0.001$ $k=5$ (Figure 20, Table 8).

ROI FB-CONT.

The ROI analysis revealed no significantly greater BOLD signal in the football group compared the control group in the prefrontal cortex (Figure 20, Table 8).

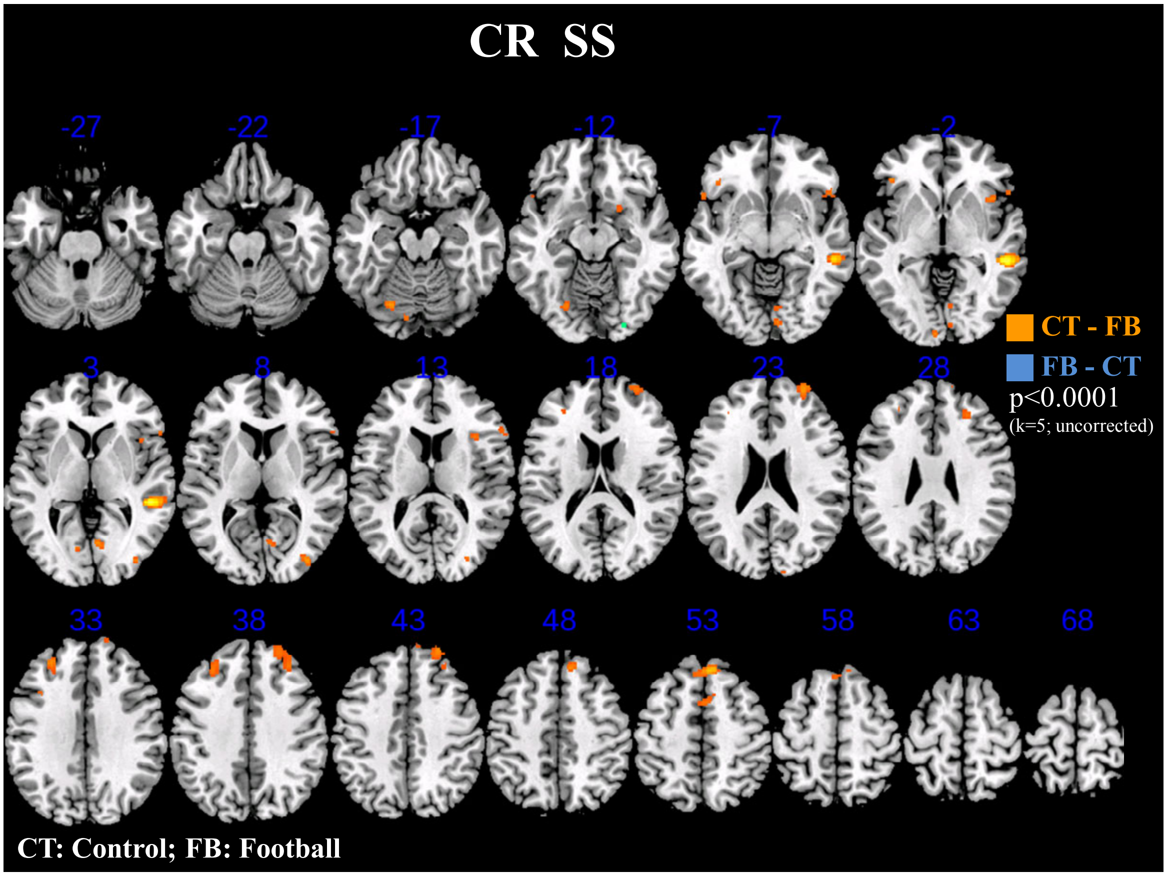


Figure 20. Whole brain axial slice results (inferior-superior) from direct comparisons between groups during the cued cognitive reappraisal of SS negative images condition (Cognitive Reappraisal SS (CR SS)). The orange indicates contrast results from Control – Football (CT-FB). The blue indicates contrasts results from Football- Control (FB-CT).

Contrast Conditions	Region	BA	Left			Right		
			Volume in Voxels	MNI coordinates x, y, z	t values	Volume in Voxels	MNI coordinates x, y, z	t values
CRSS [CONT - FB]	DLPFC	9	4	-30 42 32	3.59*	48	26 50 40	3.72*
	DMPFC	9				10	16 60 32	3.31*
	DMPFC	8	20	-2 30 56	3.63*	35	8 36 52	4.15*
	VLPFC	10	2	-28 44 30	3.44*	58	30 56 20	3.84*
	VLPFC	45				13	60 22 14	3.46*
	IFG	47	10	-52 20 -8	3.59*	17	54 20 -4	3.51*
	Premotor	6				150	6 34 54	4.25
	Insula	13				33	36 18 12	3.96
	MTG	22				238	52 -36 0	5.44*
	Lingual Gyrus	18	12	-12 -74 4	3.64			
	MOG	19				65	38 -84 6	4.24
	Lentiform Nucleus	--				12	22 8 -12	3.33
	Cerebellum	--	60	-24 -72 -16	4.24			
CRSS [CONT - FB]	IOG	18				123	24 -90 -12	3.65
	MTG	39	319	-46 -80 28	3.24			

Table 8. Results from direct comparisons between groups during the cued cognitive reappraisal of SS negative images condition (Cognitive Reappraisal SS (CR SS)). Top panel indicates contrast results from Control – Football (CONT-FB). Bottom panel indicates contrasts results from Football- Control (FB-CONT). Whole brain analysis were corrected for multiple comparisons using FDR p<0.05 (marked as *) and for exploratory purposes, uncorrected regions (p<0.001, k=5) will also be reported (no star is indicated). Red text signifies results from region of interest analysis (ROI) derived from Wake Forest anatomical mask. The ROI analysis were FDR corrected for multiple comparisons (p <0.05) (marked as *), adjusted for search volume.

Cognitive reappraisal IAPS condition.

Whole brain CONT-FB.

During the cued cognitive reappraisal of generalized negative images (IAPS), the whole brain analysis of the control group compared to the football group revealed left and right (FDR corrected) MTG (BA 22/21), left and right (FDR corrected) MOG (BA 19), bilateral IFG (BA 47), right premotor cortex (BA 6), left parahippocampal gyrus, bilateral DLPFC (BA 9), right DMPFC (BA 8), right lingual gyrus, left STG (BA 38), right pulivinar, and left cerebellum ($p<0.001$ $k=5$ uncorrected unless indicated as FDR corrected) (Figure 21, Table 9).

ROI CONT-FB.

The ROI analysis revealed the bilateral DLPFC (BA 9), bilateral DMPFC (BA 8/9), right VLPFC (BA 45) and bilateral IFG (BA 47) were significantly active in the control group compared to the football group (FDR corrected $p<0.05$) (Figure 21,Table 9).

Whole brain FB-CONT.

Whole brain analysis revealed no significantly greater BOLD signal in the football group compared the control group during cued cognitive reappraisal of IAPS images (Figure 21, Table 9).

ROI FB-CONT.

ROI analysis revealed no significantly greater BOLD signal in the football group compared the control group during cued cognitive reappraisal of IAPS images (Figure 21, Table 9).

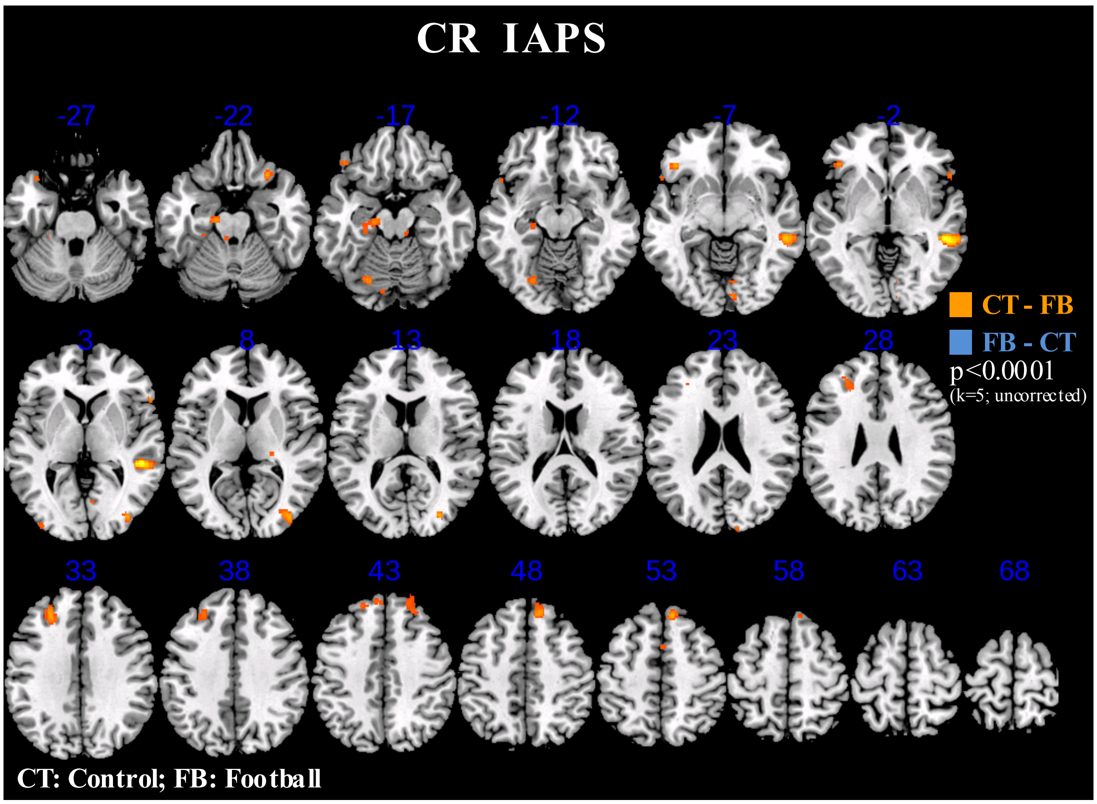


Figure 21. Whole brain axial slice results (inferior-superior) from direct comparisons between groups during the cued cognitive reappraisal of International Affective Picture System negative images condition (Cognitive Reappraisal IAPS (CRIAPS)). The orange indicates contrast results from Control – Football (CT-FB). The blue indicates contrasts results from Football- Control (FB-CT).

Contrast Conditions	Region	BA	Left			Right		
			Volume in Voxels	MNI coordinates x, y, z	t values	Volume in Voxels	MNI coordinates x, y, z	t values
CR IAPS [CONT - FB]	DLPFC	9	21	-28 36 34	3.94*	27	24 48 42	3.42*
	DMPFC	9	1	-4 50 42	3.27*			
	DMPFC	8	18	-4 48 44	3.86*	18	10 38 52	3.91*
	VLPFC	45				1	56 24 2	3.33*
	IFG	47	5	-52 20 -8	3.46*	7	56 22 -2	3.82*
	DLPFC	9	169	-26 34 34	4.02	75	24 48 46	3.62
	DMPFC	8	13	-18 44 42	3.51			
	IFG	47	44	-42 32 -4	4.19	29	30 22 -22	4.04
	Premotor	6				144	10 36 54	4.14
	MTG	22/21	12	-52 16 -10	3.49	245	50 -36 0	5.66*
	STG	38	19	-34 18 -28	3.63			
	Lingual Gyrus	18				21	8 -86 -6	3.82
	MOG	19	10	-40 -92 0	3.47	131	38 -84 6	4.54*
	Parahippocampal Gyrus	28	122	-16 -20 -20	4.07			
	Pulivinar	--				11	24 -28 8	3.55
	Cerebellum	--	8	-4 -34 -22	3.46			
CR IAPS [FB - CONT]	--	--	--	--	--	--	--	--

Table 9. Results from direct comparisons between groups during cued cognitive reappraisal of International Affective Picture System negative images condition (Cognitive Reappraisal IAPS (CRIAPS)). Top panel indicates contrast results from Control – Football (CONT-FB). Bottom panel indicates contrasts results from Football- Control (FB-CONT); nothing survived the current statistical threshold. Whole brain analysis were corrected for multiple comparisons using FDR $p<0.05$ (marked as *) and for exploratory purposes, uncorrected regions ($p<0.001$, $k=5$) will also be reported (no star is indicated). Red text signifies results from region of interest analysis (ROI) derived from Wake Forest anatomical mask. The ROI analysis were FDR corrected for multiple comparisons ($p <0.05$) (marked as *), adjusted for search volume.

Discussion

The results overall support the prediction of a greater efficiency of response to emotional stimuli in elite athletes, suggesting that economy of neural processing during emotional challenge may contribute to the psychomotor efficiency of expert performance. The comparative descriptive pattern of the two groups revealed during the four conditions reveal a tendency of anterior efficiency in the football group with greater similarity between the groups in posterior regions during three of the four conditions (the passive response to IAPS and SS and the cued cognitive reappraisal of SS). The cognitive reappraisal of generalized negative events (IAPS) appears unique in that the anterior efficiency of the football group is less evident and instead both groups appear more alike in magnitude of BOLD response. This suggests that experience may be an important mediator in the processing economy during emotional events. Independent of instructional cue, the football group appears to be more efficiency in the prefrontal cortex when challenged with SS negative events. The economy revealed in the natural response to general negative situations (IAPS) suggests that the default interpretation of the stress resilient group is similar to that when challenged with sports relevant negative events. It is only when asked to reinterpret generalized negative events into more positive terms that the football group requires greater prefrontal resources, perhaps due to a greater effort.

These findings are consistent with those of previous studies that have reported that efficiency is a hallmark of skilled individuals. In the motor domain there is evidence that experts require less neuronal resources compared to novices to accomplish the same task and that this refinement can be characterized as psychomotor efficiency (Deeny, et al., 2009; Hatfield et al., 2004; Haufler, et al., 2000). In addition, efficiency has also been examined in the context of intelligence (Neubauer & Fink, 2009), affective personality (Gray et al., 2005) and cognitive performance (Rypma et al., 2006) suggesting that a reduction in processing effort is an indicator of adaptive engagement. Our results extend this work since they indicate an efficiency in the emotive domain as revealed by a relative reduction in BOLD signal in elite athletes during affective challenge. These findings are also complementary with examinations of other stress resilient groups (elite warfighters) which have reported more focused neural processing with greater neural resources directed towards salient information (Paulus et al., 2010). Thus, elite athletes appear to have developed a means of responding to emotion in a manner characterized by an efficiency of effort utilizing minimal resources.

Direct Group Comparisons.

To validate the neural efficiency revealed by visual inspection a direct comparison between groups was executed. The results supported an overall efficiency of processing in the football group compared to the control group. Although we only predicted this in a specificity context, this economy generalized to all negative events. Consistent with the overview observations, this efficiency is robustly evident in the prefrontal cortex but the economy is expressed in all four conditions (rather than just the SS and the natural response to IAPS) and in selective posterior regions.

Prefrontal Regions of Interest.

A priori ROIs analyses of the prefrontal cortex were executed and supported the predictions of a greater economy of activation in the football group compared to the control group. Examination of the DLPFC revealed that the football group demonstrated greater economy independent of condition. This economy may in part be related to the psychomotor efficiency developed in elite athletes since the outputs of the DLPFC are directed to the motor systems and play an essential role in motor plan representation (Salzman & Fusi, 2010). In addition, the DLPFC is sensitive to the evaluative aspects of affective valence (Grimm et al., 2006), attention, working memory and cognitive control (Ochsner & Gross, 2008). An economy of processing during all conditions was also revealed in the DMPFC (Passive Negative IAPS, Passive Negative SS, Reappraisal IAPS, Reappraisal SS) a region particularly sensitive to emotional intensity and self-relevant processing (Heinzel et al., 2005; Northoff et al., 2004; Ochsner et al., 2004; Waugh, Hamilton, & Gotlib, 2010). The football players furthermore demonstrated greater economy during all conditions in the VLPFC (Passive Negative IAPS, Passive Negative SS, Reappraisal IAPS, Reappraisal SS) which is involved in assessing external emotional states, externally guided behaviors (Yamasaki, LaBar, & McCarthy, 2002) and contributes to the judgmental control of emotional intensity (Grimm et al., 2006). Economy of processing was also revealed in the inferior frontal gyrus during all conditions (Passive Negative IAPS, Passive Negative SS, Reappraisal IAPS, Reappraisal SS). This region is involved in the assessment of negative events for contextually relevant emotional cues critical for decision making and also has been reported to be critical to the successful inhibition of emotional influence during behavior (Beer, Knight, & D'Esposito, 2006). As such, virtually all of these regions show the same pattern of greater processing economy with the football group compared to the control group suggesting neural efficiency in cognitive control regions may be a critical factor that belies their ability to be consistent in their motor performance.

Examinations of prefrontal regions involved in emotional processes revealed an attenuated response in the football group compared to the control group. In the VMPFC, a region involved in emotional arousal, the football group showed less activation during the natural response conditions (Passive Negative SS, Passive

Negative IAPS) (Phan et al., 2003). This region is particularly interesting since it is not only involved in the regulation of the amygdala (Phelps, Delgado, Nearing, & LeDoux, 2004) but is a key cortical substrate of negative affective processing (Carretie, Albert, Lopez-Martin, & Tapia, 2009) and emotional valence (Grimm et al., 2006). This suggests that resilient group naturally process negative events in an attenuated manner. Congruent with these findings, the activation in mOFC (Passive Negative IAPS) was also reduced in the football group compared to the control group suggesting critical differences in representing affective values and emotional processing (Kringelbach, 2005). Interestingly, this was only apparent during the natural response to generalized negative images (IAPS) suggesting that encoding of affective values may be important to understanding emotional sports-relevant information.

In summary the refinement of activation in prefrontal cortex indicates that elite athletes, who have distinguished themselves in high stress performance situations, process emotional challenge in an efficient manner. To our knowledge, this is the first time that emotional processing has been evaluated in elite athletes (although similar elite groups have been examined, i.e., Navy Seals in (Paulus et al., 2010)) revealing a generalized efficiency in neural processing in a region essential to executive function and cognitive control (the prefrontal cortex). These findings are congruent with previous work that has reported prefrontal neural efficiency related to individual affective personality differences, with more approach (positive) oriented individuals showing less brain activity during a working memory task than inhibited individuals (negative) (Gray et al., 2005). Beyond the affective domain, the prefrontal cortex is a region particularly sensitive to motor performance efficiency, showing less cortical activity during skilled performance and in turn, showing increased neural activity with increases in reaction time in a speeded processing task (Rypma et al., 2006). This suggests, in part, that psychomotor efficiency developed by elite athletes may translate into an overall economy in the prefrontal cortex during emotional challenge.

Posterior Regions Revealed from Whole Brain Analysis.

The affective economy revealed by the whole brain analysis of the direct group comparisons extends to regions beyond the prefrontal. In particular, many of these posterior regions are critical to social cognitive processing (Lieberman, 2007). This is not surprising given the socially relevant nature of the stimuli used, often characterizing groups of individuals in aversive situations or demonstrating negative facial emotion (e.g., coach yelling at player (SS), attack (IAPS)). Thus an informative manner of interpreting the relative economy of processing seen in the football group is to examine how these regions may promote adaptive response to aversive interpersonal situations and assessment of emotive human faces (Koenigsberg et al., 2010; Pessoa, McKenna, Gutierrez, & Ungerleider, 2002). In a particular regions where the football group demonstrated greater efficiency extended into the STG (Passive Negative IAPS, Reappraisal IAPS), and premotor cortex (Passive Negative IAPS, Reappraisal IAPS, Passive Negative SS) which are involved in social perception (Lawrence, et al., 2006). This efficiency in social perception is found during generalized negative challenge and during SS challenge. On speculation, this ubiquitous effect may be related to greater sensitivity to biological motion and goal directed action (essential attributes for representing the mental states of others, see (Lieberman, 2007)) as a consequence of athletic aptitude. Congruent with this notion, the middle temporal gyrus (Reappraisal IAPS, Passive Negative SS, Reappraisal SS), caudate (Passive Negative IAPS), cerebellum (Passive Negative IAPS, Reappraisal IAPS, Passive Negative SS) which are crucial to attribute intentions and mental states to others (theory of mind), were more efficient in elite athletes (Brunet, Sarfati, Hardy-Bayle, & Decety, 2000). Once again relative processing economy in regions critical to social cognitive processing generalized to all conditions suggesting elite athletes have developed ability in understanding how other's minds operate and respond to environmental cues, although this is speculation (Lieberman, 2007). Posterior economy of processing was also revealed in the lingual gyrus, a region involved in perspective taking, during the natural response to negative events independent of situation (Passive Negative IAPS, Passive Negative SS) and during cued emotion regulation of generalized negative situations. Perspective taking is an essential element of social understanding requiring complex cognitive flexibility and assessing the self relevance of stimuli (Ruby & Decety, 2003). In addition, the anterior cingulate cortex demonstrated greater efficiency in the football group during the natural responses to negative challenge (Passive Negative IAPS, Passive Negative SS). This midfrontal region is critical to self regulation, sensitive to both reward and pain, suggesting that the innate response of the resilient group is to manage impulse and control information from the environment (Posner, Rothbart, Sheese, & Tang, 2007). Lastly, efficiency in the middle occipital gyrus (Passive Negative IAPS, Reappraisal IAPS, Passive Negative SS) indicates an economy in valence dependent modulation of visual attention (proposed to be mediated by amygdala feedback) (Pessoa et al., 2002) during the natural response to stressful challenge (independent of stimulus type) and during generalized instructed regulation. Although speculative, this response could suggest that the elite athletes may naturally respond less severely to negative events as indicated by this attenuated attentional response. In summary, regions of emotive economy were congruent with areas reported to be essential to social cognition and self regulation (Koenigsberg et al., 2010; Lieberman, 2007). Characteristics such as social assessment, attention modulation and perspective taking are congruent with the psychosocial attributes of stress resiliency; suggesting that individuals engaged in successful sport competition may have developed generalizable coping acuity to promote adaptive response to all types of stressful events (Feder et al., 2009; Koenigsberg et al., 2010).

Subcortical Efficiency.

Although the direct comparisons between groups did not demonstrate significant differences in activation in the amygdala (as was initially predicted), other regions sensitive to negative affective processing were revealed. The parahippocampal gyrus (Passive Negative IAPS, Reappraisal IAPS) is a region modulated by the amygdala, particularly during situations of emotionally arousing events (Kilpatrick & Cahill, 2003). Contrary to expectations, this economy is only apparent with the generalized negative images. In addition, the football group demonstrated greater economy in the right insula (Passive Negative IAPS, Passive Negative SS), a region particularly sensitive to bodily states which contribute to the experience of an emotion (Straube & Miltner, 2010). Interestingly this efficiency of processing is apparent during the natural response of the football group to both generalized and SS negative events suggesting a refinement of processing of body-related information during their natural response to emotional situations. Thus the relative efficiency of processing in these regions that are critical to assess affective intensity implies that the emotional appraisals of stress resilient individuals do not perceive negative events in the same intensity as age-matched controls.

Football Group Greater Than Control.

Although none of the region survived multiple comparison corrections, exploratory analysis with a more liberal statistical threshold ($p<0.001$; $k=5$ voxels) revealed greater left MTG (Reappraisal SS, Passive Negative SS) activation for the football group compared to the control group. A recent meta-analysis reported that this region is particularly sensitive to discrimination of expressive and emotional faces (Sabatinelli et al., 2010). This is consistent with the activation revealed in the inferior occipital gyrus (Reappraisal SS, Passive Negative SS) which is reported to be a critical region involved in the neural basis of human face perception (Sabatinelli, et al., 2010). The specificity of this regional activation to SS negative images implies that football players may be particularly sensitive to emotional facial cues within their domain of expertise. Lastly, the left superior occipital gyrus (Passive Negative IAPS) is reportedly more involved in implicitly processing of emotional faces (i.e., judgment of other facial cues such as gender) which is also associated with increased amygdala involvement (Scheuerecker et al., 2007). This suggests that the football group demonstrated greater affective attention to generalized negative events, although our data did not reveal amygdala activation in this group comparison.

Summary.

To account for this generalizability of economy, we examined several possible explanations. The first, is described as the gravitational hypothesis whereby individuals are drawn to particular experiences based on compatibility with their interest, personality, values and abilities (Cox, 2002; Wilk, Desmarais, & Sackett, 1995). This suggests that these individuals demonstrate a ubiquitous economy since they have innate features which have drawn them to a sport where the management of stress and stress resiliency is rewarded. Alternatively, the general adaptation syndrome, predicts that adaptive behavior in response to stressors or challenge is a consequence of repeated exposure to a stressor, resulting in a systematic adaption that leads to greater efficiency (Selye, 1975). This suggests individuals facing stressful challenge (e.g., elite athletes) may have developed adaptive and efficient processing strategies to enhance emotion regulation and maintain cognitive control of behavior and that these responses are generalized to domains beyond their developmental experience. Consistent with this notion, evidence from animal models suggestions that individuals who are exposed to early intermittent stress results in enhanced arousal regulation and resilience (Lyons, Parker, & Schatzberg, 2010). Specifically, monkeys who experience intermittent separations from their mothers as infants demonstrated less behavioral indications of anxiety in adulthood, reduced cortisol, increased sensitivity to glucocorticoid regulation of the hypothalamic–pituitary–adrenal axis and greater prefrontal cortex volume compared to monkeys who had not been separated (Lyons et al., 2010). It is impossible to determine which model may account for this generalized efficiency but elite athletes may be important groups to examine when evaluating stress resiliency, particularly in connection with human motor performance.

Although we can only report that the elite athletes have distinguished themselves in a challenging competitive environment consistently over time, the psychosocial attributes of athletes are congruent with characteristics of stress resilient populations. Qualities such as determined, confident, focused, inspired, and hopeful are reportedly essential attributes that elite athletes report during their best performances (Hanin, 2007). Stress resiliency is characterized by facing fears and active coping, optimism and positive emotions, social competence and support, purpose in life, and engaging in cognitive restructuring or cognitive reappraisal (Feder et al., 2009). Our pyschometric results support this view since the football group reported less fear of failure than the control comparison. This suggests that elite athletes may serve as important models for understanding stress resiliency both behaviorally and neurobiologically.

In summary, the results argue for a neural efficiency that extends into the affective and social cognitive domain. Elite athletes demonstrate processing economy in regions critical to self regulation and management of emotional impulses (Ochsner & Gross, 2008). Efficiency of affective processing may lead to a greater capacity to handle stressful events and promote an overall refinement of cortical activity necessary for successful performance under mental stress. This type of affective economy also suggests that resilient individuals may utilize cognitive processes allowing them perceive threatening situations as less stressful by re-evaluating the aversive evident into more positive terms (Feder et al., 2009). In addition this group demonstrates efficiency in regions essential to representing the psychological states of others (Lieberman, 2007). Evidences from military populations also supports this psychosocial attribute and have revealed that emotional intelligence, characterized as social awareness of others and their emotions, is a critical trait-like predictor of leadership and related to hardiness (Bartone, 2008). Thus, a hallmark of stress resiliency is social competence and the ability to accurately assess the emotional response of others in social situations may be critical to the qualities related to successful coping with stress (Feder et al., 2009).

By examining elite athletes we can also learn how emotional information is processed in a manner than attenuates neuromotor noise and promotes psychomotor efficiency. In conclusion affective neurobiological activity is intimately linked with the motivation and informational value of emotional experience which serve to modulate both cognitive and action tendencies (Izard, 2009). In turn, the interaction between these constructs supports the notion that a refinement of processing would facilitate the automaticity and ease through which an individual copes during extreme challenge and hence provide insight into the mechanism that contributes to optimal performance under pressure.

Chapter 6: Review of the Process Model of Emotion Regulation

In addition to the efficiency of emotive processing, we sought to examine the specificity versus generalizability of stress coping strategies. Specifically, emotion regulation may be a critical component accounting for the stress resiliency of elite athletes. Emotion regulation can be generally defined as ‘‘the processes by which individuals influence which emotions they have, when they have them, and how they experience and express these emotions’’ (Gross, 1998). Gross and Thompson describe a process model of emotion regulation whereby there are five principal means through which to engage in behavior which alters emotional response that are dependent on the timing of the regulation strategy as critical to its impact and success (Gross & Thompson, 2007). This section will review all components of the process model and discuss why cognitive reappraisal is a particularly important strategy to consider when examining stress resilience.

The first four strategies are antecedent-focused strategies since they moderate affect early-on or before emotional responses are evoked. The first is situation selection where action is directed by approaching or avoiding situations (people, places, objects) in a way that gives rise to the desired emotional state. The second approach, situation modification involves changing the existing external environment such that the emotional impact of the chosen situation is altered. The third is described as attention deployment where distraction and concentration can mediate the emotional experience. Recently the neural substrates of this particular strategy have been investigated by McRae and colleagues, who utilizes attentional modulation or distraction during emotional stimulus exposure (McRae et al., 2010). Attention deployment acts as a filter by limiting the amount of attention given to the event, thereby resulting in reductions of self reported negativity and stress (McRae et al., 2010). Selective attention recruits prefrontal and parietal regions involved in externally focused processing (McRae et al., 2010). The authors found that distraction produces a reduction in bilateral amygdala and increases in dorsolateral prefrontal and ACC, in particular, greater activity in right prefrontal areas and parietal regions consistent with the notion of increased selective attention (McRae et al., 2010). Thus attentionally demanding tasks act to reduce negative affect since selective attention acts to limit appraisal of emotional events thus reducing their impact.

The last antecedent focused approach is cognitive change which acts by altering the meaning of the emotional event. In recent years, special attention has been devoted to one of these strategies, termed cognitive reappraisal. As stated in the General Introduction, cognitive reappraisal is a "cognitive-linguistic strategy that alters the trajectory of emotional responses by reformulating the meaning of a situation" and has a stereotyped result of decreasing reported negative emotion (Goldin, et al., 2008; Wager, et al., 2008). The result of reappraisal is that it attenuates negative emotional experience and behavior resulting in an enhancement in cognitive control of emotion. Reappraisal is postulated to act through prefrontal mediation (including areas in dorsomedial prefrontal cortex (DMPFC), ventral lateral prefrontal cortex (VLPFC) and dorsolateral prefrontal cortex (DLPFC), via the anterior cingulate cortex (ACC)) of subcortical areas that process affect, thus changing the experience emotion (Goldin, et al., 2008; Wager, et al., 2008). The

ACC, which receives input from premotor, prefrontal and visual, auditory and somatosensory association areas (Haines, 2006) serves to monitor the success of the regulation (Ochsner & Gross, 2005). Collectively the ACC and DMPFC serve a monitoring role to evaluate emotional status during emotion regulation and while the lateral prefrontal regions exert the cognitive inhibition (Ochsner & Gross, 2008). Reappraisal thus acts to down regulate multiple sources of emotional evaluation processing (e.g., amygdala) representing a shift from an emotion system into a more cognitive system during stimulus appraisal (Ochsner, et al., 2002).

The last emotion regulation strategy of the process model is response modulation, which is no longer antecendent-focused but instead a response-focused strategy where affect is moderated after emotion has been expressed (Gross & Thompson, 2007). In particular, expressive suppression, a technique geared towards inhibition of emotional responses following affective generation, has been studied extensively. The consequence of this strategy includes attenuating prepotent facial emotion behaviors which reduce emotional behavior but *maintain emotional experience*. Goldin and colleagues reported that "frequent use of expressive suppression results in diminished control of emotion, interpersonal functioning, memory, and well-being and greater depressive symptomatology" (Goldin, et al., 2008). In addition expressive suppression has been linked to increases sympathetic arousal and maintained or intensified stress response (Gross, 1998). Although this strategy results in reduced negative affect and facial behavior, it also results in increased activity in right insula and right amygdala suggesting a lack of reduction in emotion-related neural activity. In addition this strategy recruits right VLPFC, DMPFC, DLPFC, and visual-sensory multimodal association (posterior occipito-temporal lobes), and visual-spatial processing (precuneus and occipital areas) (Goldin, et al., 2008). In sum this strategy has negative consequences by merely mildly reducing negative affect, but consuming cognitive resources, such that executive functions such as memory are also impaired (Gallo, Keil, McCulloch, Rockstroh, & Gollwitzer, 2009).

Although all the strategies are recruited for the purpose of emotion regulation, cognitive reappraisal has a beneficial outcome of negative affect reduction, while still engaging with the negative event (Figure 24). Unlike situation selection, situation modification andattention deployment, cognitive change (cognitive reappraisal) does not require manipulation of environment, nor workload or attention modulation, but still effectively alters affective processing and emotional experience. The response focused strategy, expressive suppression, focuses on action expression and control of emotional output and thus is less effective at altering negative affect (Figure 24). As stated above, certain individuals may have an innate capacity which facilitates their performance and coping abilities under stress. We sought to examine if through experience, these individuals may automatically engage in cognitive reappraisal of an emotional event such that the negative consequences are attenuated, altering the salient features of affective phenomenology.

Chapter 7: Review of the Neuroanatomy Underlying Emotion Regulation

The next sections will review the functional and anatomical areas critical to emotion regulation. The goal is to overview how each region plays a role in emotion and cognition and, in turn, can contribute to adaptive responses to stressful events.

Neuroanatomically, the relationship between emotion and cognition can be characterized by the bidirectional pathways of the prefrontal cortex and the amygdala. Recent work by Ghashghaei and colleagues explored this synergistic association by mapping input-output laminar zones through tracer injections into the amygdala of the rhesus monkey (Ghashghaei et al., 2007). The medial prefrontal areas and orbitofrontal (OFC) cortex demonstrated the densest connectivity between prefrontal regions and the amygdala (Figure 25). In particular when investigating the percentage of input from the amygdala relative to the percentage of output from the prefrontal cortex, the caudal medial prefrontal cortex (PFC) and medial/caudal OFC exhibited the heaviest amygdala input, typified by substantial feedback input from the amygdala (feedback input defined by axonal terminations from the amygdala terminating in layers 1- upper 3 of the prefrontal cortices). Additionally, another pattern of higher proportion of output from the prefrontal cortices compared to amygdala input emerged in the lateral/rostral OFC and rostral medial PFC which also projects feedforward inhibitory inputs (projection neurons from layers 2-3 in the prefrontal cortex into the amygdala) into the amygdala (Haines, 2006). The sparest connection between the prefrontal cortex and amygdala was found in the anterior lateral prefrontal areas. Interestingly this region has been reported to project into the cingulate gyrus which in turn proved to be the primary inhibitory feedforward input connection into the amygdala (Ghashghaei et al., 2007).

Amygdala

From a neural perspective, psychological stress and anxiety are mediated by the limbic system, in particular the *amygdala,* which is reported to play a central role in fear and novelty processing (Davidson, 2002). Human lesion studies have indicated that the amygdala is involved in recognition of facial expression of fear, trustworthiness of strangers, vocal signal of fear, threat recognition, autonomic fear conditioning and expression of learned fear response (Davidson, 2002). Neuroimaging investigations have supported these results, and provide additional insight into the time course of the amygdala response (Goldin, et al., 2008). Functional asymmetries of activation may also be present with some studies reporting right amygdala activation as unconscious emotional processing while left amygdala activation expresses conscious learned emotion (Davidson, 2002). In addition the amygdala appears to be a key element in early emotional learning as evident by amygdala habituation after conditioning (Davidson, 2002). Amygdala activity has also been linked with novelty detection, mediating motor preparation, focal attention and enhanced memory encoding (McRae, et al., 2010). The amygdala is connected with numerous sensory and association cortical areas in addition to the thalamus, hypothalamus, striatum, and brainstem areas (see figure 26; Haines, 2006). These projections to the brainstem and hypothalamus act to stimulate the release of catecholamines and glucocorticoids which in turn strengthen amygdala dependent behaviors such as fear conditioning, and emotional memory (Arnsten, 2009). Thus management of this critical brain region may be essential to promote psychomotor efficiency during skilled action execution.

Insula

The insular cortex (Figure 27) is connected directly to sensory cortices and nuclei with outputs to regions such as motor cortex, the striatum and visual cortex (Carretie et al., 2009). Neuroimaging results indicate that this regions is active during pain, fear and threat related events in addition to situations that elicit disgust (Heinzel et al., 2005). Collectively it has been suggested that the insula acts as a "somatic marker" for optimal decision making suggesting that affective reactions encoded in the insular cortex provide information for guiding rational choices (Damasio, 1996). Recent support for the evaluative qualities of the insula were discussed in a review in which the authors contend that critical regions involved in the assessment of risks and response selection include the amygdala, anterior insula, and ventromedial prefrontal cortex (Carretie et al., 2009). These regions work in concert to evaluate negative challenges and through their interconnectivity act to modulate the activity of each other (Carretie et al., 2009). Thus management of emotion may require quiescence of insular activity during adaptive stress coping.

The insular cortex region is also critical to individual differences. Paulus and colleagues challenged US Navy Seals with an emotional face processing task and found that independent of affective valence, these elite warfighters showed greater right sided insula and attenuated left sided insula activation compared toa control group. In particular the angry faces produced bilateral insula activation, which was interpreted as greater resource allocation for interoception (Paulus et al., 2010). Furthermore, Iaria and colleagues evaluated the personality trait of emotional susceptibility (ES), which is defined as "the tendency to experience feelings of discomfort, helplessness, inadequacy, and vulnerability after exposure to stimuli with salient emotional content" (Iaria et al., 2008). Thus, individual with high ES are typically more susceptive to negative and positive emotions whereas low ES individuals are typically characterized as clear minded, self confident, and efficient (Iaria et al., 2008). When viewing negative IAPS images, individuals with high ES were characterized by bilateral insula activation, whereas individuals with low ES demonstrated left lateralized insula activation (Iaria et al., 2008). The converging evidence suggests that the insula is a critical region to examine why individuals respond differently to the same emotional challenge.

Prefrontal Cortex

Lateral Prefrontal Cortex.

The lateral PFC is anatomically divided into Brodmann Areas 10, 9 and 46 and these regions are less differentiated thus having more diffuse projections making them well suited for top down, hierarchical control (Badre & D'Esposito, 2009). Studies have consistently shown that cognitive control and emotion regulation involve primarily lateral prefrontal cortical regions (Goldin, et al., 2008; Ochsner & Gross, 2008). Interestingly, the lateral prefrontal regions and ACC activity are negatively correlated with the medial OFC cortex and amygdala activity, consistent with the directional anatomical connectivity described in the monkey model (Ghashghaei et al., 2007; Northoff et al., 2000; Ochsner & Gross, 2008). In particular the DLPFC, and VLPFC have been reported to be essential to negative emotion reassessment (Wager et al., 2008). The DLPFC mediates representation of goals of the individual and acts to integrate emotional and cognitive functions (Davidson, 2002). Cognitive engagement may recruit the working memory and executive function of the lateral prefrontal cortex which may subsequently cause a decrease in amygdala activity (Ochsner et al., 2004). Additionally, during cognitive engagement, an emergence of an inverse relationship between lateral and medial prefrontal structures suggests a dynamic relationship between affective and cognitive regions of the PFC thus collectively indicating a reciprocal modulation between both limbic and prefrontal affective regions and cognitive lateral prefrontal areas (Northoff et al., 2004).

Medial Prefrontal Cortex.

The medial prefrontal cortex (VMPFC) may be the neural basis for abstract represent of reward or punishment which behaviorally shapes action and motivation, termed by Davidson "affective working memory" (Davidson, 2002). This region can act in an inhibitory capacity, modulating amygdala, the nucleus accumbens and the hypothalamus response, guiding decision making and extinction learning (classical conditioning) (Arnsten, 2009; Phelps et al., 2004). The region is associated with successful operant fear extinction learning in humans suggesting a critical role in emotion regulation by acting as a means to appropriately recode stimulus–reinforcement associations (Finger, Mitchell, Jones, & Blair, 2008). Nonetheless, it should be noted that the VMPFC is often defined as a continuous part of the medial OFC in certain studies (e.g. (Carretie et al., 2009; Heinzel et al., 2005) due to sensitivity of this prefrontal region to negative events. Thus the VMPFC acts not only to intervene in negative affective assessment, but seems a critical neural substrate of negative event evaluation (Carretie et al., 2009; Phan et al., 2003).

The dorsomedial prefrontal cortex (DMPFC) is reported involved in a range of processing including decision making (Venkatraman, Rosati, Taren, & Huettel, 2009), referential processing (Yaoi, Osaka, & Osaka, 2009), and default mode network (Greicius, Krasnow, Reiss, & Menon, 2003) but in the affective domain, there is evidence that it is engaged during higher level appraisals of emotional stimuli and monitoring of one's own emotional (Goldin et al., 2008). This self knowledge extends to semantic information and internal cues about one's mental state that are essential for self-evaluations (Beer, Lombardo, & Bhanji, 2010). Thus, this region acts to integrate not only the self's actions and abilities but also executed a real time evaluation of the self's qualities within goal of the moment (Beer et al., 2010). Consistent with this notion, a fMRI investigation of individual differences in trait mindfulness (the ability to represent a particular quality of attentional processing to the awareness of events) positively related to the BOLD response in the DMPFC and left amygdala (Frewen et al., 2010). This suggests that emotional processing is also a central feature of this region. The DMPFC is modulated when emotions are evaluated, showing valence-dependent sensitivity, suggesting a critical role in both evaluation and stimulus processing of emotion (Heinzel et al., 2005; Northoff et al., 2004).

Orbitofrontal Cortex.

The OFC is anatomically connected to regions such as the amygdala, cingulate cortex, ventral striatum, medial PFC, and entorhinal and perirhinal cortex (Rolls & Grabenhorst, 2008). The result is that this region is a hub for processing of multimodal information, influencing behavior, emotion, cognition and memory (Rolls & Grabenhorst, 2008). The lateral OFC (lOFC) is primarily connected to the amygdala, sensory and premotor areas, DLPFC and related to affective/cognitive associations (Northoff et al., 2000). Medial OFC (mOFC) activity is often coupled with amygdala response and is involved in representing the affective valence of a stimulus, in particular, negative emotion and reactivity to foreign stimuli (Banks, Eddy, Angstadt, Nathan, & Phan, 2007; Northoff et al., 2000; Ochsner et al., 2002). This region has also been implicated in a regulatory function in particular playing a critical role in fear extinguishing and decision making (Quirk & Beer, 2006). The role this region plays in decision making is further developed by examining its function in the representation of reward. A recent review by Rolls and Grabenhorst summarized these functional attributes and discussed how this extends to the representation of negative and positive reward since this region is critical to the subjective affective experience of emotionally learned behavior (Rolls & Grabenhorst, 2008). The OFC is also associated with primary reward reinforcement including taste, touch, texture and face expression. By learning associations between different stimuli, this region is essential to encoding expected reward value from multimodal sources. Thus, the role of the OFC extends into decision making by providing information on the expected reward value (Rolls & Grabenhorst, 2008).

In summary, the cognitive reappraisal emotion regulatory strategy is a particularly adaptive approach to altering the experience of negative emotion. The neural substrates of such a mental strategy involve prefrontal regions that modulate the amygdala. The last paper will thus examine if such an emotion regulation strategy is automatically utilized in elite athletes particularly under circumstances of known stressful challenge. The principal brain regions discussed above will be critically examined to further explore differences between the resilient group and a typical control population.

Chapter 8: The Specificity of Neural Regulatory Processes during Emotional Challenge in a Stress Resilient Population.

Introduction.

Emotion robustly affects the quality of cognitive-motor performance under conditions of mental stress. As such, the regulation of emotion is critical to successful execution of motor skills during competition. Previous investigations of the arousal-performance relationship have typically focused on behavioral outcomes (Hancock & Salman, 2008) but it is unclear if those who have demonstrated superior performance under stress exhibit brain responses characterized by an adaptive emotion regulatory strategy. Consistent with the reciprocal modulation model (Northoff et al., 2004); an adaptive regulatory strategy involves cognitive interpretation of emotion-eliciting stimuli in order to manage emotional responsivity. That is, from a functional neuroanatomical perspective, activation in the cognitive (lateral) prefrontal region of the cerebral cortex can be conceived as negatively associated with activation of the amygdala (a brain region underlying emotional response) and affective prefrontal regions (medial). Engagement of this network is mediated by an emotion regulation strategy called cognitive reappraisal and may be spontaneously recruited during emotional challenge in individuals who have demonstrated superior cognitive-motor performance under stress. Using functional magnetic resonance imaging (fMRI) this study seeks to determine if cognitive reappraisal is spontaneously recruited during the presentation of arousing sport-specific (SS) images in elite athletes who have demonstrated superior cognitive-motor performance under stress. Furthermore, in order to address the specificity of emotion regulation, the study will determine if such a pattern of stress resilience will generalize to non-sport emotion-eliciting scenes.

Psychological stress may be caused by social factors such as ego involvement in the challenge, perceived imbalance between ability and required success standard, and loss of social approval with failure (Hatfield & Brody, 2008). The dynamics between stress and performance can be characterized by the transactional model described by Staal (2004) in which stress is conceived as the aggregate result of the individual appraisal of the external situation and the actual situation itself. In particular this model integrates human performance and information processing capacity with the notion of appraisal of threat, controllability, and predictability into understanding the stress response. The transactional model of stress and the interactional model of competitive stress predict that the affective response to stress is influenced by the appraisal of the situation (personal interpretation) and the situational factors (environmental stressors; e.g., competition). Such personal interpretation can range from anxiety to active coping (Endler, 1997) and are dependent on personal variables such as trait anxiety, vulnerability, physiological arousal and innate biological features (Endler & Kocovski, 2001). The converging view from this literature is that a great deal of individual variation in the response to the stressor may be a consequence of the perception of the event rather than the actual environmental stressor.

Although the consequence of stress can be performance decline (Beilock & Carr, 2001), elite athletes appear to be resilient to such stress perturbation, promoting their ability to maintain a high level of performance during stressful conditions. Thus, based on their performance it is likely that skilled performers who excel during competitive stress engage in emotion regulation that neutralizes negative experience and decreases physiological arousal. But an essential question is whether they do this only in their sport domain or during numerous situations. There are many strategies through which to engage in emotion regulation (e.g., expressive suppression (Goldin et al., 2008), distraction (McRae et al., 2010), cognitive load (Van Dillen et al., 2009)) but one antecedent-focused strategy called cognitive reappraisal is a particularly adaptive. Cognitive reappraisal, or taking a cognitive interpretation of emotion-eliciting stimuli, effectively attenuates the emotional response to the objective stressor (McRae et al., 20010; Ochsner, Bunge, Gross, & Grabrieli, 2002; Ochsner et al., 2004; Ochsner & Gross, 2005; Ray et al., 2005; Wager et al., 2008). The result of cognitive reappraisal is that it modulates negative emotional experience and behavior resulting in an enhancement in cognitive control of emotion.

Neurobiologically, cognitive reappraisal is postulated to act through prefrontal mediation (including areas in dorsomedial prefrontal cortex (DMPFC), dorsolateral prefrontal cortex (DLPFC) and ventral lateral prefrontal cortex (VLPFC)) of subcortical areas that process emotion (amygdala), thus altering the perception of emotional events (Goldin et al., 2008; Wager et al., 2008). The prefrontal cortex (PFC) regulates thought, action, emotion and through its capacity to engage in top down regulation, serves to maintain appropriate actions, monitor errors and execute goals (Arnsten, 2009). The DLPFC, and VLPFC are regions essential to negative emotion reassessment (Wager, et al., 2008), while DMPFC is associated with self monitoring (Drabant, McRae, Manuck, Hariri, & Gross, 2009). Emotional prefrontal areas, specifically the ventromedial (VMPFC) and medial orbitofrontal (mOFC) cortical areas, play essential roles in the time course of affective response. The VMPFC encodes abstract representation of reward and can also act in an inhibitory capacity, modulating amygdala response (Davidson, 2002; Ochsner et al., 2002; Phelps et al., 2004; Quirk & Beer, 2006). The lateral orbitofrontal (lOFC) cortex is primarily related to affective/cognitive associations (Northoff et al., 2000), while the mOFC activity is often coupled with amygdala response and is involved in representing the affective valence of a stimulus (Banks et al., 2007; Northoff et al., 2000; Ochsner et al., 2002). Beyond the PFC, limbic regions like the amygdala play a central role in fear and novelty processing (Davidson, 2002), emotional valence and intensity (Salzman & Fusi, 2010), and influence the quality of motor preparation, focal attention and memory encoding (McRae et al., 2010). Also critical to affective response is the insula, which is part of the neural mechanism that evaluates negative events (Carretie et al., 2009) and is particularly sensitive to disgust and self-generated affect (Wright, He, Shapira, Goodman, & Liu, 2004). Thus, in summary, cognitive reappraisal may be critical to the orchestration of cognitive prefrontal processes that acts to down-regulate multiple sources of emotional evaluation processing (e.g., amygdala and insula), representing a shift from an emotion system into a more cognitive system during stimulus appraisal (Ochsner et al., 2002).

Through experience, elite athletes may have developed an automaticity of a cognitive strategy to achieve emotional control when faced with stressful challenge as a means to preserve psychomotor efficiency. In support of this notion, recent work by

Drabant and colleagues (2009) have demonstrated that individuals who behaviorally reported to use a cognitive reappraisal strategy in their daily lives, recruit similar prefrontal regions and subsequent amygdala reductions when viewing stressful events, mirroring regions active during instructed cognitive reappraisal. Since cognitive reappraisal acts to alter the trajectory of emotional responses by reformulating the meaning of a situation (Goldin, McRae, Ramel, & Gross, 2008; Wager et al., 2008), this strategy may be spontaneously recruited in elite athletes during stressful situations. By specifically examining this mental approach, it could provide critical insight into the manner through which stress resilience individuals adaptively cope with mental stress.

The overarching aim of the study is to determine if those who exhibit superior cognitive-motor performance and stress resilience are characterized by brain processes that parallel those recruited during cognitive reappraisal. To examine this model two separate types of stressful stimuli will be employed: Sport-Specific (SS) negative images and International Affective Picture System (IAPS) generalized negative images in order to test two competing hypotheses of emotion regulation: 1) hypothesis one predicts specificity of the endogenous regulatory response to emotional challenge (i.e., the domain-specific model of emotion regulation) while 2) the alternative hypothesis predicts an ubiquitous stress resilience independent of experience (i.e., the domain-general model of emotion regulation). Examination of these competing hypotheses will be executed through direct statistical comparison of the BOLD signal during the natural response to SS and generalized negative images compared to the cued cognitive reappraisal of SS negative images and generalized negative images, respectively (CONTRASTS: 1) Cognitive Reappraisal SS - Passive Negative SS; 2) Cognitive Reappraisal IAPS - Passive Negative IAPS). With elite athletes, minimal significant difference in BOLD signal between the sports specific conditions (Cognitive Reappraisal SS - Passive Negative SS) implies this population naturally resorts to an adaptive emotion regulation strategy when exposed to images that are relevant to their expertise, thus accounting for their ability to maintain skilled cognitive-motor performance during stress. On the other hand, in the case of a general model of emotion regulation, minimal difference BOLD signal between the endogenous response of the elite performers to both non-specific and specific negative images and cued cognitive reappraisal (Cognitive Reappraisal SS - Passive Negative SS; Cognitive Reappraisal IAPS - Passive Negative IAPS) implies this population naturally resorts to an adaptive emotion regulation strategy in all situations of stress.

A region of interest analyses also will be executed in the areas indentified above that are sensitive to both cognitive (PFC) and affective (insula and amygdala) processing to further examine differences between the types of emotional challenge. In the event of a domain specific model of emotion regulation, we predict that during examination of SS affective challenge, the football group will demonstrate similar patterns of activation in the PFC during the cued cognitive reappraisal and during their natural response. In turn, this will translate into attenuated amygdala and insula activation. In the event of a domain general model this effect would extend to the IAPS conditions.

However based on the transactional model (Staal, 2004) and interactional model (Endler, 1997) which posits the primarily influence of the situation on human behavior, the domain specific model of emotion regulation appears to be tenable.

Lastly, a control group will be examined and we predict that this population will demonstrate no such ability to endogenously engage in cognitive reappraisal, thus consistent with the literature[1], this group should be able to successfully engage in cognitive reappraisal (attenuated amygdala and insula response, with heightened lateral prefrontal activation, and reduced negativity of self report) when cued to do so, yet demonstrate affective processing (heightened amygdala and insula activation) during passive viewing of negative events (independent of domain).

Methods

Subjects.

Twenty-five male participants between the ages of 18 and 22 were recruited and of these 13 were football athletes (M=21.46 years; SD=0.776) and 12 were non-athletes (M= 21.08 years; SD=2.19). The football athletes were 1) senior varsity athletes 2) letter award winners 3) typically play a starting role on the team 4) on a partial or full athletic scholarship. The non-athletes were healthy subjects who never played football at a college level but reported familiarity with the goal and rules of

[1] It should be noted that the majority of the literature examining cognitive reappraisal is conducted with female participants (e.g., Goldin et al., 2008; McRae et al., 2010; Ochsner et al., 2002; Ochsner et al., 2004; Ray et al., 2005). Thus, although we base our predictions on current findings, gender-based differences in cued cognitive reappraisal may be revealed, due to the male-only sample in this dissertation.

the sport; this is critical to ensure that all subjects understand the meaning of the negative sport-relevant images. We developed a metric to quantify the football experience of the control subjects (Please select the answer that best describes your football experience : 0=no experience, do not watch or attend games (not a fan); 1=no experience, but watch occasionally (mild fan); 2=no experience, but watch frequently (avid fan); 3= some experience playing and watch frequently (e.g., intramurals); 4=several years experience playing competitively (e.g., high school); 5=currently playing competitively) such that control subjects scored a mean score of 3 (M=3; SD=0.94) for football experience. We additionally characterize their sport experience outside of football with a similar metric; mean score of 4.09 (M=4.09; SD 0.51) for sports experience in general.

Additional selection criteria included that the subjects must have been (a) native English speakers (b) free of current or past diagnosis of neurological or psychiatric disorders, and (c) MRI compatible (e.g., no metal in body, no tattoos on face, no medicine delivery patch). All subjects gave their written informed consent and all experimental procedures were approved by the University of Maryland Institutional Review Board with proper notification IRB of record for Hyman Subject Research Projects performed at the Georgetown University Center for Functional and Molecular Imaging.

Procedure.

Stimuli.

Following the approach developed by (Goldin, et al., 2008; Ochsner et al., 2004) the fMRI investigation evaluated the BOLD response during negative and neutral visually presented images. The neutral images served to provide a baseline to remove lower-level sensory processing associated with the visual modality and thus isolate affect specific networks. Negative and neutral images were selected from the International Affective Picture System (IAPS) (Lang, Bradley, & Cuthbert, 1999). In addition we developed Sport-Specific (SS) images by searching internet databases (e.g., Google Images) to find images representing unpleasant events experienced during football competition: for example: 1) injuries; 2) embarrassment due to loss (i.e., dejected players); 3) critical coaches.

Undergraduates (n=103) at the University of Florida gave their written consent (approved by the University of Florida Institutional Review Board) and the rated sport pictures (i.e., sport-specific negative images) (31 performance, 39 injury) and 48 negative IAPS images using the IAPS self assessment manikins and IAPS protocol (Lang, Bradley, & Cuthbert, 1999). The top 48 most negative sport images were selected based on valence scores (38 injury, 10 performance) and, for men, the SS images resulted in a valence rating mean of 4.131 and arousal mean rating of 4.824. In turn, IAPS images were selected with **matching** valence means scores of 4.116 and arousal mean scores of 4.896 to create equivalence between the two image sets. These ranges are consistent with what Patrick and Lavoro (1997) reported as negative for IAPS images: "Slides with mean valence ratings of less than 4.5 out of 9 were classified as unpleasant, those between 4.5 and 5.5 were classified as neutral, and those with mean ratings above 5.5 were classified as pleasant" (Patrick & Lavoro, 1997)

Task.

Each trial was composed of four events: First, instructions (watch or decrease) appeared centrally for 2 seconds. On "decrease" trials, participants were instructed to engage in cognitive reappraisal and on "watch" trials participants will be instructed simply to look at the image and let themselves respond naturally. Second, an aversive or neutral image will appear centrally for 8 seconds. This duration was selected based on a recent meta–analysis by Kalisch (2009) that suggests that 8 second image presentation time ensures examination of one concrete dimension of this psychological construct (implementation of cognitive reappraisal) (Kalisch, 2009). While the image remained on the screen, participants performed the evaluation operations specified by the prior instructional cue. Third, a rating scale will appear immediately after presentation of the image for 4 seconds asking "How negative do you feel" with a rating from 1 to 5 (1 not at all, 3 moderately, 5 extremely). This scale will allow participants to rate with a joystick the current strength of their negative affect and serve as a behavioral index of the success of reappraisal. Fourth, the transition task of fixation cross for 4 seconds in the center of the screen indicating that participants should relax until the next trial. Each subject was cued to passively view or reappraise 48 domain non-specific negative images (24 each) and 48 domain specific negative images (24 each) in addition to the passive viewing of 24 neutral images during randomly intermixed trials over 4 MRI scanning runs. Each image was shown only once for a given participant. Upon completion of the MRI, subjects returned to the Behavioral Testing room to complete questionnaires.

Prior to data collection.

Upon arrival at the Georgetown University Center for Functional and Molecular Imaging, participants were escorted to a Behavioral Testing room were written consent and MRI safety screening were attained. Task instructions consisted of a scripted training manual designed to provide an overall explanation of the goal of study, provide a detailed overview of the trial structure, review the instructional cues and describe the rating approach. During this orientation the investigator read aloud the manual while the participant followed along.

> The subject was instructed that the goal of the study was “We are interested in the biological and brain processes related to mental pressure and toughness. In order to make sense of the pattern of your brain response we need to have a consistent comparison condition. Thus, I am going to train you on a task which we will use as the comparison state but we are really interested in how you respond naturally to these pictures.” Next the subject viewed the trial structure and was read the following description: “You will be given an instructional cue of either “Watch” or “Decrease” (I will describe the instructions in greater depth next). Next you will see a picture. Some of the pictures may prompt emotional experiences; others may seem relatively neutral. You will be asked to rate the image using a joystick (which will also be described next). Lastly you will see a cross in the center of the screen; simply fix your eyes on that cross.” Next the rating instructions were given “After viewing a picture we ask that you rate it. You will be asked “how

negative do you feel?" and select the numeric value that applies to how you felt when viewing the image. If you felt in between the three descriptors, please select the appropriate intermediate value. There is no right or wrong answers, so simply respond as honestly as you can." Then the subject was introduced to the meaning of the watch instruction and shown a sample trial with a picture of an injured player: "Next, I will review the instructional cues. Below I have included one example trial in which the instruction will be "watch", which means you must simply look at the image and let yourself respond naturally." The decrease instruction was next reviewed (descriptions taken from previous protocols, e.g., (McRae, Ochsner, Mauss, Gabrieli, & Gross, 2008; K. N. Ochsner, et al., 2002): "The second instructional cue is "Decrease." What you will do when you see this instruction is transform your response or interpretation of the picture so it's not so negative. There are three ways to do this: 1) Transform the scenario depicted into positive terms; imagine that the situation is not as bad as it appears (e.g., a women crying outside of a church could be interpreted as a woman expressing tears of joy from a wedding ceremony rather than from the sorrow of a funeral); 2) Rationalize or objectify the content of the pictures; view the image from the perspective of a distant, detached observer (e.g., consider a woman with facial bruises could be an actor wearing makeup rather than a victim of domestic abuse); 3) Imagine that things will improve with time (e.g., whatever appears to be bad will resolve over time). This is called cognitive reappraisal. Cognitive means how you think and reappraisal means transforming the meaning." And then the subjects were shown an example trial (IAPS number 6212): "Here's a sample trial, and the implementation of all three strategies with this one image. Again you may choose 1 of the 3 strategies during the image viewing period: all are appropriate. 1) The Soldier is clearly not aiming at the child but at his adversary in the distance. The child is running to the safety of his family where he will avoid any harm; 2) Action movie trailer for the latest Special Forces flick; 3) The village will be safe again after the Soldiers remove the threat."

Next participants sat at a desktop computer to practice the task using a duplicate MRI compatible joystick that matched the device used in the MRI environment. Participants were introduced to all elements of the experimental protocol including the initial instructional prompt of "Remember when cued to 'watch' respond naturally and when cued to 'decrease' engage in cognitive reappraisal (as practiced)." Next the participant viewed two "watch" trials and executed their rating selection. After that, the participant viewed an investigator demonstration of reappraisal using three negative images and again executed their rating selection. The participant was then instructed to overtly engage in reappraisal during the viewing of 6 negative images (3 IAPS and 3 SS) to ensure proper use of the cognitive reappraisal strategy. All training was scored during these self paced sessions using a categorically scoring metric that included the following categories identified in (McRae, et al., 2008): 1) It is not real (e.g., it is just a scene from a movie, they are just pretending); 2) Things will improve with time (e.g., whatever is going wrong will resolve over time); 3) Things are not as bad as they appear to me (e.g., the situation looks worse than it is, it could be a lot worse, at least it's not me in that situation); 4) Expressive Suppression/ Attention Modulation; 5) Failure to Reappraise.

All subjects performed at/or better than 90% correct for the initial training session (mean percent correct: 92.14%). The final training session occurred in the MRI during which the subject viewed 6 reappraisal "decrease' trials which match the exact timing of the experiment. The subjects then retrospectively reported all of their reappraisal strategies such that the training success could be scored based on the categories mentioned above. All subjects performed at/or better than 90% correct for the in scanner training session (mean percent correct: 90.91%).

Imaging parameters.

Functional and structural magnetic imaging data were acquired on a 3T Siemens Magnetom Trio system equipped with gradients suitable for echo-planar imaging sequences. Thirty-eight axial slices (3.2 mm thick in plane) were acquired using an echo planar imaging (EPI) pulse interleaved sequence (TR 2000 ms; FOV 205; TE 30ms). For the possibility of aligning of the functional data to each subject's individual anatomy, anatomical images were obtained: a high resolution T1 3D MPRAGE. Image data were transferred via the network for quantitative analysis and to magnetic tape for backup.

Dependent Measures.

Psychometric inventories: to characterize population.

Performance Failure Appraisal Inventory (PFAI).

This inventory is a multidimensional measure of cognitive-motivational-relational appraisals associated with fear of failure (FF). FF was associated with (a) high levels of worry, somatic anxiety, cognitive disruption, and sport anxiety, and (b) low levels of optimism. General FF was unrelated to either perceived competence or fear of success. This measure consists of five questions examining failure appraisal: 1) When I am failing, I am afraid that I might not have enough talent; 2) When I am failing, it upsets my "plan" for the future; 3) When I am not succeeding, people are less interested in me; 4) When I am failing, important others are disappointed; 5) When I am failing, I worry about what others think about me. Subjects are asked to rate these questions based on the following range: Do Not Believe at All, Believe 50% of the Time, Believe 100% of the Time. To compute the general fear of failure score all 5 item scores are averaged (Conroy, 2001).

State-Trait Anxiety Inventory (STAI).

This is a 40-item self-report index of state and trait anxiety consisting 20 state items and 20 trait items. The STAI-T consists of 20-items rated on a 4-point scale ranging from ‘not at all’ to ‘very much so’ in terms of how the participant feels at the moment. The STAI-T score ranges from 20 to 80, with increasing scores reflecting greater trait anxiety (Spielberger, et al., 1970).

Dispositional Resilience Scale (DRS).

This inventory is a hardiness measure with 5 items each to measure the hardiness facets of Commitment, Control, and Challenge. Each question asks how much you think each one is true for you ranging from 0=Not at all true; 1=A little true; 2=Quite true; 3=completely true. Six items are negatively-keyed, which makes this scale quite well-balanced for negative and positive items. Results include raw scores and percentiles for commitment, control, challenge, and total hardiness (Bartone et al., 2008).

Sport Competition Anxiety Test (SCAT).

This is a 15-item questionnaire gauging an individual’s tendency to perceive competitive situations as threatening and to respond to these situations with elevated state anxiety. Subjects are asked to indicate how they generally feel when they compete in sports and games and respond to each item using a three-point scale (hardly ever, sometimes and often). Scores on the SCAT range from 10 to 30 (Martens, Vealey, & Burton, 1990).

Beck Depression Inventory (BDI).

This is a 21 item self-report questionnaire evaluating depression symptoms. It is a widely accepted measure consistent with clinician ratings and other depression scales based its comparable internal consistency and validity. Each question consists of 4 statements describing increasing intensities of symptoms of depression. Questions are rated on a scale from 0–3, reflecting how participants have felt over the past week. Possible scores range from 0–48; higher scores reflect more severe depressive symptomotology. (Beck, Rush, Shaw, & Emery, 1979).

Emotion Regulation Questionnaire (ERQ).

This is a 10-item self-report questionnaire indexing the habitual use of expressive suppression and cognitive reappraisal. This measure consists of 10 questions, 4 measuring suppression (e.g., 'I keep my emotions to myself') and 6 measuring reappraisal (e.g., 'When I want to feel more negative emotion I change what I'm thinking about'). Higher scores indicate more frequent use of each strategy. (J. J. Gross & John, 2003)

Physiological measures of arousal.

Galvanic skin response.

Skin conductance is measured using the Psylab Stand Alone Monitor through the application of a small voltage across two electrodes and in turn measures the current that flows between the electrode locations. Electrode placement is constrained to sites unique to eccrine sweating, which, is related to mental processes and exclusively under sympathetic control. Electrodes were placed on medial phalanges on left index and middle fingers. The skin conductance data were recorded continuously at a rate of 25 samples per second. Off-line analysis of skin conductance response waveforms using a local peak-detection algorithm was used to compute stimulus-related skin conductance responses defined as trough-to-peak conductance differences greater than 3.1 micro Siemens occurring within 100 second windows to minimize transition points. The amplitude of the largest skin conductance response associated with each stimulus (skin conductance response magnitude) was used as an index of the subject's maximum arousal during that stimulus (if no skin conductance response was detected, amplitude was considered to be 0) (Butler, et al., 2007). Skin conductance response were then co-registered with viewing time by examining time windows 0.5 s to 12 s following stimulus onset (Butler, et al., 2007). The skin conductance responses were then averaged within the cognitive reappraisal SS, IAPS, passive negative SS, IAPS, passive neutral conditions for each subject.

Heart rate.

HR was measured using the Invivo cart (3150 MRI) using the 4-in-1 Quadtrode® MRI ECG Electrode placed on the subject's left side, below the left pectoral, on the bottom of the ribcage. As a secondary measure, we used a pulse oximeter on the left thumb of the participant in case the ECG recording became disrupted due to the MRI gradients. HR was then co-registered with viewing time (8 s) and then averaged within the cognitive reappraisal SS, IAPS, passive negative SS, IAPS, passive neutral conditions for each subject.

Behavioral measures - affective rating.

Mean negative affect ratings will be calculated for the passive negative (SS and IAPS), passive neutral, and cognitive reappraisal (SS and IAPS) conditions for "How Negative Do You Feel?" (1= not at all, 3=moderately, 5=extremely).

Functional Magnetic Resonance Imaging: BOLD Signal.

The DICOM images were extracted and imported into the signal processing software for preprocessing (e.g., Statistical Parametric Mapping, SPM5). Slice timing correction was followed by correction for head motion during scanning (through the registration of the time series to the reference first scan). The motion parameters were saved for later statistical analysis to be used as regressors in the design matrix. This step was followed by creating binary mask so that voxels outside of the brain are removed. For statistical comparisons to be made across subjects, the data were normalized into MNI format (template EPI.mni) in order to account for variability in brain shape and size. Default SPM5 settings were used to warp volumetric MRIs to fit the standardized template (16 nonlinear iterations), and normalization parameters were applied to subject's functional images. Normalized images were resampled into 2 × 2 × 2 mm voxels. Then, a spatial smoothing of the images was performed by employing a low pass spatial filter which remove high frequency spatial components resulting in the 'blur' of the images (Huettel, Song, & McCarthy, 2003). The Gaussian filter of 6mm (the width is determined by half of the maximum value, Full-Width-Half-Maximum, FWHM) essentially acted to spread the intensity of each voxel in the image to neighboring voxels serving to maximize the signal to noise ratio and reducing false positives in the later statistical analysis (Huettel, et al., 2003).

Statistical Analysis.

Psychometric inventories: to characterize population.

For the PFAI, STAI, DRS, SCA, BDI and ERQ, mean and standard deviations for each item were computed. Group comparisons were tested using a paired t-test.

Physiological measures of arousal.

Galvanic skin response.

Two way ANOVA (2 x 5) Group (control, football) by Condition (cognitive reappraisal SS, passive negative SS, cognitive reappraisal IAPS, passive negative IAPS, passive neutral) was executed. Tukey's post-hoc tests were employed to examine all possible comparisons.

Heart rate.

Two way ANOVA (2 x 5) Group (control, football) by Condition (cognitive reappraisal SS, passive negative SS, cognitive reappraisal IAPS, passive negative IAPS, passive neutral) was executed. Tukey's post-hoc tests were employed to examine all possible comparisons.

Behavioral measures - affective rating.

To examine within group effects one way ANOVAs were executed for each group with Condition as the factor (cognitive reappraisal SS, passive negative SS, cognitive reappraisal IAPS, passive negative IAPS, passive neutral). Tukey's post-hoc tests were employed to examine all possible comparisons.

Functional Magnetic Resonance Imaging: BOLD Signal.

Preprocessed images were entered into a General Linear Model in SPM5 that modeled the canonical hemodynamic response function convolved with an 8-second boxcar representing the picture-viewing period. Motion parameters, the instructional cue period, and the rating period were entered into the model as additional regressors. The General Linear Model (boxcar models representing the picture-viewing period of each condition) was used to create contrasts for each condition, for each subject, for each domain. These individual contrasts were then entered into a Full Factorial design of a 2 x 4 ANOVA Group by Conditions to perform a random-effects group analysis. The Group factor consisted of Football and Control and the Condition factor consisting of Cognitive Reappraisal SS, Passive Negative SS, Cognitive Reappraisal IAPS, and Passive Negative IAPS. Conditions of interests were examined (Cognitive Reappraisal SS, Passive Negative SS, Cognitive Reappraisal IAPS, Passive Negative IAPS) for each group relative to the neutral baseline. Direct comparison contrasts were computed within group between each condition (Cognitive Reappraisal SS-Passive Negative SS, Passive Negative SS- Cognitive Reappraisal SS, Cognitive Reappraisal IAPS-Passive Negative IAPS, Passive Negative IAPS- Cognitive Reappraisal IAPS) for the whole brain and regions of interest (ROI). ROI analysis was executed using anatomical masks generated by the Wake Forest Pick Atlas. The ROIs examined were based on a priori theoretical predictions of areas sensitive to cognitive and affective processing (BA 8, 9, 10, 11, 45, 46, 47, taken from the Wake Forest Pick Atlas indication of Brodmann Areas for the prefrontal cortex, in addition to the insula and amygdala). ROIs of conditions of interests were examined separately (Cognitive Reappraisal SS, Passive Negative SS, Cognitive Reappraisal IAPS, Passive Negative IAPS) for each group with the neutral baseline using the same Wake Forest Pick Atlas anatomical masks.

Results

Psychometric Inventories: to Characterize Population.

Performance Failure Appraisal Inventory (PFAI).

Paired t-test revealed a significant difference between group (p=0.0073) with football group showing less fear of failure (M=-1; SD=0.66) compared to the control group (M=-0.11; SD =0.81) (Figure 22).

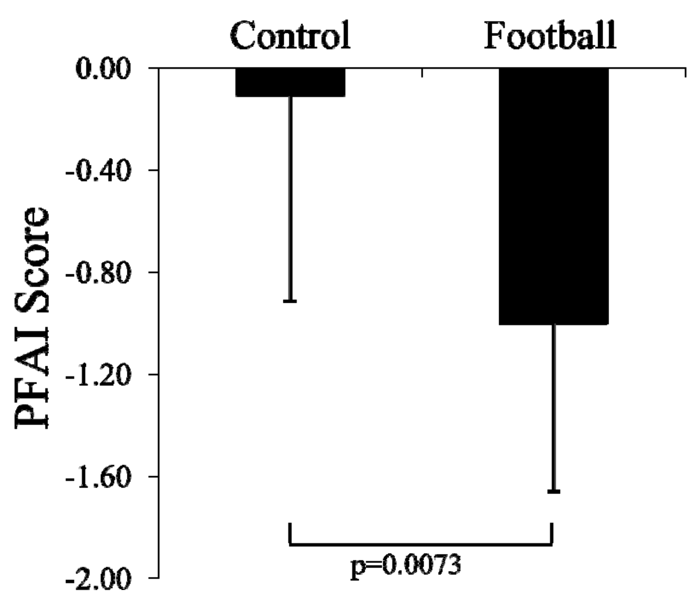


Figure 22. The PFAI revealed that the football group demonstrated significantly less fear of failure compared to the control group (same as Figure 8).

State-Trait Anxiety Inventory (STAI).

Paired t-test revealed no difference (p=0.9299) in state anxiety between the football group (M=27.5; SD=6.7) and the control group (M=27.3; SD=5.9). Paired t-test also revealed no difference (p=0.2041) between trait anxiety with the football mean of 32.4 (M=32.4; SD=4.2) and the control mean of 35.3 (M=35.3; SD=5.8) (Figure 23).

Dispositional Resiliency Scale (DRS).

The paired t-test revealed no difference (p=0.2851) between the control group (M=34; SD=4) and the football group (M=36; SD=4). The control group was in the 87.7 percentile for total hardiness and the football group was in the 94.2 percentile for total hardiness (Figure 23).

Sports Competition Anxiety Test (SCAT).

The paired t-test revealed no difference (p=0.885) between the groups with the control group mean score of 18 (M=18; SD=4) and the football mean score of 18 (M=18; SD=5) (Figure 23).

Beck Depression Inventory (BDI).

The paired t-test revealed no significant difference between group p=0.2512 with the control group mean of 5 (M=5; SD=5) and the football group mean of 3 (M=3; SD=3) (Figure 23).

Emotion Regulation Questionnaire (ERQ).

Paired t-tests between group revealed no difference (p=0.6793) between expressive suppression (Football: M=14; SD=4. Control M=15; SD=3) and no difference (p=0.2996) between cognitive reappraisal (Football M=32; SD=3. Control M=30; SD=6). Both groups scored higher on cognitive reappraisal compared to expressive suppression (Figure 23).

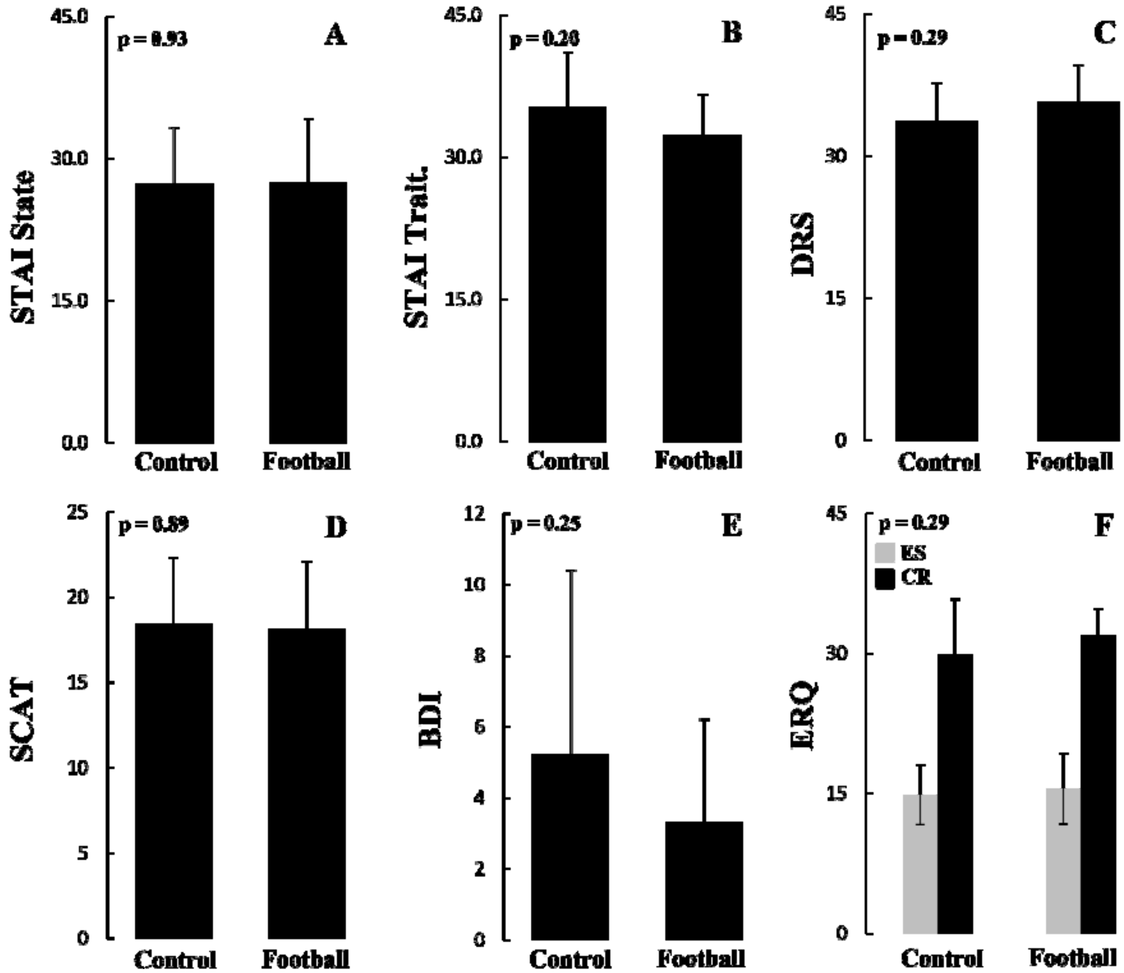


Figure 23. Self report results from psychometric inventories. The control group and football group were statistically equivalent on STAI State (A) STAI Trait (B); DRS (C); SCAT (D); BDI (E); ERQ (F) (same as Figure 11).

Physiological Measures of Arousal.

Exploratory results from HR and GSR. Datasets were incomplete due to technical problems with the recording devices (i.e., only 3 control subjects were recorded for HR).

Galvanic skin response.

A two way ANOVA (Group x Condition) revealed no significant difference between group or within condition (Condition main effect p=0.089; Group x Condition interaction p=0.31) (Figure 24).

Heart rate.

A two way ANOVA (Group x Condition) revealed no significant difference between group or within condition (Condition main effect p=0.544; Group x Condition interaction p=0.273) (Figure 24).

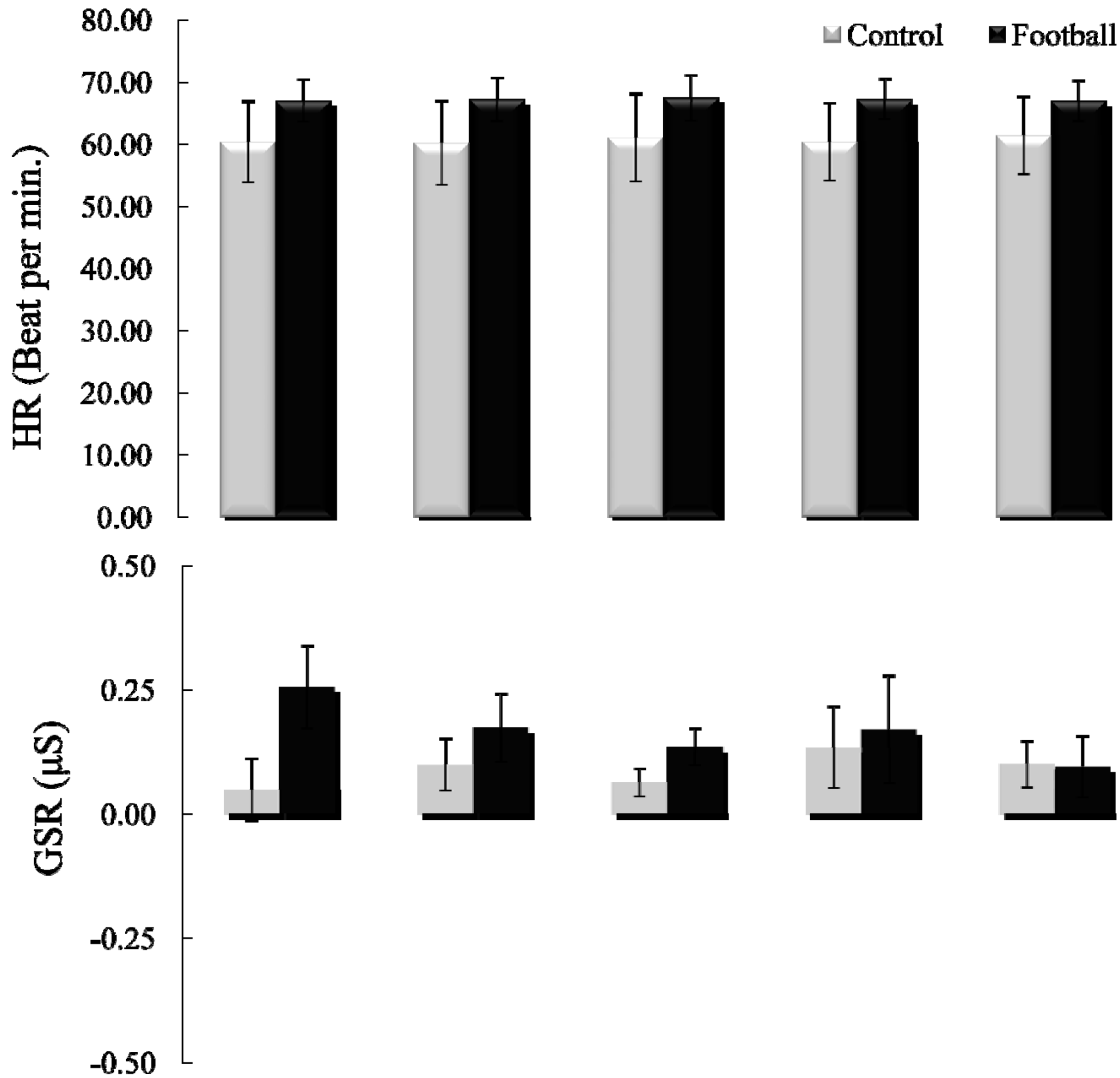


Figure 24. Exploratory results from HR and GSR. Datasets were incomplete due to technical problems with the recording devices (i.e., only 3 control subjects were recorded for HR). Results reveal no significant differences 1) Condition Main Effect: HR: $p=0.544$; GSR: $p=0.089$. 2) Group x Condition: HR: $p=0.273$; GSR: $p=0.31$ (same as Figure 12).

Behavioral Measures - Affective Rating.

Separate 1 way ANOVAs revealed significant main effects for Condition for each group. The control group ($p<0.001$) Tukey's HSD post-hoc analysis revealed significant differences between all conditions. This indicates that during cued cognitive reappraisal of SS images (M=1.89; SE=0.19) these affective effects were perceived as significantly less negative than during the nature response to SS image (M=2.72; SE=0.25). In addition the cognitive reappraisal of IAPS images (M=1.60; SE=0.17) were perceived less negative compared to the nature response to IAPS images (M=3.2; SE=0.23). Lastly the neutral images were rated significantly less negative (M=1.42; SE=0.13) compared to the negative IAPS and SS images. The football group (p=0.001) Tukey's HSD post-hoc analysis revealed that the passive viewing of negative SS images (M=2.46; SE=0.24) was significantly more negative than viewing neutral images (M=1.28; SE=0.12). In addition the cognitive reappraisal of IAPS images (M=1.65; SE=0.16) was significantly less negative than the passive viewing of IAPS (M=2.69; SE=0.22) images but more negative than viewing the neutral images (M=1.28; SE=0.12). The cognitive reappraisal of SS images (M=1.97; SE=0.19) was rated statistically equal to the natural response of viewing SS negative images (M=2.46; SE=0.24) (Figure 25).

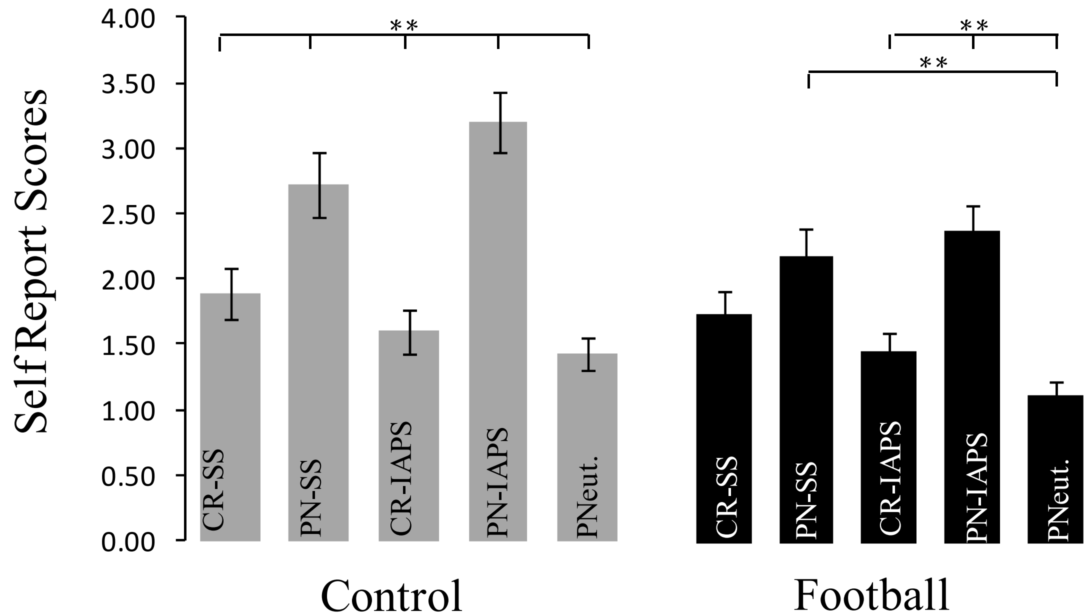


Figure 25. Self report scores from Affective Ratings of "How Negative Do You Feel?" (1=not at all, 3 moderately, 5 extremely) from separate one-way ANOVAs. The control group (left panel) rating of each condition was significantly different. The football group (right panel) rated the cognitive reappraisal of SS images and the passive response to SS images statistically equal, whereas as the generalized images (IAPS) were rated differently. CR-SS: Cognitive Reappraisal of SS Images; PN-SS: Passive (viewing of) Negative of SS Images; CR-IAPS: Cognitive Reappraisal of IAPS Images; PN-IAPS: Passive (viewing of) Negative of IAPS Images; PNEut: Passive (viewing of) Neutral of IAPS Images (same as Figure 13).

Functional Magnetic Resonance Imaging: BOLD Response.

Direct comparisons between conditions: whole brain and regions of interest.

The results trend towards support of the Domain-Specific Model of Emotion Regulation. Although these differences did not survive multiple comparisons corrections (neither FWE or FDR) the results approached significance ($p<0.05$, uncorrected) in a manner that supports the domain-specific model of emotion regulation: direct comparisons revealed no difference in ROIs between cued

Cognitive Reappraisal and Passive Negative of SS negative images for the football group. Furthermore, direct comparisons between the cued Cognitive Reappraisal and the Passive Negative conditions resulted in differences in regions of interest (PFC, insula) for the football group during conditions of IAPS challenge. Direct comparisons also revealed differences in neural processing between cued Cognitive Reappraisal and the Passive Negative conditions for the control group independent of stimulus type.

Whole brain direct comparison results were examined in addition to regions of interest (ROIs). The ROIs of the direct comparison results were executed using anatomical masks generated by the Wake Forest Pick Atlas. The ROIs examined were based on a priori theoretical predictions of areas sensitive to cognitive and affective processing (PFC, amygdala and insula).

FOOTBALL: cognitive reappraisal SS - passive viewing SS.

Direct comparison of the SS conditions (CR SS - PN SS) indicated very little differences between the natural response of football players to SS challenge and the cued emotion regulation conditions. There were no differences between these conditions in all of the ROIs. Beyond the ROIs, the left supramarginal gyrus (BA 40), the left STG (BA 38) and the left premotor cortex (BA 6) was active during Cognitive Reappraisal - Passive Negative (Figure 26, Table 10).

FOOTBALL: passive viewing SS- cognitive reappraisal SS.

No difference was detected during the Passive Negative SS – Reappraisal SS contrast (PN SS – CR SS) (Figure 26, Table 10).

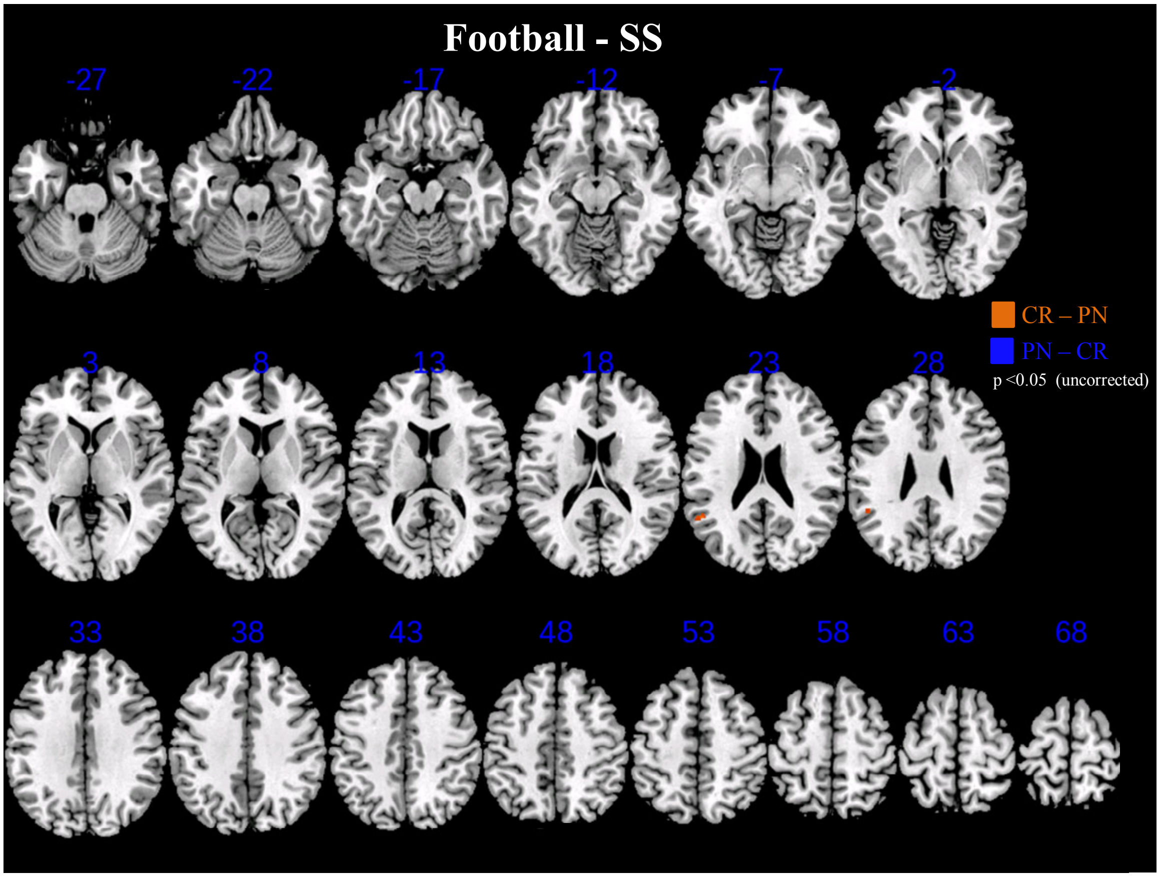


Figure 26: Whole brain axial slice results (inferior-superior) from direct comparisons between conditions for the Football group during SS Negative Images (Football – SS). The orange indicates contrast results from Cognitive Reappraisal – Passive Negative (CR - PN) for SS negative images. The blue indicates contrast results from Passive Negative - Cognitive Reappraisal (PN - CR) for SS negative images.

FOOTBALL: cognitive reappraisal IAPS - passive viewing IAPS.

Direct comparisons between the Cognitive Reappraisal of IAPS images and the Passive Response (CR IAPS – PN IAPS) to IAPS images indicated activation in the left DLPFC (BA 8,9, 46), the bilateral DMPFC (BA8), bilateral VLPFC

(BA10/45), right VMPFC (BA 10), bilateral ACC (BA 32) , left IFG (BA47), left insula (BA13), bilateral OFC (BA11), bilateral SMA (BA6), left MTG (BA 21), left postcentral gyrus (BA 43), bilateral lentiform nucleus, right uncus (BA 28), right parahippocampal gyrus, bilateral STG (BA 22), bilateral cerebellum, bilateral clustrum and left caudate (Figure 27, Table 10).

FOOTBALL: passive viewing IAPS – cognitive reappraisal IAPS.

Passive viewing of IAPS images resulted in left DMPFC (BA 10), left MTG (BA 21), left STG (BA 38), and right motor cortex (BA 4) activation compared to the Cognitive Reappraisal of IAPS images (contrast (PN IAPS- CR IAPS)) (Figure 27, Table 10).

The results indicate that there was a difference between the natural response of football players to generalized negative images (IAPS) and the cued cognitive reappraisal of IAPS images, supporting the domain-specific model of emotion regulation.

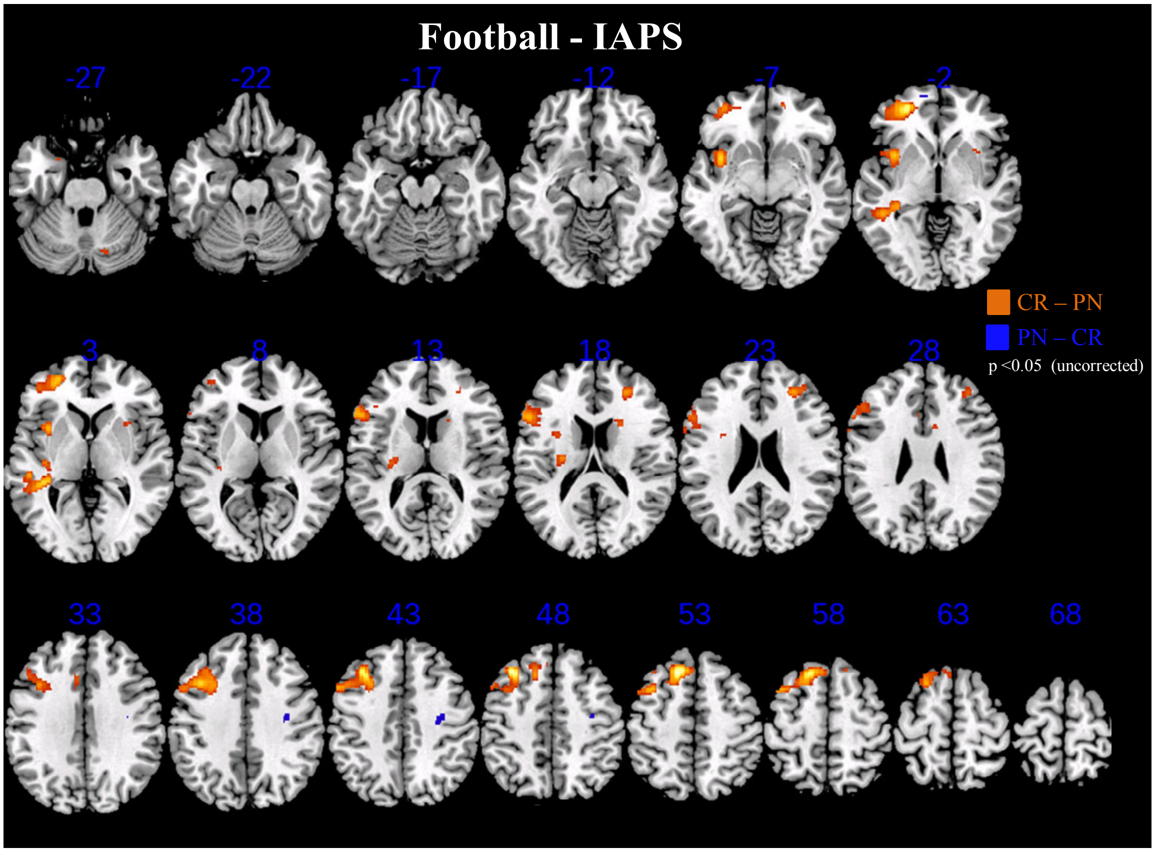


Figure 27. Whole brain axial slice results (inferior-superior) from direct comparisons between conditions for the Football group during IAPS Negative Images (Football – IAPS). The orange indicates contrast results from Cognitive Reappraisal – Passive Negative (CR - PN) for IAPS negative images. The blue indicates contrast results from Passive Negative - Cognitive Reappraisal (PN - CR) for IAPS negative images.

Group	Contrast Conditions	Region	BA	Left			Right		
				Volume in Voxels	MNI coordinates x, y, z	t values	Volume in Voxels	MNI coordinates x, y, z	t values
FOOTBALL	CRSS - PNSS	Premotor	6	3	-10 14 70	1.72			
		STG	38	4	-32 20 -28	1.84			
		Supramarginal Gyrus	40	27	-50 -52 22	1.85			
	PNSS - CRSS	--	--	--	--	--	--	--	--
	CR IAPS - PN IAPS	DLPFC	8	91	-32 26 46	2.89			
		DLPFC	9	108	-32 24 42	2.63			
		DLPFC	46	11	-56 26 26	1.93			
		DMPFC	8	28	-4 26 56	2.06	2	16 30 56	1.71
		VLPFC	10	54	-26 50 -2	2.62	183	28 40 20	2.22
		VLPFC	45				2	64 14 18	1.75
		VMPFC	10				12	14 52 -6	1.88
		IFG	47	1	-40 40 -6	1.7			
		OFC	11	2	-12 48 -18	1.9	2	12 50 -16	1.71
		ACC	32	56	-8 20 32	1.88	3	10 10 28	1.75
		Insula	13	154	-36 10 -2	2.36			
		SMA/Premotor	6	1657	-14 26 56	2.95	7	16 28 58	1.78
		MTG	21	373	-50 -30 2	2.13			
		STG	22	232	-48 10 0	1.73	3	42 16 -20	1.7
		Postcentral Gyrus	43	4	-58 -14 16	1.71			
		Uncus	28				1	28 -8 -26	1.72
		Caudate	--	373	-36 -36 0	2.39			
		Claustrum	--	373	-28 -16 18	2.04	17	32 14 0	1.83
		Leniform Nucleus	--	2	-24 -6 -8	1.7	22	22 12 18	1.85
		Cerebellum	--	12	-4 -60 -8	1.85	22	16 -70 -30	2.01
		Parahippocampal Gyrus	34				3	14 6 -12	1.86
	PN IAPS - CR IAPS	DMPFC	10	5	-12 60 -2	1.94			
		Motor Cortex	4				55	32 -14 42	2.03
		MTG	21	1	-52 4 -38	1.75			
		STG	38	1	-38 14 -40	1.71			

Table 2. Results from direct comparisons between conditions for the Football group. Top panel indicates contrast results from the Cognitive Reappraisal of SS images – Passive Negative of SS images (CRSS -PNSS). The second panel indicates contrasts results for Passive Negative of SS images - Cognitive Reappraisal of SS images (PNSS - CRSS). Third panel indicates contrast results from the Cognitive Reappraisal of IAPS images – Passive Negative of IAPS images (CRIAPS - PNIAPS). Bottom panel indicates contrasts results for Passive Negative of IAPS images - Cognitive Reappraisal of IAPS images (PNIAPS - CRIAPS). Whole brain analysis reported at uncorrected threshold $p<0.05$ (marked without star). Red text signifies results from region of interest analysis (ROI) derived from Wake Forest anatomical mask. ROI analysis is adjusted for search volume, at an uncorrected threshold $p<0.05$ (marked without star).

CONTROL: cognitive reappraisal SS - passive viewing SS.

Direct comparisons of Cognitive Reappraisal SS and Passive Negative SS (CR SS – PN SS) revealed greater activation in the left DMPFC (BA 8), left IFG (BA 47), right insula (BA 13), right IFG (BA 44), left SMA (BA 6), left caudate, left supramarginal gyrus (BA 40), bilateral pulivinar, right MTG (BA 21) and left Primary Motor cortex (BA 4) during cued emotion regulation (p<0.05, uncorrected) (Figure 28, Table 11).

In addition, the bilateral isula (BA13), right VLPFC (BA 10), right cerebellum, right postcentral gyrus (BA 2), right SPL (BA 7), and right IPL (BA 40) were active during passive viewing of negative SS images (PN SS- CR SS) (Figure 28, Table 11).

The results indicate that there was a difference between the natural response of the control group to sports specific negative images and the cued cognitive reappraisal of sports specific challenge.

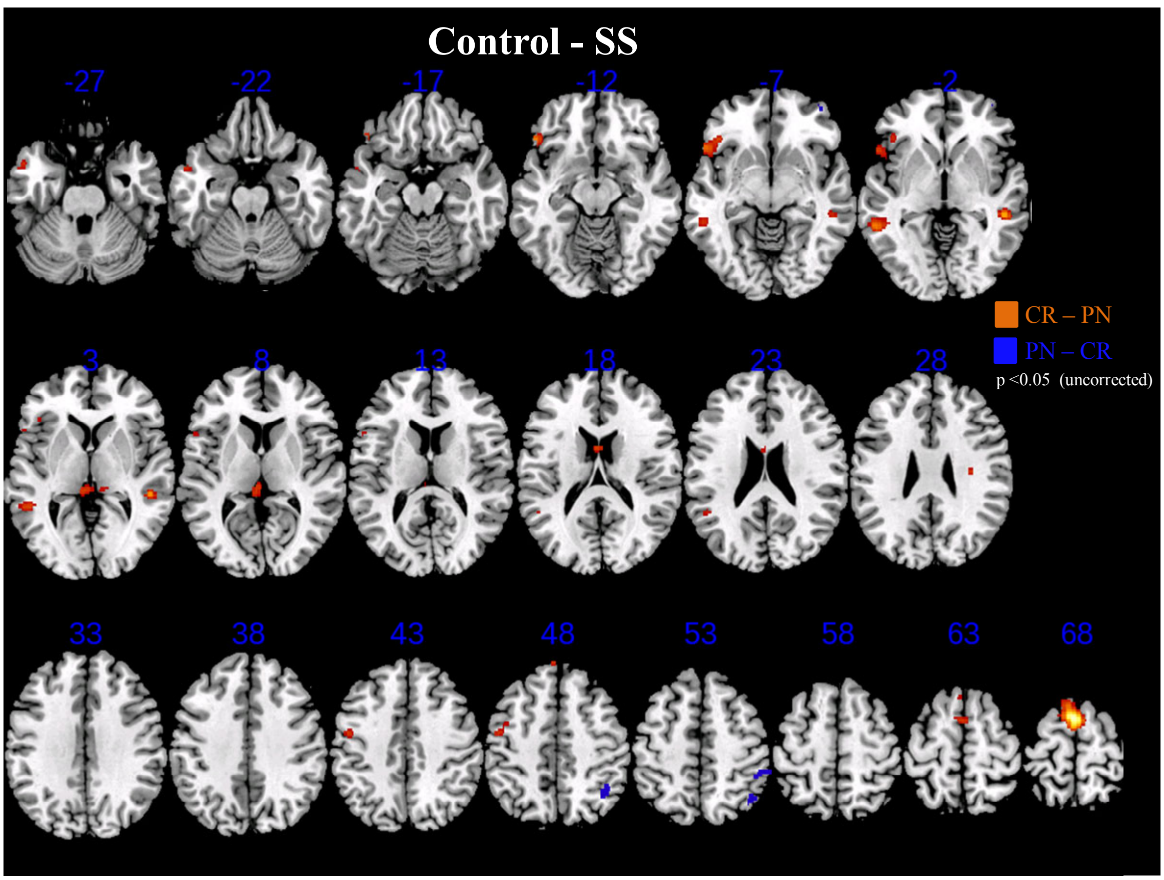


Figure 28. Whole brain axial slice results (inferior-superior) from direct comparisons between conditions for the Control group during SS Negative Images (Control –SS). The orange indicates contrast results from Cognitive Reappraisal – Passive Negative (CR - PN) for Sports Specific negative images. The blue indicates contrast results from Passive Negative - Cognitive Reappraisal (PN - CR) for Sports Specific negative images.

CONTROL: cognitive reappraisal IAPS - passive viewing IAPS.

Direct comparisons within the IAPS image set between Cognitive Reappraisal and Passive Negative (CR IAPS – PN IAPS) revealed that during cued cognitive reappraisal the left IFG (BA47/44), left parahippocampal gyrus, left SMA (BA 6), and bilateral MTG (BA 20) were active (Figure 29, Table 11).

CONTROL: passive viewing IAPS - cognitive reappraisal IAPS.

During passive viewing of negative images, right VMPFC (BA 10), right DLPFC (BA 46/9), the premotor cortex (BA 6), right SPL (BA 7), left PCC (BA 30), bilateral middle occipital gyrys (BA 18,19), right parahippocampal gyrus, left cerebellum, and right IT (BA 20) were active compared to the cued cognitive reappraisal of negative IAPS images (PN IAPS – CR IAPS) (Figure 29, Table 11).

The results indicate that there was a difference between the natural response of the control group to IAPS negative images and the cued cognitive reappraisal of generalized challenge.

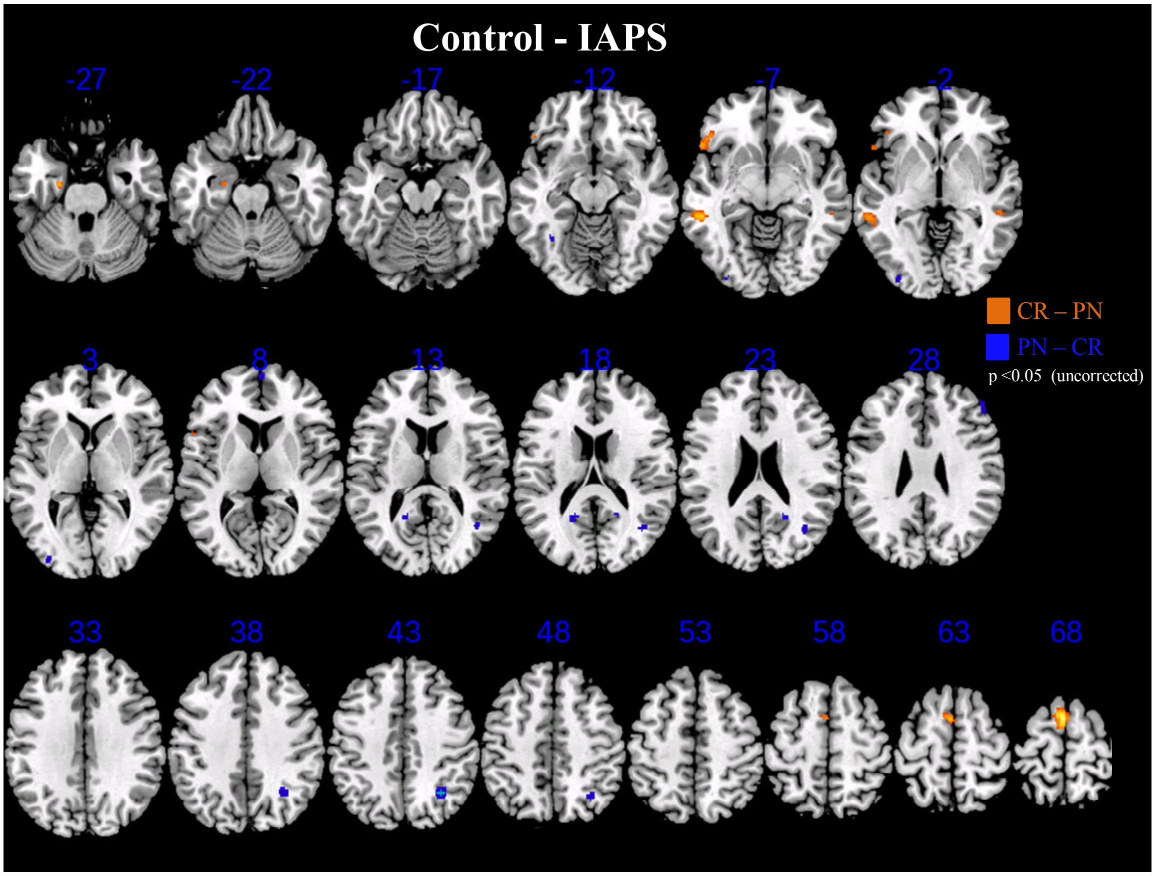


Figure 29. Whole brain axial slice results (inferior-superior) from direct comparisons between conditions for the Control group during IAPS Negative Images (Control – IAPS). The orange indicates contrast results from Cognitive Reappraisal – Passive Negative (CR - PN) for IAPS negative images. The blue indicates contrast results from Passive Negative - Cognitive Reappraisal (PN - CR) for IAPS negative images.

Group	Contrast Conditions	Region	BA	Left			Right		
				Volume in Voxels	MNI coordinates x, y, z	t values	Volume in Voxels	MNI coordinates x, y, z	t values
CONTROL	CRSS - PNSS	DMPFC	8	11	-2 52 46	1.97			
		IFG	44	22	-56 14 12	1.75			
		IFG	47	36	-50 28 -12	2.27			
		Insula	13				17	32 -16 26	1.93
		Precentral Gyrus	4	69	-48 -8 44	2.12			
		SMA/Premotor	6	426	-4 8 70	3.34			
		MTG	21				91	50 -34 0	2.51
		Supramarginal Gyrus	40	16	-48 -50 22	1.86			
		Caudate	--	27	-2 2 20	2.01			
		Pulivinar	--	128	-4 -32 6	2.15	128	12 -32 4	1.9
	PNSS - CRSS	VLPFC	10				4	40 58 -4	1.74
		Insula	13	3	-38 -18 2	1.73	2	42 -16 10	1.81
		Postcentral Gyrus	2				3	56 -28 56	1.8
		SPL	7				100	42 -62 54	1.91
		IPL	40				34	50 -40 54	1.83
		Cerebellum	--				17	14 -58 -32	1.97
	CR IAPS - PN IAPS	IFG	47	17	-54 20 -6	1.97			
		IFG	44	6	-56 14 8	1.69			
		SMA/Premotor	6	232	-2 4 68	2.34			
		MTG	20/21	100	-54 -38 -6	2.14	20	54 -36 -4	1.83
		Parahippocampal Gyrus	--	25	-22 -12 -26	2.06			
	PN IAPS - CR IAPS	DLPFC	46				25	50 40 28	1.83
		DLPFC	9				2	2 62 34	1.71
		VMPFC	10				26	2 62 8	1.89
		Premotor	6				1	12 36 60	1.71
		IT	20				1	52 -50 -12	1.68
		SPL	7				112	32 -58 42	2.34
		MOG	18/19	28	-34 -90 0	1.94	41	42 -62 16	1.85
		Parahippocampal Gyrus	--				2	36 -24 -20	1.88
		PCC	30	34	-18 -54 16	2.21			
		Cerebellum		6	-34 -58 -10	1.73			

Table 11. Results from direct comparisons between conditions for the Control group. Top panel indicates contrast results from the Cognitive Reappraisal of SS images – Passive Negative of SS images (CRSS -PNSS). The second panel indicates contrasts results for Passive Negative of SS images - Cognitive Reappraisal of SS images (PNSS - CRSS). Third panel indicates contrast results from the Cognitive Reappraisal of IAPS images – Passive Negative of IAPS images (CRIAPS - PNIAPS). Bottom panel indicates contrasts results for Passive Negative of IAPS images - Cognitive Reappraisal of IAPS images (PNIAPS - CRIAPS). Whole brain analysis reported at uncorrected threshold $p<0.05$ (marked without star). Red text signifies results from region of interest analysis (ROI) derived from Wake Forest anatomical mask. ROI analysis is adjusted for search volume, at an uncorrected threshold $p<0.05$ (marked without star).

Condition Region of Interest Analysis.

Overall the results support a specificity of self regulation, with the football group only demonstrating amygdala and bilateral insula activity during generalized negative events (IAPS) while the control group responded aversively to all negative conditions (SS and IAPS).

Region of Interest (ROI) analyses for each condition relative to the neutral baseline executed using anatomical masks generated by the Wake Forest Pick Atlas.

The ROIs examined were based on a priori theoretical predictions of areas sensitive to cognitive and affective processing (PFC, amygdala and insula). Multiple comparison corrections of the ROIs were done using Family Wise Error (FWE) thresholded at $p<0.05$ unless otherwise noted.

Prefrontal cortex.

FOOTBALL: cognitive reappraisal Sport-Specific – neutral baseline contrast.

When engaged in cued cognitive reappraisal of SS negative events the football group demonstrated similar patterns of activation to that when responding naturally to SS challenge. In the PFC, there was significant activation in the bilateral DLPFC (BA 46/9) (right region survived FDR correction $p<0.05$), bilateral DMPFC (BA 8) right region survived FDR correction $p<0.05$), bilateral VLPFC (BA 45/10) right region survived FDR correction $p<0.05$), left IFG (BA 47) and left lateral OFC (BA11) (Figure 30, Table 12).

FOOTBALL: passive negative Sport-Specific – neutral baseline contrast.

When challenged with SS negative events the football group naturally demonstrates significant activation in the bilateral DLPFC (BA 46/9), bilateral DMPFC (BA 8), bilateral VLPFC (BA 45/10), bilateral IFG (BA 47) (right IFG only survives FDR correction $p<0.05$) and bilateral lateral OFC (BA11). In addition

VMPFC (BA10) was active bilaterally at a more liberal statistical threshold (p<0.005 uncorrected) (Figure 30, Table 12).

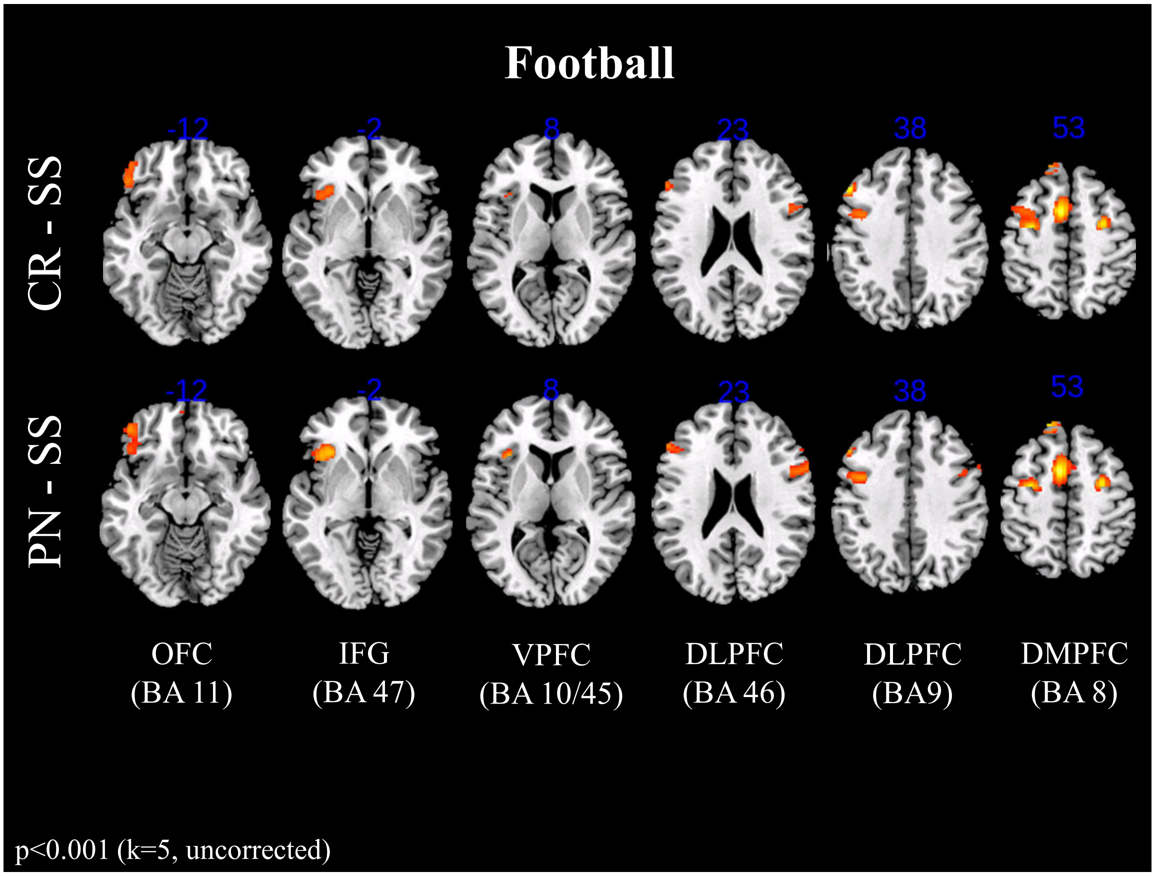


Figure 30. Football group ROI analysis results for the PFC during the SS conditions relative to the neutral baseline. Cognitive Reappraisal of SS images (CR - SS); Passive viewing of Negative SS images (PN –SS).

FOOTBALL: cognitive reappraisal IAPS – neutral baseline contrast.

Examination of the cued cognitive reappraisal of generalized negative images revealed numerous differences between natural response and instructed emotion regulation of the football group. In the PFC, significant activation was revealed in the bilateral DLPFC (BA 46/9), bilateral DMPFC (BA 8), bilateral VLPFC (BA 45/10), bilateral IFG (BA 47) (right IFG only survives FDR correction p<0.05) and bilateral lateral OFC (BA11) (Figure 31, Table 13).

FOOTBALL: passive negative IAPS- neutral baseline contrast.

When viewing generalized negative images (IAPS) the football group naturally responded with significant activation in the left DLPFC (BA46) (uncorrected p<0.002), left DMPFC (BA 8), bilateral VLPFC (BA 45/10) (right hemisphere p<0.004, uncorrected), left IFG (BA47) and bilateral lateral OFC (BA 11) (right hemisphere FDR corrected p<0.05) (Figure 31, Table 13).

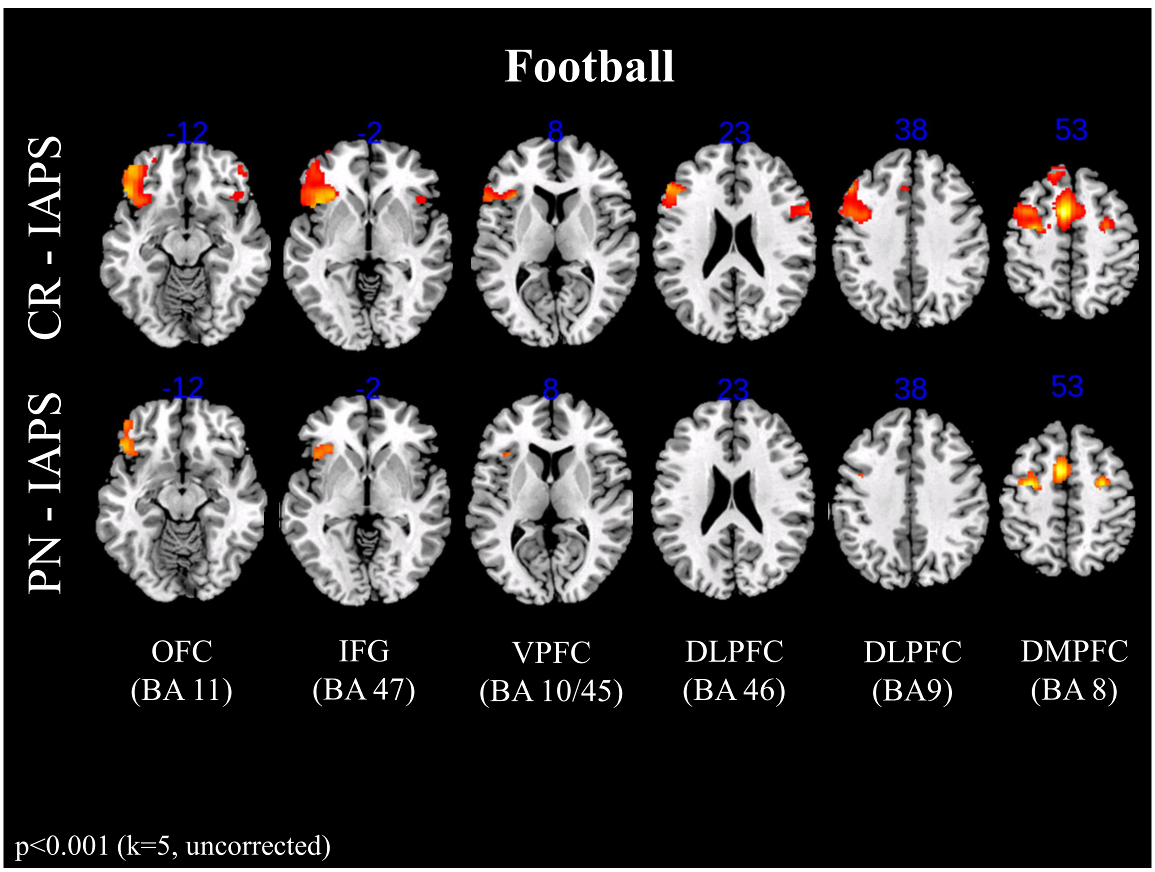


Figure 31. Football group ROI analysis results for the PFC during the IAPS conditions relative to the neutral baseline. Cognitive Reappraisal of IAPS images (CR - IAPS); Passive viewing of Negative IAPS images (PN – IAPS).

CONTROL: cognitive reappraisal Sport-Specific - neutral baseline contrast.

During cued emotion regulation of SS negative images the control group demonstrated significant activation in the bilateral DLPFC (BA 46/9), bilateral DMPFC (BA 8), bilateral VLPFC (BA 45/10), right VMPFC (BA10) (FDR correction $p<0.05$), bilateral IFG (BA 47), bilateral lateral OFC (BA11) and bilateral medial OFC (BA11) (left hemisphere, FDR correction $p<0.05$) (Figure 32, Table 14).

CONTROL: passive negative Sport-Specific - neutral baseline contrast.

When challenged with SS negative images the control group naturally demonstrated significant activation in the bilateral DLPFC (BA 46/9), bilateral DMPFC (BA 8), bilateral VLPFC (BA 45/10), right VMPFC (BA10), bilateral IFG (BA 47), bilateral lateral OFC (BA11) (left hemisphere, FDR correction $p<0.05$) and bilateral medial OFC (BA11) (left hemisphere, FDR correction $p<0.05$) (Figure 32, Table 14).

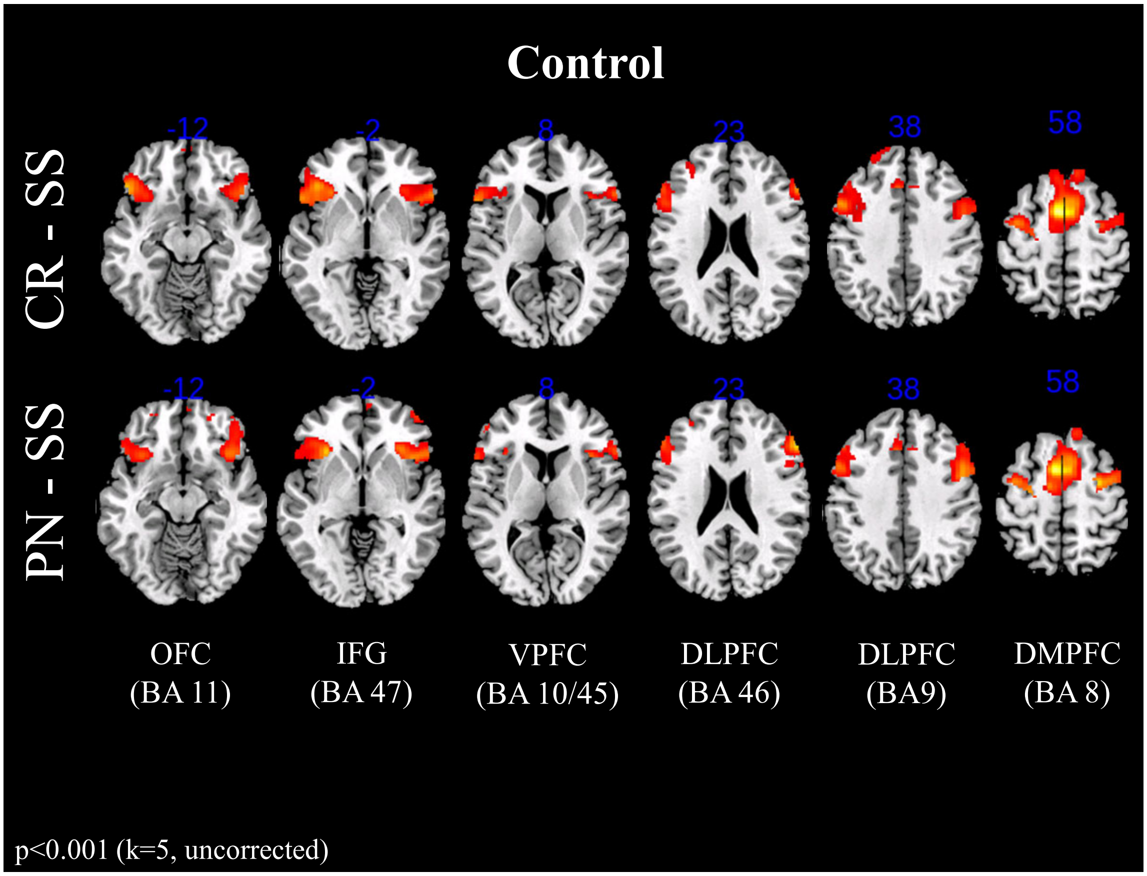


Figure 32. Control group ROI analysis results for the PFC during the SS conditions relative to the neutral baseline. Cognitive Reappraisal of SS images (CR - SS); Passive viewing of Negative SS images (PN –SS).

CONTROL: cognitive reappraisal IAPS– neutral baseline contrast.

During the instructed emotion regulation task during generalized negative events, the control group demonstrated significant activation in the PFC in the bilateral DLPFC (BA 46/9), bilateral DMPFC (BA 8), bilateral VLPFC (BA 45/10), right VMPFC (BA10) (FDR correction $p<0.05$), bilateral IFG (BA 47), bilateral lateral OFC (BA11) and bilateral medial OFC (BA11) (FDR corrected $p<0.05$) (Figure 33, Table 15).

CONTROL: passive negative IAPS – neutral baseline contrast.

The control group demonstrated significant activation in the PFC during the passive response to generalized negative images. Specifically the bilateral DLPFC (BA 46/9), bilateral DMPFC (BA 8), bilateral VLPFC (BA 45/10), bilateral VMPFC (BA10) (left hemisphere, FDR correction p<0.05), bilateral IFG (BA 47), bilateral lateral OFC (BA11) and bilateral medial OFC (BA11) were significantly active (Figure 33, Table 15).

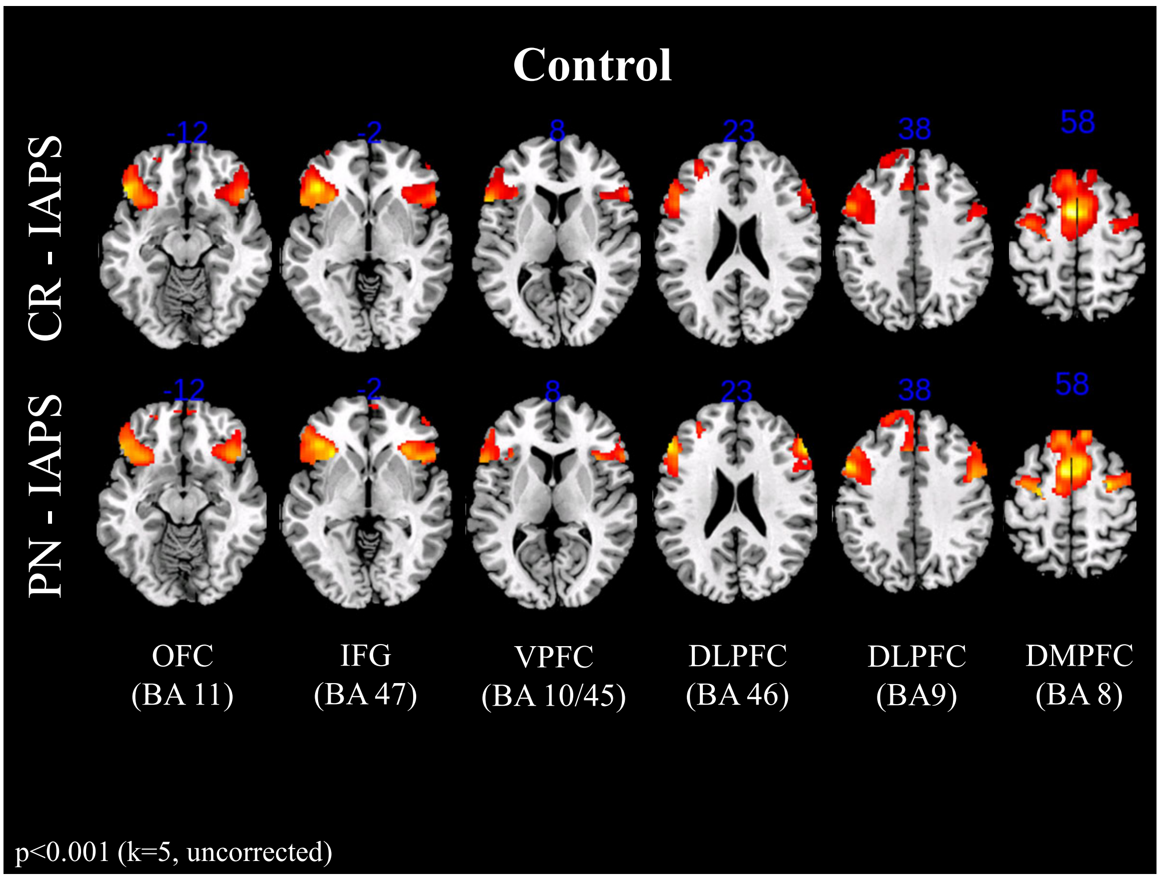


Figure 33. Control group ROI analysis results for the PFC during the IAPS conditions relative to the neutral baseline. Cognitive Reappraisal of IAPS images (CR - IAPS); Passive viewing of Negative IAPS images (PN – IAPS).

Insula and amygdala.

FOOTBALL: cognitive reappraisal Sport-Specific – neutral baseline contrast.

The football group demonstrated significant left lateralized activation in the insula and no amygdala activation during the cued cognitive reappraisal of SS challenge (Figures 34 and 35, Table 12).

FOOTBALL: passive negative Sport-Specific – neutral baseline contrast.

The insula demonstrated significant left lateralized activation and no amygdala activation during the natural response of football group to sports specific challenge (Figures 35 and 36, Table 12).

FOOTBALL: cognitive reappraisal IAPS- neutral baseline contrast.

During the cued cognitive reappraisal of generalized negative images (IAPS) the football group demonstrated bilateral amygdala activation (left $p < 0.008$, right $p < 0.014$, uncorrected) and the bilateral insula activation (right hemisphere FDR corrected $p < 0.05$) (Figures 34 and 35, Table 13).

FOOTBALL: passive negative IAPS- neutral baseline contrast.

The football group demonstrated bilateral insula activation (right hemisphere $p<0.004$, uncorrected) and no amygdala activation during the natural response to generalized negative images (IAPS) (Figures 34 and 35, Table 13).

CONTROL: cognitive reappraisal Sport-Specific - neutral baseline contrast.

During the cued cognitive reappraisal of SS negative images, the insula demonstrated significant bilateral activation and the bilateral amygdala was also active (right amygdala $p<0.012$, uncorrected) (Figures 34 and 35, Table 14).

CONTROL: passive negative Sport-Specific-neutral baseline contrast.

During the passive response of the control group to SS challenge, the insula demonstrated significant bilateral activation and left amygdala was active ($p<0.012$, uncorrected) (Figures 34 and 35, Table 14).

CONTROL: cognitive reappraisal IAPS– neutral baseline contrast.

In the control group, during the cued cognitive reappraisal of IAPS images the insula demonstrated significant bilateral activation and amygdala demonstrated significant bilateral activation (Figures 34 and 35, Table 15).

The insula demonstrated significant bilateral activation and significant bilateral amygdala activation was evident during the natural response of the control group to generalized negative challenge (IAPS) (Figures 34 and 35, Table 15).

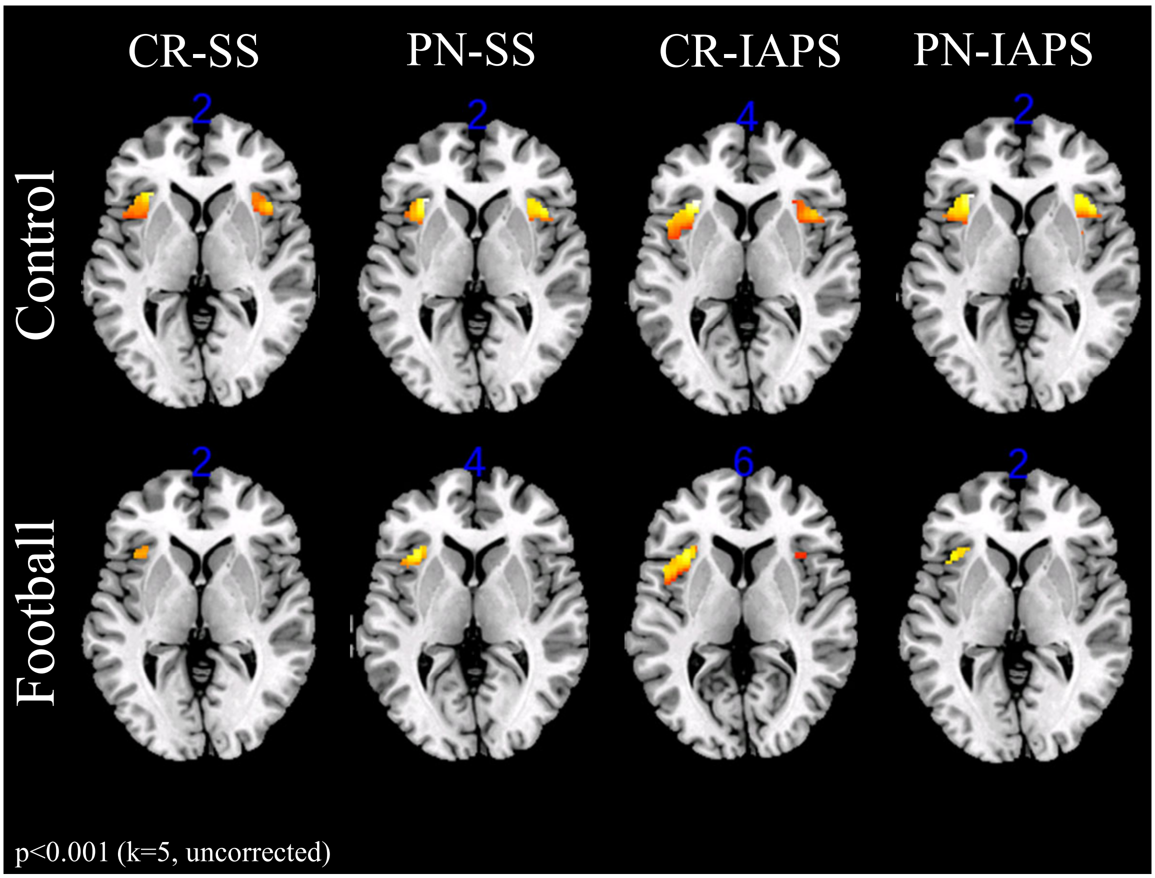


Figure 34. ROI results for the insula (BA 13) for the Control and Football group during all conditions (relative to the neutral baseline). Cognitive Reappraisal of SS images (CR - SS); Passive viewing of Negative SS images (PN – SS). Cognitive Reappraisal of IAPS images (CR - IAPS); Passive viewing of Negative IAPS images (PN – IAPS).

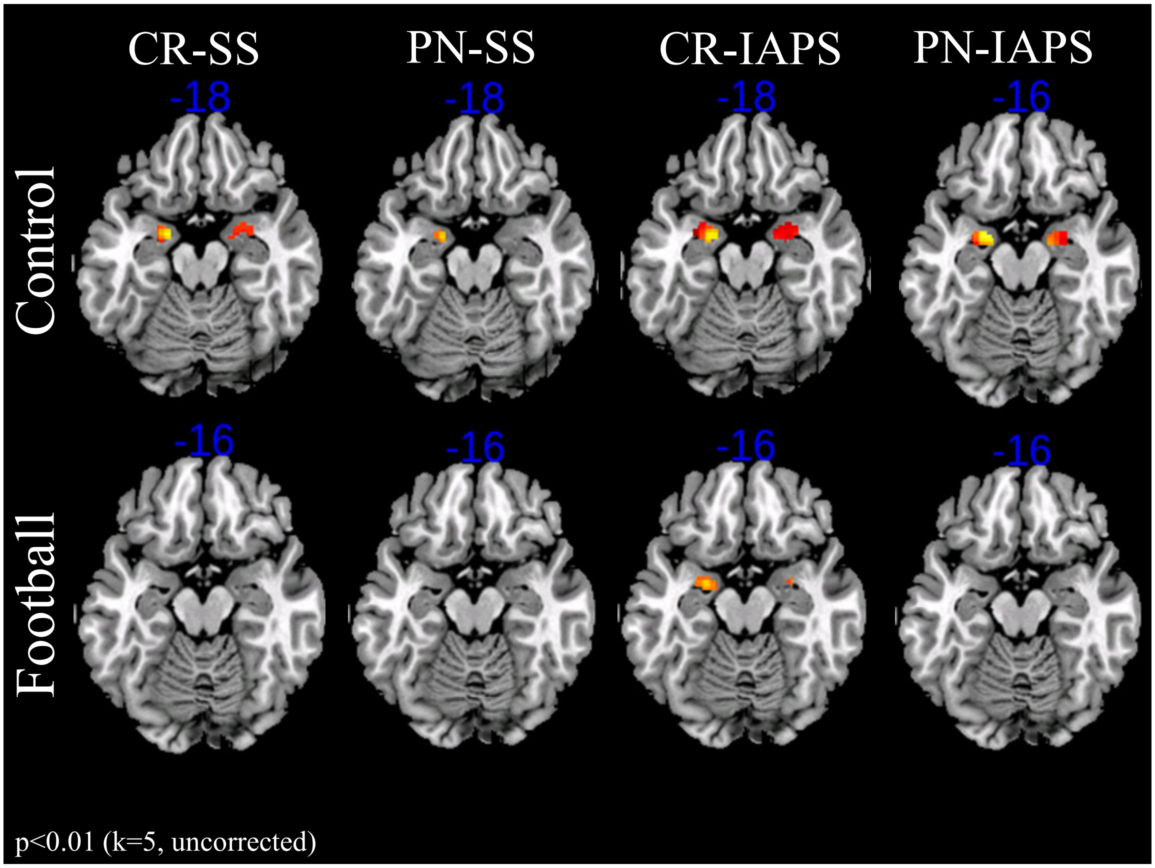


Figure 35. ROI results for the amygdala for the Control and Football group during all conditions (relative to the neutral baseline). Cognitive Reappraisal of SS images (CR - SS); Passive viewing of Negative SS images (PN – SS). Cognitive Reappraisal of IAPS images (CR - IAPS); Passive viewing of Negative IAPS images (PN – IAPS).

Group	Contrast Conditions	Region	BA	Left				Right			
				Volume in Voxels	MNI coordinates x, y, z	t values	Uncorrected P value	Volume in Voxels	MNI coordinates x, y, z	t values	Uncorrected P value
FOOTBALL	PNSS - NB	DLPFC	46	51	-54 30 24	4.59**		66	58 26 30	4.12**	
		DLPFC	9	46	-50 28 34	4.85**		220	60 12 34	4.43**	
		DLPFC	8	2	-48 16 48	3.01*					
		DMPFC	8	70	-16 44 54	5.52**		6	4 18 48	3.74**	
		VLPFC	45	45	-34 24 6	4.25**		62	58 12 22	4.13**	
		VLPFC	10	7	-22 58 -6	2.95	0.002				
		VMPFC	10	5	-10 58 -8	2.78	0.003	13	8 68 12	2.66	0.005
		IFG	47	83	-36 22 0	4.73**		9	30 32 -20	2.93*	
		LOFC	11	32	-46 44 -10	4.81**		5	44 48 -14	3.73**	
		INSULA	13	183	-34 20 6	4.88**					
	CRSS - NB	DLPFC	46	10	-54 30 24	4.19**		1	58 26 28	3.13*	
		DLPFC	9	37	-52 26 36	5.25**		30	60 16 30	3.32*	
		DLPFC	8	1	-50 22 42	3.2*					
		DMPFC	8	27	-4 16 48	4.94**		4	4 18 48	3.41*	
		VLPFC	45	16	-54 26 24	3.79**		31	56 12 22	3.19*	
		VLPFC	10					2	26 58 -8	2.55	0.006
		IFG	47	35	-48 44 -10	3.87**					
		LOFC	11	29	-46 44 -10	3.92**					
		INSULA	13	123	-38 20 0	3.66	0.001				

Table 12. ROI results for the Football Group for each Sports Specific condition relative to the neutral baseline. ROIs are derived from Wake Forest anatomical mask and adjusted for search volume. Top panel: Passive response to SS negative images (Passive Negative Sports Specific (PNSS) – Neutral Baseline (NB)). Bottom panel: cognitive reappraisal of SS negative images (Cognitive Reappraisal SS (CRSS) – Neutral Baseline (NB)). Multiple comparison corrections of the ROIs were done using Family Wise Error (FWE) thresholded at p<0.05 (marked as **), False Detection Rate (FDR) corrected at p<0.05 (marked as *), and uncorrected p values are reported (no star).

Group	Contrast Conditions	Region	BA	Left				Right			
				Volume in Voxels	MNI coordinates x, y, z	t values	Uncorrected P value	Volume in Voxels	MNI coordinates x, y, z	t values	Uncorrected P value
FOOTBALL	PN IAPS -NB	DLPFC	46	8	-54 30 24	2.91	0.002				
		DMPFC	8	12	-4 16 48	4.33**					
		VLPFC	45	38	-40 20 4	3.6**		12	56 10 22	2.73	0.004
		VLPFC	10	6	-22 58 -6	2.82	0.003	3	24 58 -8	2.68	0.004
		IFG	47	220	-48 26 -12	4.57**					
		LOFC	11	42	-46 44 -10	4.08**		5	44 46 -14	2.89*	
		INSULA	13	280	-34 20 8	3.81**		105	42 -2 8	2.68	0.004
	CR IAPS - NB	DLPFC	46	64	-54 30 24	6.42**		12	60 22 28	3.09*	
		DLPFC	9	415	-50 28 34	6.25**		195	62 14 26	4.08**	
		DLPFC	8	88	-48 16 48	4.88**		40	48 8 46	3.09*	
		DMPFC	9	26	-6 28 36	3.16*					
		DMPFC	8	113	-4 16 48	6.64**		52	4 18 48	4.79**	
		VLPFC	45	216	-54 26 24	5.89**		67	64 12 20	4.97**	
		VLPFC	10	29	-32 50 28	3.6	0.001	8	26 58 -8	3.11	0.001
		LOFC	11	47	-46 44 -10	6.8**		15	46 44 -14	4.98**	
		IFG	47	474	-48 26 -12	6.59**		35	48 42 -14	4.39**	
		INSULA	13	583	-40 16 -2	6.41**		93	36 20 6	3.44*	
		AMYGDALA	--	65	-22 -4 -14	2.48	0.008	29	30 -4 -18	2.23	0.014

Table 13. ROI results for the Football Group for each IAPS condition relative to the neutral baseline. ROIs are derived from Wake Forest anatomical mask and adjusted for search volume. Top panel: passive response to IAPS negative images (Passive Negative IAPS (PN IAPS) – Neutral Baseline (NB)). Bottom panel: cognitive reappraisal of IAPS negative images (Cognitive Reappraisal IAPS (CR IAPS) – Neutral Baseline (NB)). Multiple comparison corrections of the ROIs were done using Family Wise Error (FWE) thresholded at p<0.05 (marked as **), False Detection Rate (FDR) corrected at p<0.05 (marked as *), and uncorrected p values are reported (no star).

Group	Contrast Conditions	Region	BA	Left				Right			
				Volume in Voxels	MNI coordinates x, y, z	t values	Uncorrected P value	Volume in Voxels	MNI coordinates x, y, z	t values	Uncorrected P value
CONTROL	PNSS - NB	DLPFC	46	1	-54 28 30	4.99**		152	58 30 18	6.65**	
		DLPFC	9	392	-44 12 32	5.96**		472	50 10 36	5.71**	
		DLPFC	8	51	-54 10 42	4.24**		113	50 8 42	4.93**	
		DMPFC	9	44	-8 26 36	3.86**		48	10 26 36	3.6*	
		DMPFC	8	336	-6 16 48	5.88**		295	6 14 54	6.4**	
		VLPFC	45	208	-30 24 6	5.66**		226	58 28 20	6.46**	
		VLPFC	10	5	-32 50 28	4.03**		7	44 54 -4	4.34**	
		VMPFC	10					17	4 58 -8	4.08**	
		IFG	47	387	-30 20 -4	5.81**		344	42 18 0	5.29**	
		LOFC	11	4	-44 48 -14	3.42*		39	44 34 -14	4.17**	
		MOFC	11	3	-2 40 -24	3.66*		9	4 60 -10	4.04**	
		INSULA	13	310	-30 24 2	6.22**		295	42 18 0	5.29**	
		AMYGDALA	--	36	-16 -6 -16	2.3	0.012				
	CRSS - NB	DLPFC	46	42	-54 28 24	5.21**		87	58 30 18	6**	
		DLPFC	9	404	-44 12 32	6.33**		382	50 4 38	4.93**	
		DLPFC	8	78	-52 12 42	5.41**		74	50 8 42	4.52**	
		DMPFC	9	43	-8 26 36	4.52**		30	10 26 34	4.11**	
		DMPFC	8	368	-6 16 48	6.31**		328	6 14 54	6.49**	
		VLPFC	45	212	-56 18 6	6.05**		223	58 28 20	6.06**	
		VLPFC	10	45	-30 46 26	4.7**					
		VMPFC	10					7	4 58 -8	3.63*	
		IFG	47	385	-42 28 -8	7.26**		345	50 22 -8	5.84**	
		LOFC	11	7	-44 34 -14	4.7**		12	44 34 -14	4.45**	
		MOFC	11	1	-4 58 -12	3.43*		2	4 60 -10	3.58**	
		INSULA	13	396	-30 24 4	5.69**		304	42 16 -2	4.99**	
		AMYGDALA	--	80	-18 -4 -16	3.04**		37	18 -8 -14	2.3	0.012

Table 14. ROI results for the Control Group for each SS condition relative to the neutral baseline. ROIs are derived from Wake Forest anatomical mask and adjusted for search volume. Top panel: passive response to SS negative images (Passive Negative SS (PNSS) – Neutral Baseline (NB)). Bottom panel: cognitive reappraisal of SS negative images (Cognitive Reappraisal SS (CRSS) – Neutral Baseline (NB)). Multiple comparison corrections of the ROIs were done using Family Wise Error (FWE) thresholded at p<0.05 (marked as **), False Detection Rate (FDR) corrected at p<0.05 (marked as *), and uncorrected p values are reported (no star).

Group	Contrast Conditions	Region	BA	Left				Right			
				Volume in Voxels	MNI coordinates x, y, z	t values	Uncorrected P value	Volume in Voxels	MNI coordinates x, y, z	t values	Uncorrected P value
CONTROL	PN IAPS -NB	DLPFC	46	106	-54 28 24	6.78**		165	58 30 18	6.76**	
		DLPFC	9	436	-44 10 32	7.09**		6	38 4 30	2.96**	
		DLPFC	8	111	-54 12 42	5.59**		100	52 6 42	4.84**	
		DMPFC	9	1	-8 26 36	4.37**					
		DMPFC	8	388	-4 36 50	6.4**		290	6 14 54	6.69**	
		VLPFC	45	216	-54 26 24	6.21**		226	58 28 20	6.71**	
		VLPFC	10	94	-32 50 28	4.58**		38	36 60 20	3.19*	
		VMPFC	10	112	-4 62 30	3.6*		76	4 58 -8	4.2**	
		IFG	47	484	-42 28 -8	7.38**		434	44 18 0	5.63**	
		LOFC	11	37	-44 34 -14	5.33**		27	42 34 -14	4.12**	
		MOFC	11	6	-4 40 -24	3.79**		13	4 60 -10	4.32**	
		INSULA	13	633	-30 24 2	6.51**		451	42 18 0	5.6**	
		AMYGDALA	--	139	-18 -4 -18	4.81**		141	18 -8 -16	3.44**	
	CR IAPS - NB	DLPFC	46	81	-54 28 24	5.96**		87	58 30 18	6.07**	
		DLPFC	9	445	-52 10 38	6.76**		341	50 4 40	4.63**	
		DLPFC	8	113	-52 12 42	5.93**		44	52 6 46	4.46**	
		DMPFC	9	336	-8 26 36	4.98**		49	10 26 34	4.44**	
		DMPFC	8	391	-2 14 56	6.88**		274	4 14 56	6.52**	
		VLPFC	45	216	-56 18 6	7.95**		226	58 28 18	6.05**	
		VLPFC	10	80	-30 46 26	5.96**					
		VMPFC	10					2	4 58 -8	3.21*	
		IFG	47	477	-44 28 -8	9.66**		396	48 24 -12	6.77**	
		LOFC	11	44	-44 34 -14	7.21**		32	44 34 -14	5.43**	
		MOFC	11	3	-24 52 -12	3.42*		6	4 60 -10	3.37*	
		INSULA	13	708	-30 24 2	7.16**		367	42 18 0	5.24**	
		AMYGDALA	--	161	-20 -4 -18	5.77**		143	30 -4 -18	3.29**	

Table 15. ROI results for the Control Group for each IAPS condition relative to the neutral baseline. ROIs are derived from Wake Forest anatomical mask and adjusted for search volume. Top panel: passive response to IAPS negative images (Passive Negative IAPS (PN IAPS) – Neutral Baseline (NB)). Bottom panel: cognitive reappraisal of IAPS negative images (Cognitive Reappraisal IAPS (CR IAPS) – Neutral Baseline (NB)). Multiple comparison corrections of the ROIs were done using Family Wise Error (FWE) thresholded at $p<0.05$ (marked as **), False Detection Rate (FDR) corrected at $p<0.05$ (marked as *), and uncorrected p values are reported (no star).

Discussion

Previous investigations of performance under stress have focused primarily on behavioral outcomes (Hancock & Szalma, 2008), but it is unclear if those who have demonstrated stress resilience (superior performance under pressure) exhibit a specific pattern of neural responses characterized by adaptive cognitive self regulation. The study attempted to reveal the specific nature of the proactive countermeasures to stress that allows individuals to adapt, perform effectively and in some situations derive positive effects for affective challenge. Consistent with predictions the elite athletes were less perturbed by emotional challenge within their domain of experience. Furthermore, the direct comparison between the sport specific conditions indicates that through experience, these individuals automatically engage in mental transformation of an emotional event such that the negative consequences are attenuated (use a cognitive reappraisal strategy), supporting the domain specific model of emotion regulation. This suggests that such resilient individuals automatically engage in cognitive control and that resilience is not simply the absence of maladaptive changes that occur in vulnerable individuals, rather, it is mediated by a unique set of adaptive changes (Feder, et al., 2009).

In addition the results also suggest that a great deal of individual variation in the response to challenge may be a consequence of the perception/interpretation of the event rather than the actual environmental stressor; and the perception is highly related to the individual's experience, training, and background. This is consistent with the transactional model of stress (Staal, 2004) and the interactional model of competitive stress (Endler & Kocovski, 2001). Our results also reveal an experience dependent "coping" ability to specific stressful challenges that is congruent with a cognitive reappraisal strategy in the resilient group. This may have developed as a mean of prohibiting a state were behavior is completely controlled by emotion (anxiety, panic, and anger have a steering precedence, focusing attention and interfering with processing of task information) (Hancock & Szalma, 2008). Nonetheless, this endogenous emotion regulation is lost when elite athletes are challenged with generalized negative events, supporting the domain specific model of emotion regulation.

Direct Comparisons Cognitive Reappraisal - Passive Negative.

Football group – Sport-Specific.

The results support the predictions that the cognitive reappraisal strategy is spontaneously utilized by elite athletes during domain specific challenge. Direct comparison reveal no significant difference in the PFC, amygdala and insula between the natural response of the football group to sports specific negative challenge and cued cognitive reappraisal of sports specific negative events. The left supramarginal gyrus (BA 40), the left STG (BA 38) and the left premotor cortex (BA 6) were more active during the cued cognitive regulation condition compared to the natural response, suggesting that instructed transformation of negative events into more positive terms may have required greater processing of regions involved in action observation (Lawrence et al., 2006) and self regulation associated with aversive social events (Koenigsberg et al., 2010). This is not surprising considering the nature of the sports specific images which often depicted situations of action execution (tackle) and social exchange (coach yelling at player).

Our findings extend previous work that indicate cognitive reappraisal relative to other emotion regulation approaches (i.e., expressive suppression (Goldin et al., 2008), distraction (McRae et al., 2010), cognitive load (Van Dillen et al., 2009)) may be a particularly adaptive response to affective challenge (see (Gross & Thompson, 2007) for a review). This mental profile to cope with stressful events is automatically utilized by elite athletes and in turn may promote flexible thinking, goal oriented behavior, and decision making agility; all processes disrupted by acute stress (Hancock & Szalma, 2008). In addition, these findings are congruent with other works examining the neural processes involved in the automaticity of self regulation in individuals who score high psychometric inventories of cognitive reappraisal (Drabant et al., 2009) and agreeableness (Haas, Omura, Constable, & Canli, 2007).

Football group – IAPS: prefrontal cortex.

When examining the football group's response to generalized negative images they demonstrated activation in the DLPFC (BA 8,9, 46), the DMPFC (BA8), VLPFC (BA10/45), right VMPFC (BA 10), left IFG (BA47), OFC (BA11), and the ACC (BA 32), during cued cognitive reappraisal compared to nature response condition (Passive Negative IAPS). These findings are consistent with studies that have examined the down regulation of negative emotion using a cognitive reappraisal strategy (Ochsner et al., 2002). In particular the DLPFC is associated with a situation-focused reappraisal, indicative of emotional modulation of external information which does not have a personal relevance (Ochsner, et al., 2004). In a similar reappraisal task, the VLPFC was associated with inference control and behavioral inhibition (Ochsner, et al., 2004). The DMPFC is also a critical region in the execution of cognitive reappraisal, involved in emotional awareness and self-related processes(Ochsner, et al., 2002), while the VMPFC is a region that has been linked with extinction learning and fear reduction during cognitive inhibition (Phelps & LeDoux, 2005). The ACC is involved in behavioral inhibition and acts as a critical control region, although there is evidence that this region also plays an important role in affective processing, thus acting as a integrative interface between cognition and emotion (this functional attribute is also shared by the VMPFC and OFC) (Pessoa, 2008). Lastly, the OFC and inferior IFG are prefrontal regions that act in emotional processing and show strong reciprocal connections to the basolateral complex of the amygdala (Pessoa, 2008). Thus the football group appears similar to a typical population during the cued cognitive reappraisal of generalized negative events.

Football group – IAPS: regions beyond the prefrontal cortex.

In addition to activation in the PFC, the direct comparison between cognitive reappraisal and passive viewing of negative images revealed more posterior patterns of activation in the football group during generalized negative images (IAPS). The premotor cortex (Shamay-Tsoory et al., 2005), MTG (Critchley et al., 2000), STG (Lawrence et al., 2006), and postcentral gyrus (Adolphs, Damasio, Tranel, Cooper, & Damasio, 2000) are cortical regions which showed activation and are critical to social cognition, and empathic response to emotional events; in other words, emotional processing. Thus, this suggests that although the football group demonstrates prefrontal activation during the cognitive reappraisal of IAPS images (compared to the natural response to IAPS images) that there are regions sensitive to affective processing also engaged. Congruent with this notion, the lentiform nucleus (Adolphs, 2002) the parahippocampal gyrus (Kilpatrick & Cahill, 2003), and insula (Carretie et al., 2009) were also active during this comparison (CR IAPS - PN IAPS) indicative of emotional recognition of visual events. In summary the results suggest a specificity of adaptive emotion regulation, since examination of the generalized negative images revealed a coupling between affective and cognitive regions possibly indicative of less agility with affective control during unfamiliar events.

Control Group – Sport-Specific and IAPS.

Unlike the football group, in which the direct comparisons between cognitive reappraisal and passive negative reveal unique patterns of response for sports specific (very little difference between cued cognitive reappraisal and the natural response) and IAPS (greater prefrontal activation during cued emotion regulation in addition to heighted posterior processing in regions sensitive to social cognition and affective processing) stimuli, the control group demonstrates a very stable response across stimulus types. Specifically, in the control group, direct comparisons of Cognitive Reappraisal and Passive Negative revealed similar activation in the IFG, SMA, and MTG (independent of stimulus type). The IFG is involved in evaluating the implications of negative events and recently was implicated in emotion regulation during a gambling task (Beer et al., 2006). The premotor cortex, in the context of emotional processing, is a component of a network reportedly involved in the simulation of affective information during empathic response (understanding the distress of others) (Shamay-Tsoory et al., 2005). This suggests that during cued emotion regulation, the control group may have been still affectively perturbed by these images independently of the domain, whereas the football group demonstrates a domain specific management of emotional processing. Lastly, the MTG is a region sensitive to facial processing, modulated by top down attentional input (Critchley et al., 2000), thus this ubiquitous findings in this region may be due to attentional effort in the control population. In summary, the control group approaches the negative events, independently of domain, in relatively stable manner, showing no specificity of emotion regulation. Thus, the learned adaptive response of the football players is unique since the control group appears demonstrated a generalized response regardless of challenge.

Similarities between the Football and Control Group.

Activations during cognitive reappraisal.

Interestingly the football group and control group do share similar patterns of activation in the more posterior regions when the football group is engaged the cognitive reappraisal of IAPS images (relative to passive negative IAPS). The control group demonstrated activation in the DMPFC (SS), Primary Motor cortex (SS), supramarginal gyrus (SS), caudate (SS), pulivinar (SS), the insula (SS) and the parahippocampal (IAPS). The football group also demonstrated activation in parietal, insula, basal ganglia and parahippocampal regions possibility suggesting an inability to effectively manage affective response during generalized challenge.

Deactivation during cognitive reappraisal.

In addition to examine regions that were more active during cued cognitive reappraisal (compared to passive negative); there were regions that showed deactivation during cued cognitive reappraisal. Remarkably, the football group did not reveal deactivations during sports specific images, but during IAPS challenge, there was deactivation in the left DMPFC (BA 10). The control group also demonstrated deactivations in the right VLPFC (BA 10) during negative sports specific images and the right VMPFC (BA 10), right DLPFC (BA 46/9) during negative IAPS images. The pattern that emerges is an attenuation of cognitive recruitment in the PFC for the control group during all conditions and during the IAPS condition for the football group (Chambers, et al., 2006). In addition, other regions such as the left MTG (BA 21), left STG (BA 38), and right motor cortex (BA 4) (Football Group, IAPS images), bilateral insula (BA13), right cerebellum, right postcentral gyrus (BA 2), right SPL (BA 7), and right IPL (BA 40) (Control Group, SS images) and the premotor cortex (BA 6), right SPL (BA 7), left PCC (BA 30), bilateral middle occipital gyrys (BA 18,19), right parahippocampal gyrus, right cerebellum, and right IT (BA 20) (Control Group, IAPS images) were congruent with emotional modulatory whole brain networks (Damasio, et al., 2000). Thus the results support the notion that during cued cognitive reappraisal of IAPS images the football group appeared more similar to the control group supporting a situational specificity of the football group's adaptive response.

Condition Region of Interest Analysis.

Our results from the direct comparison between cognitive reappraisal and the natural response to negative challenge support the domain specific model of emotion regulation in competitive athletes. Nonetheless, this direct comparison only indicates a lack of difference between the cued cognitive reappraisal of sports specific negative events and the natural response of the football group to the same type of challenge. It is thus important to examine each condition (Cognitive Reappraisal SS, Passive Negative SS, Cognitive Reappraisal IAPS, Passive Negative IAPS, each relative to neutral baseline) in each group to understand the pattern of activation which accounts for the differences (or lack of differences) observed in the direct comparisons. Therefore, examination of theoretically relevant regions of interest is critical to understand the specificity of the endogenous self regulation of the football group to sports specific challenge was executed.

Football – Sport-Specific.

Examination of the PFC results from the present study revealed the similarity of processing during the cued emotion regulation and natural response to sports specific challenge with the football group. The bilateral DLPFC (BA 46/9), bilateral DMPFC (BA 8), bilateral VLPFC (BA 45/10), bilateral IFG (BA 47) and bilateral lateral OFC (BA11) were active during both conditions (passive response to SS and cognitive reappraisal to SS). In addition, during both conditions the insula was left lateralized. This pattern of left lateralized insula activation may be an index of an adaptive response to stressful challenge since the literature shows it preserves executive processing (emotional interference resolution aids conflict resolution in working memory) (Levens & Phelps, 2010) and is associated with lower emotional susceptibly (reduced emotion vulnerability) (Iaria et al., 2008). Importantly, the amygdala was not present during both conditions (cognitive reappraisal of SS, passive negative SS) suggesting that non-essential networking was attenuated to maintain an adaptive state in competitive sports situations. Thus, consistent with predictions, the amygdala, which is highly connected to cortical regions (Pessoa, 2008), responds in an attenuated manner during domain specific challenge, thereby promoting the ability to maintain psychomotor efficiency in the football group under stress. In summary, this descriptive comparison indicates that individuals who excel in sport competitive reveals an experience-dependent automaticity of cognitive reappraisal exposing a critical component of their resiliency to stress; elite athletes appear to experience less negative emotion and in turn avoid maladaptive physiological responding.

Football- IAPS.

Interestingly, this pattern of similarity between the natural response and the cued cognitive reappraisal is lost during the IAPS images, with the natural response of the football players, resulting in left DLPFC, left DMPFC (BA 8), bilateral VLPFC (BA 45/10), left IFG (BA47) and bilateral lateral OFC (BA 11) activation but during the cued cognitive reappraisal more bilateral patterns are evident: DLPFC (BA 46/9),

DMPFC (BA 8), VLPFC (BA 45/10), IFG (BA 47) and bilateral OFC (BA11). Thus not only do the patterns of activation appear distinct during the cued cognitive reappraisal of IAPS images, but they also appear more similar to the patterns observed in the control group during cued cognitive reappraisal (independent of stimulus type). Furthermore during the generalized negative image conditions (Cognitive Reappraisal IAPS, Passive Negative IAPS), the football group no longer shows the adaptive left lateralization of the insula but instead bilateral patterns are evident, similar to what is seen in the control group during all conditions. Consequently the adaptive response identified above is specific to domain of experience. The right insula plays an essential role in increasing attention to self-generated emotion (Straube & Miltner, 2010) and is associated with high emotionally susceptibility (Iaria, et al., 2008).

Thus, counter to the expectations that the cued emotion regulation of IAPS images would attenuate the affective response, the results suggested that in the resilient group, cognitive restructuring of generalized negative images may have created a tendency to focus on and enhance the affective value of the event leading to the maladaptive cognitive process of rumination (Ray et al., 2005). Rumination is related to reappraisal since it requires cognitive operations that evaluate and maintain alternative interpretations of events but the consequence is to focus on the negative aspects and amplify the negative emotion (Ray, et al., 2005). Our results further support this notion since the football group demonstrated amygdala activation during the cued cognitive reappraisal of IAPS images. Interestingly this pattern does not extend to the natural response of the football group to generalized negative events, since during this condition the football group demonstrated efficient prefrontal activation, and no amygdala regions were active. Nonetheless, this self regulation was lost when the elite athletes had to cognitively restructure the meaning of the events outside of their domain of experience, thus supporting the domain specific model of emotion regulation.

Control SS and IAPS.

The control group revealed activation in the DLPFC (BA 46/9), bilateral DMPFC (BA 8), bilateral VLPFC (BA 45/10), right VMPFC (BA10) (SS), bilateral VMPFC (BA10) (IAPS), bilateral IFG (BA 47), bilateral lateral OFC (BA11) and bilateral medial OFC (BA11) during the natural response to affective challenge independent of stimulus type. Importantly the control group also demonstrated left amygdala activation during SS challenges and bilateral amygdala activation during IAPS challenge. In addition the instructed cognitive reappraisal of negative affective challenge also revealed bilateral DLPFC (BA 46/9), bilateral DMPFC (BA 8), bilateral VLPFC (BA 45/10), right VMPFC (BA10), bilateral IFG (BA 47), bilateral lateral OFC (BA11) and bilateral medial OFC (BA11) and bilateral amygdala activation independently of image type. These findings are on congruent with other studies examining amygdala-frontal connectivity during emotion regulation. Banks and colleagues reported amygdala-frontal coupling during cognitive reappraisal and suggested that these interactions represented an enhancement of cognitive recruitment due to the inability to down-regulate the amygdala activity (Banks et al., 2007). These findings are not unique. The OFC and medial PFC are frequently reported as demonstrating a positive correlation with amygdala activation (Heinzel et al., 2005; New et al., 2007; Schmitz & Johnson, 2006). These regions are bidirectionally connected to the amygdala and thus may serve as an emotion generation–regulation circuit (Ghashghaei et al., 2007). Interestingly, Banks and colleagues also reported differences in self report (with cued cognitive reappraisal results in lower negative affect ratings compared to passively viewing) similar to our results and suggested that this indicated that participants had successfully intended to self-regulate (Banks et al., 2007).

The results suggest a less successful engagement of self regulation in the control group relative to the football group since the control group shows activation in the bilateral DLPFC, lOFC (cognitive control) but still showed mOFC, amygdala and bilateral insula activation (affective response). In addition, compared to the football group, the overall pattern observed in the control group shows a remarkable degree of activation (with a greater spatial extent apparent in all regions), suggesting that under situations of stress, a loss of neural processing efficiency. Interestingly, both groups scored high on cognitive reappraisal and are not significantly different on the emotion regulation questionnaire. This indicates that both the control and football groups can be considered high reappraisers, which according to Gross & John, is a relatively stable trait (Gross & John, 2003). Thus, although the control group may use this adaptive emotion regulation, they are less successful in managing the maladaptive physiological response (amygdala and insula) in many different emotional contexts, whereas the football group demonstrates this trait primarily during sports specific challenge.

Summary.

In summary, the results suggest that the football group processes sports relevant affective information in an automatic manner that neutralized the negative response (similar network patterns in the PFC for sports specific negative images, with left lateralized insula, and no amygdala). When challenged with generalized negative events, the football group appears to be more similar to the control group (similar prefrontal networking, bilateral insula, and amygdala activation). In conclusion, examination of elite athletes serves as an important model for revealing the nature of the attenuation of stress introduced to central nervous system. This may promote a more stable and controlled affective-cognitive motor response, which, in turn, may explain how elite performers can achieve high levels of skill under stress.

Chapter 9: General Summary

There is a robust relationship between one's emotional state and the ability to effectively perform cognitive-motor skills. Elite performers must balance competing task demands such as physical requirements (dexterity, force), physiological recovery (metabolic rate, body temperature), psychological focus (memory, decision making), etc. during high levels of performance (Andre, 2001). Critical to the orchestration of adaptive responses to the challenge of competitive sport, is the management of the emotional component of the task. Mental stress can lead to detrimental outcomes like stat anxiety, burnout, exhaustion, strain, and tension, but it can also evoke adaptations such as hardiness, resilience and resistance (Tepas & Price, 2001). Thus, these divergent outcomes must be explained not only in terms of the nature of the stressor but also in terms of the individual's *perception of the challenge*. The transactional model (Staal, 2004) predicts a high degree of specificity of the response to mental stress based on an individual's perception and appraisal of a stressful event. Thus, the confluence of experience based-factors such as controllability, emotional coping strategies, motivational efforts, trait/state anxiety and individual personality, in addition to the qualities of the objective stressor, cumulatively interact to produce the stress response.

The disruptive effects of stress on human performance have been understood neurobiologically as a loss of neural processing efficiency (Eysenck & Calvo, 1992) leading to hyperactivity of non-essential brain regions (van Galen & van Huygevoort, 2000) that interfere with the cognitive-motor task demands. Conceptualized as “neuromotor noise,” this process affects cortical arousal and redistributes processing resources away from those dedicated to the goal-directed behavior. From a neurobiological perspective, state anxiety (i.e., negative appraisal accompanied by elevated arousal) is coupled with increased amygdala activity, which, in turn, influences numerous sensory and association cortical areas (Haines, 2006) creating neuromotor noise.

The loss of neural processing efficiency caused by stress-induced neuromotor noise can explain the phenomenon of “choking” or performance decline under pressure (Beilock, 2010; Beilock & Carr, 2001). The EEG findings reported in the first empirical paper support this claim, indicating that non-essential neuromotor noise is manifested as an increase in complexity of cerebral cortical dynamics (relative to a relaxed state) during a stressful cognitive-motor challenge. In turn, the loss of neural efficiency translated into the quality of motor behavior resulting in an increase in disfluency during the aiming movement. Mechanistically, mental stress may increase limbic activity, in addition to the recruitment of non-essential associative areas, resulting in increased cortico-cortical communication. Peripherally, these central events can lead to a loss of motor coordination via compromised reciprocal inhibition of agonist and agontagonist muscles (Hatfield & Kerick, 2007). The loss in motor coordination, in turn, increases movement variability and reduces the efficiency and smoothness in skeletal muscle performance leading to performance decline under pressure.

Since stress perturbs the efficiency of neural processing and the quality of motor behavior in non-experts as employed in study 1, then examination of experts who have a history of high-quality performance during mental stress, may serve as exemplars for understanding adaptive ways to mentally approach challenge. However, in the literature, brain processes associated with skilled performance have been mostly been examined in non-stress situations (Hatfield et al., 2004). In such non-stressed venues, converging neuroimaging evidence suggests that experts require less neuronal resources compared to novices to accomplish the same task (Deeny, et al., 2009; Del Percio, Babiloni, Marzano, et al., 2009). These findings indicate that experts attend to essential salient features of the task to maximize performance in a manner that results in cortical (Hatfield, et al., 1984) refinement and effortless action, which is understood as psychomotor efficiency (Hatfield & Kerick, 2007). Thus the maintenance of psychomotor efficiency under mental pressure may be a hallmark of an adaptive response to stressful challenge.

To examine the validity of this reasoning we studied individuals actively involved in high levels of sport since they provide exemplars of stress resilience and superior motor performance. This population is not only highly skilled, but is able to perform at high levels under variable and challenging psychological conditions. As noted above, competitive stress produces an affective response in performers, which, in turn, can affect the quality of behavior and intended action (Cerin & Barnett, 2009). Nonetheless, elite-level athletes are typically resilient to such stress perturbation, enabling them to maintain a high level of performance during stressful conditions. Importantly, the results from the second empirical paper reported that efficiency in the motor domain (this is assumed due to the expert characteristics of the cohort) extends to emotional domain. This, in turn, would promote an overall refinement of cortical activity necessary for successful performance under mental stress and allow for a greater capacity to handle stressful events (less neuromotor noise).

Interestingly, the elite athletes demonstrate efficiency during both specific (sport-specific) and generalized (IAPS) challenge. On speculation, this pattern may be a consequence of repeated exposure to competitive stress, which can lead to active coping strategies that would translate to an ubiquitous planning and problem solving approach to challenge (Feder et al., 2009). Our results also support efficiency in brain regions sensitive to social competence and understanding, which may promote adaptive neural processing mediated by oxytocin (reduces fear response) (Feder et al., 2009). In addition physical fitness is associated with altered behavioral and neuromodulator responses to stressors (e.g. Disman, 1997). Lastly, genetic factors could also contribute to adaptive responses to stress by way of mediating reward circuits and protecting against depression (Vialou et al., 2010) and trait disposition to anxiety (Canli, Ferri, & Duman, 2009). Our present design cannot address the speculations identified here, but we examined one specific element of stress resiliency, cognitive reappraisal.

Cognitive reappraisal is a cognitive-linguistic strategy that changes the trajectory of emotional responses by reformulating the meaning of a situation such that negative affect experience is reduced (Ochsner & Gross, 2008). The notion of cognitive reappraisal is exemplified by the following examples: transforming the scenario depicted into positive terms (e.g., woman crying outside of a church could be alternatively interpreted as expressing tears of joy from a wedding ceremony rather than of sorrow from a funeral) and rationalizing or objectifying the content of the pictures (e.g., a woman with facial bruises could be translated as an actor wearing makeup rather than a victim of domestic abuse) (McRae et al., 2010; Ochsner et al., 2002; Ochsner & Gross, 2005; Ochsner & Gross, 2008; Ray, et al., 2005; Wager, et al., 2008). Thus cognitive reappraisal serves 1) as a means for understanding the qualities that contribute to the unique features of stress resilient population compared to a representative sample population and 2) a critical reference for understanding what stress resilient individuals do when responding naturally to stressful events.

Neuroimaging studies have examined this cognitive approach to mental stress and have revealed that frontally mediated executive processes act to manage the response of the amygdala and medial prefrontal regions (brain regions central to emotional processing). This relationship has been characterized by a reciprocal modulation model, which is based on a demonstrated inverse relationship between affective and cognitive processes during emotional appraisal (Northoff et al., 2004). This model implies that a cognitive interpretation of emotion-eliciting stimuli effectively suppresses emotional responsivity in critical brain such that increased activation in the lateral prefrontal region is associated with attenuated affective processing.

Therefore, we examined if those who have demonstrated stress resilience (superior performance under pressure) exhibit such a specific pattern of neural responses characterized by this adaptive emotion regulatory strategy (cognitive reappraisal). In addition, as stated earlier, the transactional model (Staal, 2004) predicts a high degree of specificity of the stress response based on an individual's perception and appraisal of the stressful event. Consequently, an athlete may have developed through experience and training a domain-specific reaction to stressful challenge, which allows them to endogenously regulate their affective response to familiar stressors. The third empirical paper supports the domain-specific model of emotion regulation. The direct comparison between the sport specific conditions (cued cognitive reappraisal and passive viewing of negative sport-specific images) indicates that through experience, these individuals automatically engage in mental transformation of an emotional event such that the negative consequences are attenuated, i.e. they appear to endogenously engaged in cognitive reappraisal. This equivalence of processing between the natural response to mental stress and cued cognitive reappraisal is lost during the generalized negative events (IAPS images). The results suggest that skilled performers who excel during competitive stress engage in cognitive regulation in their domain of expertise, decreasing physiological arousal thereby enabling them to sustain elevated performance.

Also critical to understanding the unique set of adaptive changes in elite athletes, was the region of interest analysis during with which we examined the prefrontal cortex (both lateral and medial regions), the amygdala and the insula (regions critical to negative affective processing). The results support the direct comparison findings, with similar network patterns in the prefrontal cortex revealed during the natural response and cued cognitive reappraisal of sport-specific negative images in athletes. In addition adaptive emotional control was found during sport-specific challenge: left lateralized insula, and no amygdala activation. This pattern was disrupted when the elite athletes were challenged with generalized negative events (IAPS images), again supporting the specificity of successful emotion regulation. This specificity suggests that emotion regulation promotes refinement of brain activity resulting in an optimal state for effective task execution particularly under conditions of known stressful challenge (i.e., sport competition). By investigating a stress resilient population (elite athletes), this study provides an assessment of the postulated dynamic between cognitive (prefrontal) and affective (limbic and insula) brain networks as related to skilled motor performance. The data reveal a neural processing efficiency during affective challenge in which elite athletes are less perturbed by mental stress and suggests this may be a critical quality contributing to their stress resilience. When examining the specific patterning of neural processing during the natural response of the elite athletes to stressful challenges, our data show that they demonstrate similar neural processes to those used during cognitive reappraisal, but this is only within their domain of expertise. What emerges is a generalized neural efficiency that appears to be a quality of resiliency to promote a mental state where neuromotor noise is attenuated. However a specific element of resiliency (i.e., automaticity of cognitive reappraisal) is dependent on experience. In the context of performance, cognitive reappraisal, through prefrontal regulation of the amygdala, may maintain an adaptive level of arousal to promote a state of psychomotor efficiency during mental stress. The establishment of this protocol as an effective means through which to probe the emotion regulatory processes in elite groups, holds promise to facilitate more tactical psychological interventions that aid in motor performance.

Appendix A: Institutional Review Board Documentation

Institutional Review Board Documentation

Letter of IRB Approval: University of Maryland, College Park

January 07, 2010

To: **Investigator:** Bradley D. Hatfield
Co-Investigator(s): Not Applicable
Student Investigator: Michelle Elizabeth Costanzo
Department: KNES - Kinesiology

From: Joseph M. Smith, MA, CIM
Manager
University of Maryland, College Park

Re: **IRB Application Number:** 09-0836 (PAS# 2816)
Project Title: "Study on the Emotion Regulation of Competitive Athletes"

Approval Date: 12-22-2009

Expiration Date: 12-22-2010

Type of Application: New Application

Type of Research: Non-Exempt

Type of Review: Expedited

The University of Maryland, College Park Institutional Review Board (IRB) approved your IRB application. The research was approved in accordance with the University's IRB policies and procedures and 45 CFR 46, the Federal Policy for the Protection of Human Subjects. Please reference the above-cited IRB application number in any future communications with our office regarding this research.

Recruitment/Consent: For research requiring written informed consent, the IRB-approved and stamped informed consent document is enclosed. The IRB approval expiration date has been stamped on the informed consent document. Please keep copies of the consent forms used for this research for three years after the completion of the research.

Continuing Review: If you want to continue to collect data from human subjects or analyze data from human subjects after the expiration date for this approval, you must submit a renewal application to the IRB Office at least 30 days before the approval expiration date.

Modifications: Any changes to the approved protocol must be approved by the IRB before the change is implemented except when a change is necessary to eliminate apparent immediate hazards to the subjects. If you want to modify the approved protocol, please submit an IRB addendum application to the IRB Office.

Unanticipated Problems Involving Risks: You must promptly report any unanticipated problems involving risks to subjects or others to the IRB Manager at 301-405-0678 or jsmith@umresearch.umd.edu.

Student Researchers: Unless otherwise requested, this IRB approval document was sent to the Principal Investigator (PI). The PI should pass on the approval document or a copy to the student researchers. This IRB approval document may be a requirement for student researchers applying for graduation. The IRB may not be able to provide copies of the approval documents if several years have passed since the date of the original approval.

Additional Information: Please contact the IRB Office at 301-405-4212 if you have any IRB-related questions or concerns.

Georgetown University IRB of Record

22101

Georgetown University Institutional Review Board

Date:	January 29, 2010
To:	Bradley Hatfield, PhD Kinesiology University of Maryland, 2134C Health & Human Perfo College Park, MD 20742
From:	Bronwyn Murray Senior Coordinator Institutional Review Board
Title:	Study on the Emotion Regulation of Competitive Athletes
IRB#:	2010-049
Expiration Date:	December 22, 2010
Action:	Facilitated Review IRB of record request - UMD only Approval letter from UMD IRB, dated January 7, 2010 (approval date 12/22/09; expiration date 12/22/10) UMD approved consent form UMD protocol application

Your above referenced protocol was approved through facilitated review by Dr. Mary Young, the Chair of the Institutional Review Board or the designee on January 27, 2010. The Georgetown University IRB recognizes the University of Maryland IRB as the IRB of record for the above referenced protocol. This is to inform you that you may commence your project.

The IRB requests that you submit the annual renewal approval from the UMD IRB at the end of the study review period and/or at study completion.

Any investigator whose project is externally funded must submit the applicable sponsor grant or contract for review and approval by the appropriate sponsored research office of the recipient institution [GU]. The project cannot proceed without the approval of the sponsored research office.

The International Committee of Medical Journal Editors (ICMJE) has established a requirement for registration of clinical trials in a public registry prior to enrollment as a condition of consideration for publication. Georgetown University has established a central registration process through the National Library of Medicine's Clinical Trials Protocol Registration System ("PRS") known as ClinicalTrials.gov. Please contact the Georgetown University PRS administrator, Patricia Mazar, by e-mail at mazarp@georgetown.edu to set up a PRS user account to register clinical trials. The e-mail should contain the principal investigator's full name, department, phone number and e-mail address.
Additional information may be found at http://ora.georgetown.edu, http://clinicaltrials.gov/, and at http://www.icmje.org/clin_trialup.htm

For **all DoD sponsored research** please make note that you must obtain approval from the DoD human subjects committee as well as the local IRB approval before commencing research on this project.

3900 Reservoir Rd NW, MedDent SW104, Washington DC 20057
202 687-1506 *telephone* 202 687-4847 *facsimile*

**If promotional advertisements will be used for patient recruitment, they must be submitted for IRB review and approval prior to their use.
**Any incentives for participation in research are subject to IRB review and approval as well.

Please remember to:

1. Seek and obtain prior approval for any modifications to the approved protocol.
2. Promptly report any unexpected or otherwise significant adverse effects encountered in the course of this study to the Institutional Review Board within 7 calendar days. This includes information obtained from sources outside MedStar Research Institute and Georgetown University that reveals previously unknown risks from the procedures, drugs or devices used in this study.

Please refer to the above mentioned date and protocol number when making inquiries concerning this protocol.

CC: IRB file

Determination / Notification
IRB of Record for Human Subject Research Projects
performed at Georgetown University (GU)
and University of Maryland, College Park

Principal Investigator: Hatfield, Bradley D.
Address: 2341 SPH Bldg.
Dept. of Kinesiology
School of Public Health
University of Maryland
City: College Park State: MD
Phone: 301-405-2485 E-mail:
bhatfiel@umd.edu

Project Coordinator: Costanzo, Michelle
2341 SPH Bldg.
Dept. of Kinesiology
School of Public Health
University of Maryland
City: College Park State: MD
Phone: 301-405-2485 E-mail:
mcostanz@umd.edu

Title of Project: Study on the Emotion Regulation of Competitive Athletes

Location where project will be conducted: (1): Georgetown University Center for Functional and Molecular Imaging (2):
Source of Funding: n/a **Award number,** if any:

Submit the following (required) one to each institution:	**To the following Institutional Review Boards:**
☐ Two copies of the **IRB of Record Form** (this form) ☐ Two copies of a detailed **summary of the proposed research protocol** ☐ Two copies of the **consent form.** (Please submit the consent forms for the IRB of the institution that you propose will be the IRB of record).	**Georgetown University IRB** SW 104, Med-Dent Building 3900 Reservoir Rd NW, Washington DC 20007 202-687-1506 (phone) 202-687-4847 (fax) and ***IRB*** Address

Please identify the IRB most likely to review the research project
☐ Committee A (Biomedical and Pediatric Oncology Research)
x☐ Committee B (Biomedical Research)
☐ Committee D (Oncology Research)
☐ Committee C (Social and Behavioral Research)

The Principal Investigator will be informed which IRB will take jurisdiction of the research. If any additional information is needed the Principal Investigator will be notified. **The Principal Investigator then should submit the full IRB application to the appropriate Institution's IRB. (<other location> documents for <other location> IRB submission, and GU documents for GU IRB submission)**

IRB Office Use Only

Revision 06-01-2006

Protocol#_09-0836_________

The official(S) signing below agree that the designated IRB (or both) will be responsible for review and continuing oversight of the human subject research described above and that such review and oversight will meet the human subjects protection requirements of the applicable OHRP-approved assurance.

IRB(s) of Record will be: ☐ **GU Only** ☒ **UMD Only** ☐ **GU and UMD**

Authorized institutional official or IRB chair for:

[signature]	Mary Ann Ottinger
Signature	Signature
Date 1/27/10	Date 1/13/10
Mary A Young MD	
Type in Name	Type in Name
Georgetown University	University of Maryland, College Park

Revision 06-01-2006 Protocol#_09-0836__________

IRB Protocol

(New) - Initial Application for Research Involving Human Subjects(New) - Initial Application for Research Involving Human Subjects

Select the appropriate request type. You may select all that apply.

Does this project involve Human Subjects?

Principal Investigator Information
The Principal Investigator may not be a student or fellow. If you are a student preparing a protocol, please select your advisor as the Principal Investigator of this protocol.To assign a different investigator (or to assign an advisor) to this application, please enter a portion of the desired name, click the "Search" button, and then choose from a listing of possible persons
Principal Investigator °
bhatfiel@MAIL.UMD.EDU

Co-Investigator Information
To add one or more co-investigators to this application, please enter a portion of the desired name, click the "Search" button, and then choose from a listing of possible persons. Once selected, choose "Add to list" to add this person to your application. Repeat these steps to add additional co-investigators.

Address Information
Use the field below for the mailing address you want the IRB to use when sending the Approval Letter and any Stamped Consent Forms.
Mailing Address
2341 SPH Bldg.
Dept. of Kinesiology
School of Public Health
University of Maryland

Primary Student Investigator Information
To assign a new or different student to this application, please enter a portion of the desired name, click the "Search" button, and then choose from a listing of possible persons. Students should also choose their advisor in the "Investigator Information" section.
Student Investigator
mcostanz@mail.umd.edu
Student Dissertation

Project Information

Title Study on the Emotion Regulation of Competitive Athletes

Exemption Category
You may recommend your research for exemption or non-exemption by checking the appropriate box below. If you are not sure which category would apply, please skip this Exemption Category section.

Click Here to review a description of each Exemption Category

1. Research conducted in established or commonly accepted educational settings, involving normal educational practices, such as (a) research on regular and special education instructional strategies, or (b) research on the effectiveness or the comparison among instructional techniques, curricula, or classroom management methods. Research involving surveys or interviews with children does not qualify for exemption. Also, this exemption does not apply to research involving the collection of person identifiable data in which any disclosure of the data outside of the research could reasonably place the subjects at risk of criminal or civil liability or be damaging to the subjects' financial standing, employability or reputation.

2. Research involving the use of educational tests (cognitive, diagnostic, aptitude, achievement), survey procedures, interview procedures or observation of public behavior, unless: (a) information obtained is recorded in such a manner that human subjects can be identified, directly or through identifiers linked to the subjects; and (b) any disclosure of the human subject's responses outside the research could reasonably place the subjects at risk of criminal or civil liability or be damaging to the subjects' financial standing, employability, or reputation. Exemption category #2 does not apply to research with children, except for research involving observations of public behavior when the investigator(s) does not participate in the activities being observed. Also, this exemption does not apply to research involving the collection of person identifiable data in which any disclosure of the data outside of the research could reasonably place the subjects at risk of criminal or civil liability or be damaging to the subjects' financial standing, employability or reputation.

3. Research involving the use of educational tests (cognitive, diagnostic, aptitude, achievement), survey procedures, interview procedures, or observation of public behavior that is not exempt under paragraph (2) if: (a) the human subjects are elected or appointed public officials or candidates for public office; or (b) Federal statute(s) require(s) without exception that the confidentiality of the personally identifiable information will be maintained throughout the research and thereafter. E.g.the research is conducted for the Department of Justice under Federal statute 42 U.S.C. 3789g and the research conducted for the National Center for Education Statistics under Federal statute 20 U.S.C. 12213 1, which provide certain legal protections and requirements for confidentiality.

4. Research involving the collection or study of existing data, documents, records, pathological specimens, or diagnostic specimens, if these sources are publicly available or if the information is recorded by the

investigator in such a manner that subjects cannot be identified, directly or through identifiers linked to the subjects.
5. Research and demonstration projects which are conducted by or subject to the approval of Department or Agency heads, and which are designed to study, evaluate, or otherwise examine: (i) Public benefit or service programs; (ii) procedures for obtaining benefits or services under those programs; (iii) possible changes in or alternatives to those programs or procedures; or (iv) possible changes in methods or levels of payment for benefits or services under those programs.
If the research is funded by the United States Department of Health and Human Services, the following criteria must be met:
a. The program under study must deliver a public benefit (e.g., financial or medical benefits as provided under the Social Security Act) or service (e.g., social, supportive, or nutrition services as provided under the Older Americans Act);
b. The research or demonstration project must be conducted pursuant to specific federal statutory authority;
c. There must be no statutory requirement that the project be reviewed by an Institutional Review Board (IRB); and
d. The project must not involve significant physical invasions or intrusions upon the privacy of participants.

6. Taste and food quality evaluation and consumer acceptance studies, if (a) wholesome foods without additives are consumed or (b) a food is consumed that contains a food ingredient at or below the level and for a use found to be safe, or agricultural chemical or environmental contaminant at or below the level found to be safe, by the Food and Drug Administration or approved by the U.S. Environmental Protection Agency or the Food Safety and Inspection Service of the U.S. Department of Agriculture.
NOTE: The 6 exemption categories do not apply to research involving prisoners.

Next, briefly describe why this research is exempt or, if non-exempt, why you believe it involves minimal or more than minimal risk.
Note: This section is optional and your notation is a suggestion to the IRB.

Human Subjects Responses
Please provide the following information in a way that will be intelligible to non-specialists in your specific subject area. Field size is limited to 2048 characters.
1. Abstract
Provide an abstract (no more than 200 words) that describes the purpose of this research and summarizes the strategies used to protect human subjects. For HHS sponsored or funded research, you must submit a copy of your grant application for review. (1353 of 2048 characters)

There is a robust relationship between one's emotional state and the ability to effectively perform cognitive motor skills. Emotion regulation promotes refinement of brain activity resulting in an optimal state for effective task execution particularly under conditions of stressful challenge. Previous investigations of performance under stress have focused primarily on behavioral outcomes, but it is unclear if those who have demonstrated stress resilience (superior performance under stress, such as sports participants) exhibit neural responses characterized by an adaptive emotion regulatory strategy. To gain further insight into the neural basis of performance under pressure, the purpose of the present study is to examine the role of frontally mediated executive processes during emotion regulation as they relate to management of the amygdala (a brain region central to emotional processing) in individuals who have demonstrated resilience to stress and skilled motor performance. By challenging such skilled performers with standardized emotion-eliciting stimuli (International Affective Picture System and sports specific images), and measuring the hemodynamic responses of the brain (Blood Oxygen Level Dependent (BOLD)) we predict heightened activity in frontal brain regions will be associated with reduced BOLD activity in the amygdala.

2. Subject Selection

a. Who will the subjects be? How will you recruit them? If you plan to advertise for subjects, include a copy of the advertisement. (1177 of 4096 characters)

Competitive sport participants will be recruited by flyers at targeted locations at the University of Maryland, College Park (Comcast Center, Student Union, & Gossett Field House). The expansive recruitment strategy ensures access to elite performers by targeting many athletic groups. Sixteen intercollegiate athletes will be recruited by Flyer A posted on a publicly displayed boards across campus. Recruitment will be directed towards individuals who are 1) varsity athletes 2) letter award winners 3) typically play a starting role on the team and 4) are on partial or full athletic scholarship award. In addition an aged matched group of student participants (n=16) with no competitive sports history will also be recruited by flyers posted on campus public bulletin boards (Flyer B).

Volunteers will contact the investigators, directly by flyer information, as contact information is on the flyers (email address of student investigator). Written informed consent will be obtained prior to MRI safety screening. This will be done at Georgetown University Center for Functional and Molecular Imaging in the Behavioral Testing room such that the subject has privacy.

b. Will the subjects be selected for any specific characteristics (e.g. age, sex, race, ethnic origin, religion or any social or economic qualifications)? (557 of 4096 characters)

No other identifying characteristics will be employed in subject selection (such as race, ethnicity, sex, religion, or socio-economic characteristics) beyond the selection criteria that they be performers in competitive sports who meet requirements 1, 2, 3, and 4 stated above in subject selection a. In addition we will be targeting aged matched volunteer participants with no competitive sports history. All participants will be screened for neurological disease and psychiatric disorders during MRI safety screening (Behavioral Assessments, page 1).

c. State why the selection will be made on the basis or base given in 2(b).
(151 of 4096 characters)
No other identifying characteristics will be employed in subject selection (such as race, ethnicity, sex, religion, or socio-economic characteristics)
d. How many subjects will participate in this protocol?

3. Procedures
What precisely will be done to the subjects? Describe in detail your methods and procedures in terms of what will be done to subjects. How many subjects are being recruited? What is the total investment of time of the subjects? If subjects will complete surveys and/or other instruments on more than one occasion, state this in the procedures section. If you are using a questionnaire or handout, please include a copy within each set of application documents. If you are conducting a focus group, include a list of the questions for the focus group. If you plan to collect or study existing data, documents, records, pathological specimens or diagnostic specimens, state whether the sources are publicly available and if the information will be recorded in such a manner that subjects can be identified, directly or through identifiers linked to the subjects. If you are collecting or studying existing data, describe the dataset and list the data elements that you will extract from the dataset.

Data collection will occur at the Georgetown University Center for Functional and Molecular Imaging.

Upon arrival, subjects will be escorted the Behavioral Testing Room, where after written informed consent is given, they will complete the following questionnaires:

Behavioral Inventories (30 minutes)
1. MRI safety screening (MRI_screening, pages 8-10)

2. Beck Depression Inventory (BDI) is a 21 item self-report questionnaire evaluating depression symptoms. It is widely accepted measure consistent with clinician ratings and other depression scales based its comparable internal consistency and validity (Behavioral Assessments, pages 4-5).

3. State-Trait Anxiety Inventory (STAI) is a 40 item self-report index of state and trait anxiety consisting 20 state items and 20 trait items. (Behavioral Assessments, pages 2-3).

4. Emotion Regulation Questionnaire (ERQ) is a 10 item self-report questionnaire indexing the habitual use of expressive suppression and cognitive reappraisal (Behavioral Assessments, page 6)

5. Sport Competition Anxiety Test (SCAT), Form A is 15-item questionnaire gauging an individual's tendency to perceive competitive situations as threatening and to respond to these situations with elevated state anxiety (Behavioral Assessments, pages 7-8)

6. Sport Experience Questionnaire including the Performance Failure Appraisal Inventory (PFAI)

Sport Experience Questionnaire

Please select the answer that best describes your **football** experience

0=no experience, do not watch or attend games (not a fan) 1=no experience, but watch occasionally (mild fan) 2=no experience, but watch frequently (avid fan) 3= some experience playing and watch frequently (e.g. intramurals) 4=several years experience playing competitively (e.g. high school) 5=currently playing competitively.

Please select the answer that best describes your sports experience **in general**

0=no experience, do not watch or attend games (not a fan) 1=no experience, but watch occasionally (mild fan) 2=no experience, but watch frequently (avid fan) 3= some experience playing and watch frequently (e.g. intramurals) 4=several years experience playing competitively (e.g. high school) 5=currently playing competitively.

Please write down what sports you play, have played or watch:

The Performance Failure Appraisal Inventory (PFAI) is a multidimensional measure of cognitive-motivational-relational appraisals associated with fear of failure (FF). FF was associated with (a) high levels of worry, somatic anxiety, cognitive disruption, and sport anxiety, and (b) low levels of optimism. General FF was unrelated to either perceived competence or fear of success.

Conroy, D. E. (2001). Fear of failure as an exemplar for social development research in sport. Quest, 53, 165-183. (Behavior Assessment, page 9)

Prior to Data Acquisition (30 minutes):

Task instructions will consist of an overall explanation of the study and a training session. Training will include viewing of all three conditions (passive viewing negative image, passive viewing neutral image, cognitive reappraisal negative image, (see Images.doc) outside of the scanner including an investigator demonstration of cognitive reappraisal using three negative images. Psychological engagement of the reciprocal modulation functional brain network is mediated by an emotion regulation strategy called cognitive reappraisal. The notion of cognitive reappraisal is exemplified by the following example: transforming the scenario depicted into positive terms (e.g., woman crying outside of a church could be alternatively interpreted as expressing tears of joy from a wedding ceremony rather than of sorrow from a funeral) and rationalizing or objectifying the content of the pictures (e.g., a woman with facial bruises could be translated as an actor wearing makeup rather than a victim of domestic abuse). Passive viewing is simply to look at the image and let themselves respond naturally. The subject will be asked to practice cognitive reappraisal during the viewing of twelve negative images (6 in-person with the investigator and 6 in the scanner) to ensure proper use of the cognitive reappraisal strategy and accurate manipulation of joy stick rating method.

Data Collection (1 hour):
Brain:
Participants will be placed on the bed of the MRI scanner and their head will be positioned into a stabilization device. While scanning is occurring, the participant will not be able to see the experimenter/technicians, but voice contact will be maintained. If participants are unable to tolerate confinement for the necessary period of time, the scan will be stopped. Functional and structural magnetic imaging data will be acquired on a Siemens Magnetom Trio system equipped with gradients suitable for echo-planar imaging sequences. With this system, it is possible to perform multislice EPI acquisitions of 64x64x50 voxel volumes (3mm cubic voxels) at a rate of one brain volume every 2 seconds. In order to align the functional data to each subject's individual anatomy, two types of anatomical images are obtained: a high resolution T1 3D MPRAGE based on the sequence developed for the ADNI (Alzheimer's Disease Neuroimaging Initiative) for co-registration with functional images (8 minutes) with 160 1mm slices, FOV=2562, matrix=256mm2, TR/TE/TI=2300/2.94/900ms, Flip angle=9°. Single-shot gradient echo, echo-planar imaging (EPI) is used for the functional MR scans with whole-brain volumes acquired every three seconds, with 43 axial slices (TR/TE=3000/30ms, FA=90°, FOV = 192mm, 64x64 matrix, slice thickness = 2.5mm, interslice interval = 0.5mm, effective resolution is 3mm3). Image data will be transferred via the network for quantitative analysis and to magnetic tape for backup.

Following the approach developed by Goldin McRae, Ramel, & Gross (2008) and Ochsner et al (2004) the functional magnetic resonance imaging investigation will evaluated the Blood Oxygen Level Dependent (BOLD) response during negative and neutral visually presented images (see Images.doc). The neutral images will serve to provide a baseline to remove lower-level sensory processing associated with the visual modality and thus isolate affect specific networks. Negative and neutral images were selected from the International Affective Picture System and additional sports relevant images (see Images.doc).

Each trial will be composed of four events: First, instructions (watch or decrease) will appear centrally for 2 s. On "decrease" trials, participants will reappraise images as described above and on "watch" trials participants will be instructed simply to look at the image and let themselves respond naturally. Second, an aversive or neutral image will appear centrally for 8 s. While the image remained on the screen, participants performed the evaluation operations specified by the prior instructional cue. Third, a rating scale will appear immediately after presentation of the photo for 4 seconds asking "How negative do you feel" with a rating from 1 to 5 (1 not at all, 3 moderately, 5 extremely). Fourth, the transition task of fixation cross for 4 s in the center of the screen indicating that participants should relax until the next trial. Each subject will be cued to passively view or reappraise 48 domain non-specific negative images (24 each) and 48 sports specific negative images (24 each) in addition to the passive viewing of 24 neutral images during randomly intermixed trials over 4 MRI scanning runs. Each image will be shown only once for a given participant.

Goldin, P. R, McRae, K., Ramel, W., & Gross, J. J. (2008) The Neural Bases of Emotion Regulation: Reappraisal and Suppression of Negative Emotion. BIOL PSYCHIATRY, 63:577–586

Ochsner, K.N., Ray, R.D., Cooper, J.C., Robertson, E., Chopr S., J., D., & Gross, J.J. (2004). For better or for worse: neural systems supporting the cognitive down- and up-regulation of negative emotion. NeuroImage, 23 483– 499

Autonomic Measures:
Heart rate (ECG electrocardiogram), and galvanic skin response known to related to emotional response.

Heart Rate: Quadtrode Magnetic Resonance Imaging (MRI) Electro-Cardiogram (ECG) Electrode, affixed to chest

Galvanic Skin Response: electrodes secured to first two medial phalanges with KY gel, adhesive sticker and tape of left hand

4. Risks and Benefits
Are there any risks to the subjects? If so, what are these risks including physical, psychological, social, legal and financial risks? Please do not describe the risk(s) as minimal. If there are known risks, please list them. If not, please state that there are no known risks. What are the benefits? If there are known risks associated with the subject's participation in the research, what potential benefits will accrue to justify taking these risks? (3475 of 4096 characters)
Magnetic resonance imaging (MRI) technique, it is a noninvasive technology and there are few potential risks associated with it. MRI uses powerful magnetic fields and weak electromagnetic radiation, which have not been associated with significant adverse biological effects in patients. The 3.0T MRI system meets FDA requirements for field strength, gradient switching and RF power disposition for all acquisitions used in the proposed research. Some possible risks include anxiety in the scanner and noise during the MRI experiments. Due to the small bore of the scanner, claustrophobic subjects may not tolerate the confinement in the magnet and the head coil. Subjects will be in visual and verbal contact with the experimenter throughout the scan through a video monitoring system and can be removed quickly. Some subjects have experienced dizziness or a metallic taste if they move their heads rapidly in the magnet. This, however, is only temporary and does not occur if the head is still. Acoustical noise is generated by the charging and discharging of the gradient coils which create the magnetic fields used to generate an image. Generally, this is not a significant problem in clinical scanners, but additional precautions will be taken to provide subjects with earplugs to reduce acoustic noise to be no greater than 30dB. All possible measures will be taken to educate research personnel concerning the dangers of metallic projectiles in the magnet room and any individuals entering the magnet room will be thoroughly screening for ferromagnetic material.

Precautions have been taken at the Georgetown University Research Imaging Center to map the peripheral fringe magnetic fields to comply with the accepted level of less than 5 Gauss in unrestricted corridors and outside areas. Warnings, including the specific dangers of high magnetic fields, are posted where necessary. All research personnel are thoroughly trained concerning safe magnet operation and are required to attend an annual refresher course.

Avoidance of Pregnancy:
The procedures used in this study may be unsafe for an unborn baby, an infant, sperm, and eggs. If the subject of study, is a woman of child bearing potential, she must agree to avoid pregnancy during the periods of this study that involve MRI procedures; if the subject of the study is a man, he must agree to not conceive a child during his participation in the MRI procedures. If the subject does become pregnant during the study or if the subject fathers a child during the study, she/he should immediately notify Dr. John VanMeter at 202-687-3592 (the Director of the Center for Functional and Molecular Imaging, at Georgetown University Medical Center). In addition, if the subject is already pregnant or are breast feeding, she cannot participate in this study.

Subjects will not benefit directly from participation in this study. The results of this experiment may help the research team better understand the neural mechanisms of emotional regulation. Because the procedures used are non-invasive, the risk/benefit ratio is low.

The BDI instrument contains a question on suicidal thoughts if the participant exhibits suicidal thoughts. We will follow the University of Maryland, University Health Center MentalHealth recommendations (http://www.health.umd.edu/services/mentalhealth.html) We will contact the Mental Health Service in the event of an individual reporting suicidal thoughts and wishes.

5. Confidentiality

Adequate provisions must be made to protect the privacy of subjects and to maintain the confidentiality of identifiable information. Explain how your procedures accomplish this objective, including such information as the means of data storage, data location and duration, description of persons with access to the data, and the method of destroying the data when completed. If the research involves audio taping, videotaping or digital recordings, state who will have access to the tapes or recordings, where the tapes or recordings will be kept, and state the final disposition of the tapes or recordings (i.e. Will the tapes or recordings be destroyed? If so, when will the tapes or recordings be destroyed?). Please note that as per the University of Maryland policy on records retention and disposal, all human subject files, including work done by faculty, staff, and students, must be retained for a period of no less than 10 years after the completion of the research and can then be destroyed. Human subject files include IRB applications, approval notices, consent forms, and other related documents. For more information on records retention, go to: http://www.dbs.umd.edu/records_forms/schedule.php (Faculty and Academic Records) or contact Michelle Solter Evers, Assistant to the Director of Business Services at 301.405.9277 or mevers@mercury.umd.edu. (1145 of 4096 characters)

Every precaution will be taken to keep personal information confidential. All subject records will be maintained in locked and/or password protected files. All forms will be identified by a unique numeric code and this code will be used for all levels of processing and analysis. In other words, the personal identification information such as subject name will not be associated with any forms of data. The informed consent document (on which the subject has provided his signature) will be retained in a separate locked filing cabinet in the School of Public Health, University of Maryland, in 0110H to assure confidentiality and protection of the subject's identity. Please note that these procedures will be followed for data retained on the campus of the University of Maryland and brain imaging and other data obtained and processed at Georgetown University. All information collected will be kept for a period of 15 years, at which point it will be destroyed. When we write a report or article about this research project, we will present grouped results only; the subject's identity will be protected to the maximum extent possible.

6. Information and Consent Forms
State specifically what information will be provided to the subjects about the investigation. Is any of this information deceptive? State how the subjects' informed consent will be obtained.Include a final draft of the consent form that you propose to use. Include a description of the data storage methods which will be used to ensure confidentiality within the consent form. Click here to review the consent form guidelines located on pages 5 - 11 of the Initial IRB Application and Instructions.
There is no deception involved in the proposed protocol. Interested volunteers will be informed of the purpose of the study and provided background about the task in the MR scanner (response to the International Affective Picture Series). Written informed consent will be obtained at Georgetown University Center for Functional and Molecular Imaging.

Subjects will complete the consent process and surveys in a private behavioral testing room at the Georgetown University Center for Functional and Molecular Imaging. All participants will receive a copy of the consent form for their records.

Appendix B: Data Collection Documents

	Investigator 1 (Michelle)	Investigator 2.
Scheduling	1. Schedule MRI and Behavioral time on CFMI calendar: a. **username**: costanzo **password**: JKdfq=7f b. Behavioral (45 mins) MRI (1 hr) c. Enter subject information by logging onto CFMI, enter subject ID	Be available.

While participant is in the Behavioral Testing Room

1. University of Maryland IRB written consent
2. MRI Safety
3. Task Training;
   a. Review "watch" and "decrease" conditions
   b. Read examples of reappraisal
   c. Run E Prime training script: y:costanzo Training.es2.
      i. Select "running man" icon
      ii. Enter subject ID ("SPORTS___")
      iii. Enter session #

   d. Start Training Script
      i. Passive viewing ("watch"): negative (1) and neutral (1)
      ii. Reappraisal ("Decrease")" investigator lead(3)
      iii. Reappraisal ("Decrease")" Subject overtly reports (6)
         1. Record responses on spreadsheet
         2. Investigator may provide feedback for each trial
4. First Review of MRI safety screen with subject
5. Explain scanner protocol: in-scanner training structural scans, functional scans
6. Instruct Subject that NOW is time to use the restroom if necessary

IN CONTROL ROOM

1. Turn on PC3 for HR and PC2 for GSR; pull up respective programs according to HR and GSR runsheets
2. **Set up ECG cart in behavioral testing room**. Plug cart into the wall and attach wireless transmitter to portal in the corner of the room

IN BEHAVIORAL TESTING ROOM

3. If Subject information not yet entered into the CFMI system, use the information printed on the consent form to log in the participant.
4. **CfMI website: subjects (rt of screen), enter info from MRI safety form, "Study on Emotion Regulation of Competitive Athletes"**
5. Attach GSR electrodes to participant's fingers while training on joystick
   a. Attach collars to electrodes and fill electrode wells with gel;
   b. Stick electrodes to middle phalange of **LEFT** index and middle fingers making sure wires run down the length of the fingers away from the subject's body. Secure with medical tape.
6. When subject is finished training, attach HR 4-in-1 Quatrode to particpant's chest, below left pectoral. Abrade or shave area as needed. "Buckle" should be oriented horizontally.
7. Attach Quatrode electrodes to ECG cart:
   a. Smoke over fire (on subject's left side);
   b. Snow over grass (on subject's right side)
   c. Make sure HR signal is transmitting to control room
8. Ask subject to carry wires for GSR and HR electrodes with him as he walks to fMRI room.

fMRI ROOM	1. Explain joystick manipulation and button press. Secure joystick to the right thigh with medical tape i. Suggest optimal grip for manipulation 2. Initiate protocol to place subject in the bore of the magnet a. Special attention to placement of mirror so that the subject can see the display b. Secure headphones c. Pillow or blankets if necessary	8. Attach GSR Wires to red and black nodes in control box (nothing attaches to the ground) a. **ask participant not to move hand during scan** 9. Make sure wires run straight down the bed and do not loop or cross. 10. sandbag wires once properly arranged

Control room	1. **Second review of** MRI safety screen sheet with subject a. a. Photocopy signed consent form and MRI safety screening form for CFMI records 2. Login to CFMI scan session using subject ID and information from MRI safety form (start billing time) a. MRI calendar: start session (bottom of page) 3. Hatfield, Costanzo Folder, Sports protocol 4. In-scanner training with joy-stick d. Use index finger and click red button. Try to select the middle of the number. The cursor will jump but that's ok e. Load "In scanner training" script in E prime f. Reappraisal ("Decrease"): subject performs task with reappraisal (6); focus on joystick practice 5. Open Black Screen in E Prime 6. Localizer 7. MPRAGE (subject can relax) 8. Check motion parameters to provide subject with feedback about moving (less than 2) 9. E Prime: g. SportsRun1.es2 to initiate E prime script h. Select "running man" icon i. Enter Subject ID *j.* Enter Session number "SPORTSXXX" (*subject 1 was SPORTS001)* 10. Cue start of GSR recording time in synchrony with scanner start time 11. EPI (experimental task) Sports_task1 12. E Prime: k. Sports Run2.es2 to initiate E prime script l. Select "running man" icon m. Enter Subject ID 001 n. Enter Session number 13. Cue start of GSR recording time 14. EPI (experimental task) Sports _task2 15. E Prime: o. Sports Run3.es2 to initiate E prime script p. Select "running man" icon q. Enter Subject ID r. Enter Session number 001 16. Cue start of GSR recording time 17. EPI (experimental task) Sports _task3 18. E Prime: s. Sports Run4.es2 to initiate E prime script t. Select "running man" icon u. Enter Subject ID v. Enter Session number 001 19. Cue start of GSR recording time 20. EPI (experimental task) Sports _task4	10. Check GSR by asking subject to wave or hand while investigator watches computer trace 11. Check HR signal in the scanner on Hyperterminal on PC3; Start HR acquisition during in scanner training WHEN SCANNING BEGINS (After practice session): 12. Run the HR hyperterminal continuously. We will record one large file for HR thus **it is VERY important to note start/stop times for each of the four testing sessions.** a. Note time difference between the fMRI computer and the hyperterminal window on PC3 b. Note start/stop times for each session on lab notebook sheet (remind investigator 1 to provide "start" cue for each block) c. Name file "SportsHRXXX" where XXX is the subject's number. (*Subject 1 was "SportsHR001")* 13. GSR: Run new data acquisition file for each of the four trial blocks. a. Note time difference between the fMRI computer and PC2 (the computer's clock timestamps the GSR datafile; the software does not have it's own clock) d. Note start/stop times for each session on lab notebook sheet (remind investigator 1 to provide "start" cue for each block) e. Name Files: "SportsGSRXXX_1", where xxx = subject # and the number after the underscore is the session number. *(Subject 1, block 2 was "SportsGSR001_2")*

After scanni	21. Remove subject from scanner
	22. Saving E Prime
	    w. .edat2 export save as text file, open with excel
	23. Behavioral Inventories: review instructions
	    x. Emotion Regulation Questionnaire
	    y. Dispositional Resilience Scale
	    z. SCAT
	    aa. Spielberger STAI
	    bb. BDI
	    cc. Sports Questionnaire
	24. Subject leaves CFMI
		14. Follow directions on GSR sheet to prepare GSR files for transfer/saving (run BHATT1 macro)
		15. Email data files to Michelle and self for both GSR & HR (total of 5 files: 4 from GSR, 1 from HR)
		16. Remove electrodes/tape.
		    a. Clean GSR electrodes
		    b. Throw out quatrode and put away ECG cart
		17. Close software screens, logout of computers
		18. Make photocopies of run sheets; give copy to Investigator 1 for records

Subject ID_______________
Date_______________
Investigator Name_______________

Lab Notebook

DATA COLLECTION OVERVIEW:

Siemens 3T Tim Trio, 12-channel head coil. Joystick in Right hand, GSR to index and middle fingers on Left hand, ECG hookup & cart, leg pad.

Heart Rate

TIME DIFFERENCE BETWEEN PC2 and fMRI computer: __________

File Name:_________SportsHR _ _ _ ____

Start Time1: _______Start Time2: _______ Start Time3: _______ Start Time4: _______

End Tim1: ________ End Time2: _______ End Time3: _________ End Time4: _________

Emailed____

NOTES

Skin Conductance – 4 files

TIME DIFFERENCE BETWEEN PC2 and fMRI computer: __________

Block 1 File Name:___SportsGSR __ _ __

Start Time: __________

End Time: ___________

Block 2 File Name:___SportsGSR __ _ __

Start Time: _________

End Time: ___________

Block 3 File Name:___SportsGSR __ _ __

Start Time: _________

End Time: __________

Block 4 File Name:___SportsGSR __ _ __

Start Time: _________

End Time: _________

Transformed Macro and Emailed____

NOTES

Subject ID_______________
Date_______________
Investigator Name_______________

Lab Notebook

Scan Sequence

-- Practice task with joystick--

Start Time: ______________________________

---Open Black Screen---

PA_Multi Plane 50Slice Loc

Start Time: ______________________________

Siemens_MPRAGE

Start Time: ______________________________

ep2d 3.0mm Sport-1 Start time on ECG Monitor, Skin Conductance

Start Time: ______________________________

ep2d 3.0mm Sport-2 Start time on ECG Monitor, Skin Conductance

Start Time: ______________________________

ep2d 3.0mm Sport-3 Start time on ECG Monitor, Skin Conductance

Start Time: ______________________________

ep2d 3.0mm Sport-4 Start time on ECG Monitor, Skin Conductance

Start Time: ______________________________

NOTES

Subject ID________________
Date________________
Investigator Name________________

Lab Notebook

Documents

Informed Consent ◊

Emotion Regulation Questionnaire ◊

Dispositional Resilience Scale ◊

SCAT ◊

Spielberger STAI ◊

BDI ◊

MRI safety screening ◊

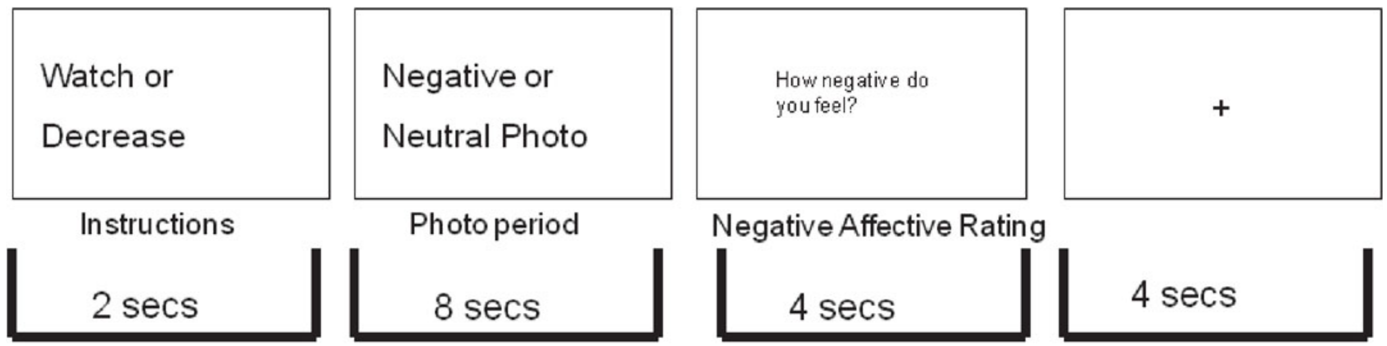
NOTES

Study Orientation

We are interested in the biological and brain processes related to mental pressure and toughness. In order to make sense of the pattern of your brain response we need to have a consistent comparison condition. Thus, I am going to train you on a task which we will use as the comparison state but we really interested in how you respond naturally to these pictures.

The goal of this training session is to familiarize you with the instructional cues and the layout of the trial structure in the experiment.

First here is the structure of a trial



You will be given an instructional cue of either “Watch” or “Decrease” (I’ll describe the instructions in greater depth next)

Next you will see a picture. Some of the pictures may prompt emotional experiences; others may seem relatively neutral

You will be asked to rate the image using a joy stick (which will also be described next).

Lastly you will see a cross in the center of the screen; simply fix your eyes on that cross.

Rating

After viewing a picture we ask that you rate it.

You will be asked "how negative do you feel?" and select the numeric value that applies to how you felt when viewing the image.

If you felt in between the three descriptors, please select the appropriate intermediate value. There are no right or wrong answers, so simply respond as honestly as you can.

How negative do you feel?

1	2	3	4	5
not at all		moderately		extremely

Next, I will review the instructional cues.

Below I have included one example trial in which the instruction will be "watch", which means you must simply look at the image and let yourself respond naturally

Please rate it:

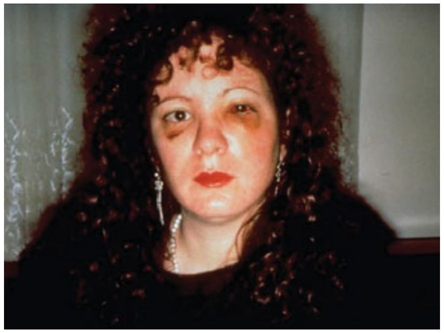
How negative do you feel?

1	2	3	4	5
not at all		moderately		extremely

The second instructional cue is "Decrease." What you will do when you see this instruction is transform your response or interpretation of the picture so it's not so negative. There are three ways to do this:

1) Transform the scenario depicted into positive terms; imagine that the situation is not as bad as it appears (e.g., a women crying outside of a church could be interpreted as a woman expressing tears of joy from a wedding ceremony rather than from the sorrow of a funeral)

2) Rationalize or objectify the content of the pictures; view the image from the perspective of a distant, detached observer (e.g., consider a woman with facial bruises could be an actor wearing makeup rather than a victim of domestic abuse).



3) Imagine that things will improve with time (e.g. whatever appears to be bad will resolve over time)

This is called cognitive reappraisal. Cognitive means how you think and reappraisal means transforming the meaning

Decrease →

→ How negative do you feel? → +

Here's a sample trial, and the implementation of all three strategies with this one image. Again you may choose 1 of the 3 strategies during the image viewing period: all are appropriate.

1) The Soldier is clearly not aiming at the child but at his adversary in the distance. The child is running to the safety of his family where he will avoid any harm

2) Action movie trailer for the latest Special Forces flick

3) The village will be safe again after the Soldiers remove the threat

I will now show you examples of both instructions (watch or decrease). I will focus on practicing the “decrease” cue so you have no confusion regarding what you need to do when you receive this instruction in the MRI.

First, let’s review the “watch” instruction.

Next, let me give you an example of how to “decrease” when viewing the next three image trials.

The pilot was able to safely eject and was later located by his unit and returned to base
Documentary on spider behavior. It is remarkable how advanced the film making technology has become which allows such a close view of a small animal.
The coach is just trying to make a point with the player which will only have a positive effect on the outcome of the game

Now it’s your turn to practice. Please tell me what you think of when asked to “Decrease” over the next six practice sessions. If you’re stuck, I’ll help you. For the purpose of the study, I’ll be making a few notes, but there is no incorrect response

Reappraisal_Subject_Overt	AimedGun	6210	Could be from a movie, clearly an action scene
Reappraisal _Subject_Overt	Attack	6561	Her brother is teasing her so she's trying to get away
Reappraisal _Subject_Overt	Tornado	5971	There are no people in the buildings since they've been evacuated but it appears the tornado is moving away from the city thus no damage will occur to the infrastructure
Reappraisal _Subject_Overt	Injury	74	Doesn't seem very painful, perhaps just a good bruise which will heal with some ice.
Reappraisal _Subject_Overt	performance	25	Game is not over yet, so although they are struggling now, they will win in the end

This time please focus on getting comfortable with using the joystick while rating the images. Again, we're going to practice the "Decrease" instruction so you should feel confident in the task. Please practice these as you would during the actual experience thus do not state what you are thinking out loud.

JOYSTICK: Use index finger and click red button. Try to select the middle of the number. The cursor will jump but that's ok

Reappraisal _Subject_Covert	DentalExam	9584	The patient is anesthetized locally while he is getting his tooth repair to stop the tooth ach
Reappraisal _Subject_Covert	Missiles	6930	Research center testing new equipment
Reappraisal _Subject_Covert	Snake	1022	TV show reporting on the snake in the wild to promote public understanding of nature
Reappraisal _Subject_Covert	performance	19	The helmet is protecting him so he will not be hurt
Reappraisal _Subject_Covert	performance	9	The referee is just doing his job to keep the game clean and make sure everyone is careful and plays fair
Reappraisal _Subject_Covert	performance	16	It is the end of the game during over time and the coach is encouraging him to stay focused so they can win the game

Quickly, before we proceed, can you please tell me what you thought of when you saw the dental exam, the missiles, snake, player getting hit, referee and two players?

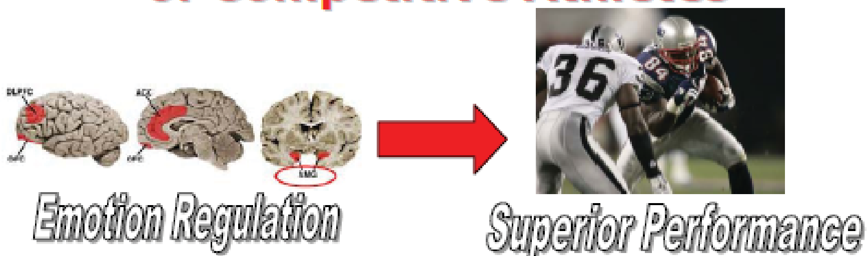
Thank you. Let's get started.

Instuctions	Description	Image Number	Instructor Script	It's not real (e.g. it's just a scene from a movie, they're just pretending),	Things will improve with time (e.g. whatever is going wrong will resolve over time),	Things aren't as bad as they appear to me (e.g. the situation looks worse than it is, it could be a lot worse, at least it's not me in that situation).	Expressive Suppression/ Attention Modulation	Failure to Reappraise
Passive_Neutral	Chess	2580	N/A					
Passive_Negative	Performance	15	N/A					
Reappraisal_Instructor	Jet	9622	The pilot was able to safely eject and was later located by his unit and returned to base					
Reappraisal_Instructor	Spider	1200	Documentary on spider behavior. It is remarkable how advanced the film making technology has become which allows such a close view of a small animal.					
Reappraisal_Instructor	performance	10	The coach is just trying to make a point with the player which will only have a positive affect on the outcome of the game					
Reappraisal_Subject_Overt	AimedGun	6210	Could be from a movie, clearly an action scene					
Reappraisal_Subject_Overt	Attack	6561	Her brother is teasing her so she's trying to get away					
Reappraisal_Subject_Overt	Tornado	5971	There are no people in the buildings since they've been evacuated but it appears the tornado is moving away from the city thus no damage will occur to the infrastructure					
Reappraisal_Subject_Overt	Injury	74	Doesn't seem very painful, perhaps just a good bruise which will heal with some ice.					
Reappraisal_Subject_Overt	performance	25	Game is not over yet, so although they are struggling now, they will win in the end					
Reappraisal_Subject_Overt	performance	30	He may be just tired but his teammate is there to encourage him and make sure his mind is back in the game					

Instuctions	Description	Image Number	Instructor Script	It's not real (e.g. it's just a scene from a movie, they're just pretending),	Things will improve with time (e.g. whatever is going wrong will resolve over time),	Things aren't as bad as they appear to me (e.g. the situation looks worse than it is, it could be a lot worse, at least it's not me in that situation).	Expressive Suppression/ Attention Modulation	Failure to Reappraise
Reappraisal_Subject_Covert	Dental Exam	6930	The tooth ache is bad now, but with the help of the dentist he will feel better soon					
Reappraisal_Subject_Covert	Missiles	6930	Research center testing new equipment					
Reappraisal_Subject_Covert	Snake	1022	TV show reporting on the snake in the wild to promote public understanding of nature					
Reappraisal_Subject_Covert	performance	19	The helmet is protecting him so he will not be hurt					
Reappraisal_Subject_Covert	performance	9	The referee is just doing his job to keep the game clean and make sure everyone is careful and plays fair					
Reappraisal_Subject_Covert	performance	16	It is the end of the game during over time and the team captain is encouraging him to stay focused so they can win the game					

Flyer A:

Study on the Emotion Regulation of Competitive Athletes



The purpose of this study is to examine the brain's response (via functional Magnetic Resonance Imaging) to images (known to produce a mental stress response) in individuals who are successful athletes. This research is associated with and conducted by the University of Maryland staff/faculty.

Who is eligible to volunteer to participate?

- **Varsity Athletes who are letter award winners (age of 18-22)**
- **Typically play a starting role on the team**
- **Hold a partial or full time athletic scholarship**

You must NOT have:

- **Any ferromagnetic metal implants or clips in your body**
- **Claustrophobia (fear of enclosed spaces)**

What will you do?

• Fill out questionnaires

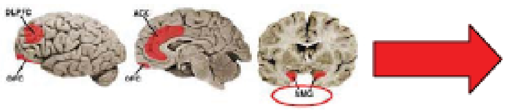
• MRI at Georgetown University: the MRI scanner will be taking many pictures of your brain while you view images on a screen and rate how they make you feel.

•Get a picture of your brain and all participants will be provided a report of the study results

Michelle Costanzo mcostanz@umd.edu
Michelle Costanzo mcostanz@umd.edu
Michelle Costanzo mcostanz@umd.edu
Michelle Costanzo mcostanz@umd.edu
Michelle Costanzo mcostanz@umd.edu
Michelle Costanzo mcostanz@umd.edu
Michelle Costanzo mcostanz@umd.edu
Michelle Costanzo mcostanz@umd.edu
Michelle Costanzo mcostanz@umd.edu
Michelle Costanzo mcostanz@umd.edu
Michelle Costanzo mcostanz@umd.edu
Michelle Costanzo mcostanz@umd.edu
Michelle Costanzo mcostanz@umd.edu
Michelle Costanzo mcostanz@umd.edu
Michelle Costanzo mcostanz@umd.edu
Michelle Costanzo mcostanz@umd.edu
Michelle Costanzo mcostanz@umd.edu
Michelle Costanzo mcostanz@umd.edu
Michelle Costanzo mcostanz@umd.edu

Flyer B:

Study on the Emotion Regulation of Competitive Athletes



Emotion Regulation → **Superior Performance**

The purpose of this study is to examine the brain's response (via functional Magnetic Resonance Imaging) to images (known to produce a mental stress response) in individuals who are successful athletes. This research is associated with and conducted by the University of Maryland staff/faculty.

Who is eligible to volunteer to participate?

- **Students between the age of 18-22**
- **All majors welcome!**

You must NOT have:

- **Any ferromagnetic metal implants or clips in your body**
- **Claustrophobia (fear of enclosed spaces)**

What will you do?

• Fill out questionnaires

• MRI at Georgetown University: the MRI scanner will be taking many pictures of your brain while you view images on a screen and rate how they make you feel.

•Get a picture of your brain and all participants will be provided a report of the study results

Michelle Costanzo
mcostanz@umd.edu
Michelle Costanzo
mcostanz@umd.edu
Michelle Costanzo
mcostanz@umd.edu
Michelle Costanzo
mcostanz@umd.edu
Michelle Costanzo
mcostanz@umd.edu
Michelle Costanzo
mcostanz@umd.edu
Michelle Costanzo
mcostanz@umd.edu
Michelle Costanzo
mcostanz@umd.edu
Michelle Costanzo
mcostanz@umd.edu
Michelle Costanzo
mcostanz@umd.edu
Michelle Costanzo
mcostanz@umd.edu
Michelle Costanzo
mcostanz@umd.edu
Michelle Costanzo
mcostanz@umd.edu
Michelle Costanzo
mcostanz@umd.edu
Michelle Costanzo
mcostanz@umd.edu
Michelle Costanzo
mcostanz@umd.edu
Michelle Costanzo
mcostanz@umd.edu
Michelle Costanzo
mcostanz@umd.edu
Michelle Costanzo
mcostanz@umd.edu

CONSENT FORM

Project Title	***Study on the Emotion Regulation of Competitive Athletes***
Why is this research being done?	This is a research project being conducted by the Cognitive Motor Neuroscience Laboratory of the University of Maryland, College Park at the Georgetown University Center for Functional and Molecular Imaging by Dr. Bradley Hatfield and Ms. Michelle Costanzo. We are inviting you to participate in this research project because you have responded to the posted flyer. The purpose of this research project is to examine the brain's response (via functional Magnetic Resonance Imaging (fMRI)) to images (known to produce a mental stress response).
What will I be asked to do?	The procedures involve 1) answering questionnaires and 2) functional and structural brain magnetic images obtained at the Center for Functional and Molecular Imaging (CMFI) at Georgetown University (approximately 2 hrs of which only about 1 hr is in the scanner). The questions will ask your feelings of anxiety or stress, your emotional life and a short screening survey to ensure your safety in the scanner. The staff will provide an orientation to the MR scanner and will give you instructions about what to do in the scanner during the test and what to do if you experience discomfort. Before entering the scanner you will learn to use an emotion regulation strategy called cognitive reappraisal. When cued ("Decrease") you will transform the meaning of the negative scenario into positive terms (e.g., woman crying outside of a church could be alternatively interpreted as expressing tears of joy from a wedding ceremony rather than of sorrow from a funeral) or rationalize/objectify the content of the pictures (e.g., a woman with facial bruises could be translated as an actor wearing makeup rather than a victim of domestic abuse). You will be asked to rate how negative the pictures make you feel. You will then be prepared for the magnetic resonance (MR) imaging session which involves wearing a heart rate monitor (electrodes placed on chest), and a skin conductance monitor (bands are worn around two fingers to sense the electrical activity of your skin surface). You will then go into the scanning room and will lie down in supine position (on your back) the scanner. First you will relax during the first scan (structural scan) by closing your eyes. Then you will practice using a joy stick which you will use to select your ratings of the images. During brain imaging, you will be instructed to "decrease" during which you will reappraise images as described above or instructed to "watch" during which you will simply look at the image and let yourself respond naturally. There will also be periods where you will see a fixation cross where you should just keep your eyes still. When scanning is completed, all monitoring equipment will be removed and

	you may leave. In total, it is estimated that your participation including the question session and the brain imaging session will take about 2 hours excluding travel time to Georgetown University (30 minutes of surveys and cognitive testing, 30 minutes of task training, 60 minutes of scan time).
What about confidentiality?	We will do our best to keep your personal information confidential. To help protect your confidentiality, all subject records will be maintained in locked and/or password protected files. All forms will be identified by a unique numeric code and this code will be used for all levels of processing and analysis. In other words, your personal identification information such as your name will not be associated with any forms of data. The informed consent document (on which you have provided your signature) will be retained in a separate locked filing cabinet in the School of Public Health, University of Maryland, to assure confidentiality and protection of your identity. Please note that these procedures will be followed for data retained on the campus of the University of Maryland and brain imaging and other data obtained and processed at Georgetown University. All information collected will be kept for a period of 15 years, at which point it will be destroyed. When we write a report or article about this research project, we will present grouped results only; your identity will be protected to the maximum extent possible. Your information may be shared with representatives of the University of Maryland, College Park or governmental authorities if you or someone else is in danger or if we are required to do so by law.
What are the risks of this research?	The magnetic resonance brain imaging technique is noninvasive and there are few potential risks associated with it. This technology uses powerful magnetic fields and weak electromagnetic radiation, which have not been associated with significant adverse biological effects in patients. The 3.0T MRI system meets federal government requirements for field strength, gradient switching and power disposition for all acquisitions used in the proposed research. Some possible risks include anxiety or discomfort in the scanner and noise during scanning. Due to the small size of the scanner, claustrophobic subjects may not tolerate the confinement in the scanner and the head position apparatus. You will be in visual and verbal contact with the experimenter throughout the scan through a video monitoring system and can be removed quickly. You may experience dizziness or a metallic taste if you move your heads rapidly in the magnet. This, however, is only temporary and does not occur if the head is still. Loud sounds are generated by the scanner used to generate a brain image. Generally, this is not a significant problem in clinical scanners, but additional precautions will be taken to provide you with earplugs to reduce the noise (not greater

	than 30dB). The investigators for this project are not trained to perform radiological diagnosis, and the scans performed are not optimized to find abnormalities. The investigators are not responsible for failure to find existing abnormalities in your MRI scans. However, on occasion the investigator may notice a finding on a MRI scan that seems abnormal. When this occurs, a neurologist will be consulted as to whether the finding merits further investigation, in which case the investigator or the consulting neurologist would contact you and your primary care physician to inform you of the finding. The decision as to whether to proceed with further examination lies with you and your physician. The investigators, the consulting neuroradiologist or neurologist, and Georgetown are not responsible for any examination or treatment that you undertake based upon these findings. Because images in this study do not comprise a proper clinical MRI series, these images will not be made available for diagnostic purposes. We will make every effort to prevent study-related injuries and illnesses. If you are injured or become ill while you are in the study and the illness or injury is due to your participation in this study, you will receive necessary medical care at the usual charge. The costs of this care will be charged to you or to your health insurer. No funds are available from Georgetown University, Georgetown University Hospital, MedStar Research Institute, or their affiliates, the University of Maryland, the District of Columbia government or the federal government to repay you or compensate you for a study related injury or illness. **Avoidance of Pregnancy:** The procedures used in this study may be unsafe for an unborn baby, an infant, sperm, and eggs. If you, as a subject of study, are a woman of child bearing potential, you must agree to avoid pregnancy during the periods of this study that involve MRI procedures; if you, as a subject, are a man, you must agree to not conceive a child during your participation in the MRI procedures. If you do become pregnant during the study or if you father a child during the study, you should immediately notify Dr. John VanMeter at 202-687-3592. In addition, if you are already pregnant or are breast feeding, you cannot participate in this study
What are the benefits of this research?	This research is not designed to help you personally, but the results may help the investigator learn more about whether emotion regulation can account for stress resilience and maintained elite motor performance. This could ultimately result in more tactical interventions which target psychological strategies that help motor performance. In turn, this has a broad application to human performance ranging from activities of daily living in seniors to that of elite athletes engaged in sport competition.
Do I have to be in	Your participation in this research is completely voluntary. You may

this research? May I stop participating at any time?	choose not to take part at all. If you decide to participate in this research, you may stop participating at any time. If you decide not to participate in this study or if you stop participating at any time, you will not be penalized or lose any benefits to which you otherwise qualify.
What if I have questions?	This research is being conducted by Bradley D. Hatfield, Ph.D. FACSM, FAAKPE, Department of Kinesiology at the University of Maryland, College Park. If you have any questions about the research study itself, please contact Bradley D. Hatfield, Ph.D. FACSM, FAAKPE at: Dept. of Kinesiology, School of Public Health, University of Maryland College Park MD 20742. Phone : 301-405-2485 bhatfiel@umd.edu or Michelle Costanzo, Dept. of Kinesiology, School of Public Health, University of Maryland College Park MD 20742, Phone: 301 405 2572 mcostanz@umd.edu If you have questions about your rights as a research subject or wish to report a research-related injury, please contact: **Institutional Review Board Office, University of Maryland, College Park, Maryland, 20742; (e-mail) irb@umd.edu; (telephone) 301-405-0678** This research has been reviewed according to the University of Maryland, College Park IRB procedures for research involving human subjects.
Statement of Age of Subject and Consent	Your signature indicates that: you are at least 18 years of age; the research has been explained to you; your questions have been fully answered; and you freely and voluntarily choose to participate in this research project.
Signature and Date	**NAME OF SUBJECT**
	SIGNATURE OF SUBJECT
	DATE

MAGNETIC RESONANCE (MR) PROCEDURE SCREENING FORM FOR PATIENTS

Date _____/_____/_____ Patient Number ____________________

Name ____ Age ________ Height ________ Weight ________
Last name First name Middle Initial

Date of Birth _____/_____/_____ Male ❒ Female ❒ Body Part to be Examined ______________________
month day year

Address ____ Telephone (home) (____) _____-_______

City ____ Telephone (work) (____) _____-_______

State ____________________ Zip Code __________

Reason for MRI and/or Symptoms ____

Referring Physician ______________________________ Telephone (____) _____-___________

1. Have you had prior surgery or an operation (e.g., arthroscopy, endoscopy, etc.) of any kind? ❒ No ❒ Yes
   If yes, please indicate the date and type of surgery:
   Date _____/_____/_____ Type of surgery ______________________________
   Date _____/_____/_____ Type of surgery ______________________________
2. Have you had a prior diagnostic imaging study or examination (MRI, CT, Ultrasound, X-ray, etc.)? ❒No ❒ Yes
   If yes, please list:

	Body part	Date	Facility
MRI	____________	____/____/____	____________
CT/CAT Scan	____________	____/____/____	____________
X-Ray	____________	____/____/____	____________
Ultrasound	____________	____/____/____	____________
Nuclear Medicine	____________	____/____/____	____________
Other________	____________	____/____/____	____________

3. Have you experienced any problem related to a previous MRI examination or MR procedure? ❒ No ❒ Yes
   If yes, please describe: ______________________________
4. Have you had an injury to the eye involving a metallic object or fragment (e.g., metallic slivers, shavings, foreign body, etc.)? ❒ No ❒ Yes
   If yes, please describe: ______________________________
5. Have you ever been injured by a metallic object or foreign body (e.g., BB, bullet, shrapnel, etc.)? ❒ No ❒ Yes
   If yes, please describe: ______________________________
6. Are you currently taking or have you recently taken any medication or drug? ❒ No ❒ Yes
   If yes, please list:______________________________
7. Are you allergic to any medication? ❒ No ❒ Yes
   If yes, please list:______________________________
8. Do you have a history of asthma, allergic reaction, respiratory disease, or reaction to a contrast medium or dye used for an MRI, CT, or X-ray examination? ❒ No ❒ Yes
9. Do you have anemia or any disease(s) that affects your blood, a history of renal (kidney) disease, or seizures? ❒ No ❒ Yes
   If yes, please describe: ______________________________

For female patients:

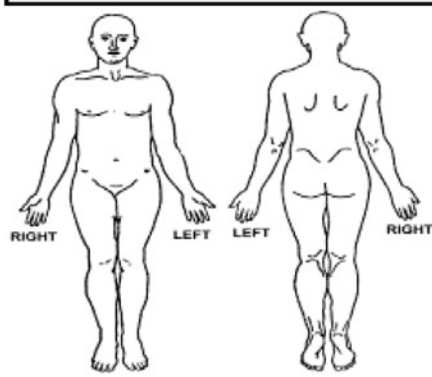
10. Date of last menstrual period:_____/_____/_____ Post menopausal? ❒ No ❒ Yes
11. Are you pregnant or experiencing a late menstrual period? ❒ No ❒ Yes
12. Are you taking oral contraceptives or receiving hormonal treatment? ❒ No ❒ Yes
13. Are you taking any type of fertility medication or having fertility treatments? ❒ No ❒ Yes
    If yes, please describe: ______________________________
14. Are you currently breastfeeding? ❒ No ❒ Yes

> ⚠ **WARNING:** Certain implants, devices, or objects may be hazardous to you and/or may interfere with the MR procedure (i.e., MRI, MR angiography, functional MRI, MR spectroscopy). **Do not enter** the MR system room or MR environment if you have any question or concern regarding an implant, device, or object. Consult the MRI Technologist or Radiologist BEFORE entering the MR system room. **The MR system magnet is ALWAYS on.**

Please indicate if you have any of the following:

- ❒ Yes ❒ No Aneurysm clip(s)
- ❒ Yes ❒ No Cardiac pacemaker
- ❒ Yes ❒ No Implanted cardioverter defibrillator (ICD)
- ❒ Yes ❒ No Electronic implant or device
- ❒ Yes ❒ No Magnetically-activated implant or device
- ❒ Yes ❒ No Neurostimulation system
- ❒ Yes ❒ No Spinal cord stimulator
- ❒ Yes ❒ No Internal electrodes or wires
- ❒ Yes ❒ No Bone growth/bone fusion stimulator
- ❒ Yes ❒ No Cochlear, otologic, or other ear implant
- ❒ Yes ❒ No Insulin or other infusion pump
- ❒ Yes ❒ No Implanted drug infusion device
- ❒ Yes ❒ No Any type of prosthesis (eye, penile, etc.)
- ❒ Yes ❒ No Heart valve prosthesis
- ❒ Yes ❒ No Eyelid spring or wire
- ❒ Yes ❒ No Artificial or prosthetic limb
- ❒ Yes ❒ No Metallic stent, filter, or coil
- ❒ Yes ❒ No Shunt (spinal or intraventricular)
- ❒ Yes ❒ No Vascular access port and/or catheter
- ❒ Yes ❒ No Radiation seeds or implants
- ❒ Yes ❒ No Swan-Ganz or thermodilution catheter
- ❒ Yes ❒ No Medication patch (Nicotine, Nitroglycerine)
- ❒ Yes ❒ No Any metallic fragment or foreign body
- ❒ Yes ❒ No Wire mesh implant
- ❒ Yes ❒ No Tissue expander (e.g., breast)
- ❒ Yes ❒ No Surgical staples, clips, or metallic sutures
- ❒ Yes ❒ No Joint replacement (hip, knee, etc.)
- ❒ Yes ❒ No Bone/joint pin, screw, nail, wire, plate, etc.
- ❒ Yes ❒ No IUD, diaphragm, or pessary
- ❒ Yes ❒ No Dentures or partial plates
- ❒ Yes ❒ No Tattoo or permanent makeup
- ❒ Yes ❒ No Body piercing jewelry
- ❒ Yes ❒ No Hearing aid
  (Remove before entering MR system room)
- ❒ Yes ❒ No Other implant ______________
- ❒ Yes ❒ No Breathing problem or motion disorder
- ❒ Yes ❒ No Claustrophobia

Please mark on the figure(s) below the location of any implant or metal inside of or on your body.



⚠ IMPORTANT INSTRUCTIONS

Before entering the MR environment or MR system room, you must remove __all__ metallic objects including hearing aids, dentures, partial plates, keys, beeper, cell phone, eyeglasses, hair pins, barrettes, jewelry, body piercing jewelry, watch, safety pins, paperclips, money clip, credit cards, bank cards, magnetic strip cards, coins, pens, pocket knife, nail clipper, tools, clothing with metal fasteners, & clothing with metallic threads.

Please consult the MRI Technologist or Radiologist if you have any question or concern BEFORE you enter the MR system room.

NOTE: You may be advised or required to wear earplugs or other hearing protection during the MR procedure to prevent possible problems or hazards related to acoustic noise.

I attest that the above information is correct to the best of my knowledge. I read and understand the contents of this form and had the opportunity to ask questions regarding the information on this form and regarding the MR procedure that I am about to undergo.

Signature of Person Completing Form: ______________________ Date ____/____/____
Signature

Form Completed By: ❒ Patient ❒ Relative ❒ Nurse ______________________ ______________________
Print name Relationship to patient

Form Information Reviewed By: ______________________ ______________________
Print name Signature

❒ MRI Technologist ❒ Nurse ❒ Radiologist ❒ Other______________________

Subject ID:

DIRECTIONS: A number of statements which people have used to describe themselves are given below. Read each statement and circle the appropriate number to the right of the statement to indicate how you feel *right* now, that is, *at this moment*. There are no right or wrong answers. Do not spend too much time on any one statement but give the answer which seems to describe your present feelings best.

	Not at all	Somewhat	Moderately so	Very Much so
1. I feel calm	1	2	3	4
2. I feel secure	1	2	3	4
3. I am tense	1	2	3	4
4. I feel strained	1	2	3	4
5. I feel at ease	1	2	3	4
6. I feel upset	1	2	3	4
7. I am presently worrying over possible misfortunes	1	2	3	4
8. I feel satisfied	1	2	3	4
9. I feel frightened	1	2	3	4
10. I feel comfortable	1	2	3	4
11. I feel self-confident	1	2	3	4
12. I feel nervous	1	2	3	4
13. I am jittery	1	2	3	4
14. I feel indecisive	1	2	3	4
15. I am relaxed	1	2	3	4
16. I feel content	1	2	3	4
17. I am worried	1	2	3	4
18. I feel confused	1	2	3	4
19. I feel steady	1	2	3	4
20. I feel pleasant	1	2	3	4

Subject ID:

DIRECTIONS: A number of statements which people have used to describe themselves are given below. Read each statement and circle the appropriate number to the right of the statement to indicate how you *generally* feel. There are no right or wrong answers. Do not spend too much time on any one statement but give the answer which seems to describe how you generally feel.

	Not at all	Somewhat	Moderately so	Very Much so
21. I feel pleasant……..……………………………………...……	1	2	3	4
22. I feel nervous and restless...…………………………………….	1	2	3	4
23. I am satisfied with myself…...………………………………….	1	2	3	4
24. I wish I could be as happy as others seem to be………………..	1	2	3	4
25. I feel like a failure………………………………………………	1	2	3	4
26. I feel rested...…...…………………………………...………..	1	2	3	4
27. I am "calm, cool, and collected"…………………...……...…...	1	2	3	4
28. I feel that difficulties are piling up so that I cannot overcome them	1	2	3	4
29. I worry too much over something that really doesn't matter…...	1	2	3	4
30. I am happy……...…………………………………………….	1	2	3	4
31. I have disturbing thoughts……..………………………………..	1	2	3	4
32. I lack self-confidence…………...………………………………	1	2	3	4
33. I feel secure..……………………………………………………	1	2	3	4
34. I make decisions easily…………………………………………	1	2	3	4
35. I feel inadequate…….………………………………………….	1	2	3	4
36. I am content……………………….………………………….	1	2	3	4
37. Some unimportant thought runs through my mind and bothers me	1	2	3	4
38. I take disappointments so keenly that I can't put them out of my mind	1	2	3	4
39. I am a steady person……………………………………………	1	2	3	4
40. I get in a state of tension or turmoil as I think over my recent concerns and interests	1	2	3	4

Subject ID ________

Instructions: This questionnaire consists of 21 groups of statements. Please read each group of statements carefully, and then pick out the **one statement** in each group that best describes the way you have been feeling during the **past two weeks, including today**. Circle the number beside the statement you have picked. If several statements in the group seem to apply equally well, circle the highest number for that group. Be sure that you do not choose more than one statement for any group, including Item 16 (Changes in Sleeping Pattern) or Item 18 (Changes in Appetite).

1. Sadness

0 I do not feel sad.
1 I feel sad much of the time.
2 I am sad all the time.
3 I am so sad or unhappy that I can't stand it.

2. Pessimism

0 I am not discouraged about my future.
1 I feel more discouraged about my future than I used to be.
2 I do not expect things to work out for me.
3 I feel my future is hopeless and will only get worse.

3. Past Failure

0 I do not feel like a failure.
1 I have failed more than I should have.
2 As I look back, I see a lot of failures.
3 I feel I am a total failure as a person.

4. Loss of Pleasure

0 I get as much pleasure as I ever did from the things I enjoy.
1 I don't enjoy things as much as I used to.
2 I get very little pleasure from the things I used to enjoy.
3 I can't get any pleasure from the things I used to enjoy.

5. Guilty Feelings

0 I don't feel particularly guilty.
1 I feel guilty over many things I have done or should have done.
2 I feel quite guilty most of the time.
3 I feel guilty all of the time.

6. Punishment Feelings

0 I don't feel I am being punished.
1 I feel I may be punished.
2 I expect to be punished.
3 I feel I am being punished.

7. Self-Dislike

0 I feel the same about myself as ever.
1 I have lost confidence in myself.
2 I am disappointed in myself.
3 I dislike myself.

8. Self-Criticalness

0 I don't criticize or blame myself more than usual.
1 I am more critical of myself than I used to be.
2 I criticize myself for all of my faults.
3 I blame myself for everything bad that happens.

9. Suicidal Thoughts or Wishes

0 I don't have any thoughts of killing myself.
1 I have thoughts of killing myself, but I would not carry them out.
2 I would like to kill myself.
3 I would kill myself if I had the chance.

10. Crying

0 I don't cry anymore than I used to.
1 I cry more than I used to.
2 I cry over every little thing.
3 I feel like crying, but I can't.

11. Agitation

0 I am no more restless or wound up than usual.
1 I feel more restless or wound up than usual.
2 I am so restless or agitated that it's hard to stay still.
3 I am so restless or agitated that I have to keep moving or doing something.

12. Loss of Interest

0 I have not lost interest in other people or activities.
1 I am less interested in other people or things than before.
2 I have lost most of my interest in other people or things.
3 It's hard to get interested in anything.

13. Indecisiveness

0 I make decisions about as well as ever.
1 I find it more difficult to make decisions than usual.
2 I have much greater difficulty in making decisions than I used to.
3 I have trouble making any decisions.

14. Worthlessness

0 I do not feel I am worthless.
1 I don't consider myself as worthwhile and useful as I used to.
2 I feel more worthless as compared to other people.
3 I feel utterly worthless.

15. Loss of Energy

0 I have as much energy as ever.
1 I have less energy than I used to have.
2 I don't have enough energy to do very much.
3 I don't have enough energy to do anything.

16. Changes in Sleeping Pattern

0 I have not experienced any change in my sleeping pattern.

1a I sleep somewhat more than usual.
1b I sleep somewhat less than usual.

2a I sleep a lot more than usual.
2b I sleep a lot less than usual.

3a I sleep most of the day.
3b I wake up 1–2 hours early and can't get back to sleep.

17. Irritability

0 I am no more irritable than usual.
1 I am more irritable than usual.
2 I am much more irritable than usual.
3 I am irritable all the time.

18. Changes in Appetite

0 I have not experienced any change in my appetite.

1a My appetite is somewhat less than usual.
1b My appetite is somewhat greater than usual.

2a My appetite is much less than before.
2b My appetite is much greater than usual.

3a I have no appetite at all.
3b I crave food all the time.

19. Concentration Difficulty

0 I can concentrate as well as ever.
1 I can't concentrate as well as usual.
2 It's hard to keep my mind on anything for very long.
3 I find I can't concentrate on anything.

20. Tiredness or Fatigue

0 I am no more tired or fatigued than usual.
1 I get more tired or fatigued more easily than usual.
2 I am too tired or fatigued to do a lot of the things I used to do.
3 I am too tired or fatigued to do most of the things I used to do.

21. Loss of Interest in Sex

0 I have not noticed any recent change in my interest in sex.
1 I am less interested in sex than I used to be.
2 I am much less interested in sex now.
3 I have lost interest in sex completely.

Subject ID:

Instructions and Items
We would like to ask you some questions about your emotional life, in particular, how you control (that is, regulate and manage) your emotions. The questions below involve two distinct aspects of your emotional life. One is your emotional experience, or what you feel like inside. The other is your emotional expression, or how you show your emotions in the way you talk, gesture, or behave. Although some of the following questions may seem similar to one another, they differ in important ways. For each item, please answer using the following scale:

1-----------------2------------------3------------------4------------------5------------------6------------------7

strongly disagree	**neutral**	**strongly agree**

Write the number that corresponds with your

1. ____ When I want to feel more *positive* emotion (such as joy or amusement), I *change what I'm thinking about*.

2. ____ I keep my emotions to myself.

3. ____ When I want to feel less *negative* emotion (such as sadness or anger), I *change what I'm thinking about*.

4. ____ When I am feeling *positive* emotions, I am careful not to express them.

5. ____ When I'm faced with a stressful situation, I make myself *think about it* in a way that helps me stay calm.

6. ____ I control my emotions by *not expressing them*.

7. ____ When I want to feel more *positive* emotion, I *change the way I'm thinking* about the situation.

8. ____ I control my emotions by *changing the way I think* about the situation I'm in.

9. ____ When I am feeling *negative* emotions, I make sure not to express them.

10. ____ When I want to feel less *negative* emotion, I *change the way I'm thinking* about the situation.

Subject ID:

Instructions:

- **Below are statements about life that people often feel differently about.**
- **Please show how much you think each one is TRUE.**
- **Give your own honest opinions . . . There are no right or wrong answers.**
- **Circle one response for each question.**
- **Response options are as follows:**

  0 Not At All True **1** A Little True **2** Quite True **3** Completely True

Questions:	**Not At All True 0**	**A Little True 1**	**Quite True 2**	**Completely True 3**
1. Most of my life gets spent doing things that are meaningful	0	1	2	3
2. By working hard you can nearly always achieve your goals.	0	1	2	3
3. I don't like to make changes in my regular activities.	0	1	2	3
4. I feel that my life is somewhat empty of meaning.	0	1	2	3
5. Changes in routine are interesting to me.	0	1	2	3
6. How things go in my life depends on my own actions.	0	1	2	3
7. I really look forward to my work activities.	0	1	2	3
8. I don't think there is much I can do to influence my own future.	0	1	2	3
9. I enjoy the challenge when I have to do more than one thing at a time.	0	1	2	3
10. Most days, life is really interesting and exciting for me.	0	1	2	3
11. It bothers me when my daily routine gets interrupted.	0	1	2	3
12. It is up to me to decide how the rest of my life will be.	0	1	2	3
13. Life in general is boring for me.	0	1	2	3
14. I like having a daily schedule that doesn't change very much.	0	1	2	3
15. My choices make a real difference in how things turn out in the end.	0	1	2	3

Subject ID _______

Study on the Emotion Regulation of Competitive Athletes

1. Please select the answer that best describes your **football** experience

0=no experience, do not watch or attend games (not a fan)
1=no experience, but watch occasionally (mild fan)
2=no experience, but watch frequently (avid fan)
3= some experience playing and watch frequently (e.g. intramurals)
4=several years experience playing competitively (e.g. high school)
5=currently playing competitively.

2. Please select the answer that best describes your sports experience **in general**

0=no experience, do not watch or attend games (not a fan)
1=no experience, but watch occasionally (mild fan)
2=no experience, but watch frequently (avid fan)
3= some experience playing and watch frequently (e.g. intramurals)
4=several years experience playing competitively (e.g. high school)
5=currently playing competitively.

3. Please write down what sports you play, have played or watch:

4. Please answer the questions below based on the response scale:

Response Scale				
-2	-1	0	+1	+2
Do Not Believe At All		Believe 50% of the Time		Believe 100% of the Time

______ 1. When I am failing, I am afraid that I might not have enough talent.

______ 2. When I am failing, it upsets my "plan" for the future.

______ 3. When I am not succeeding, people are less interested in me.

______ 4. When I am failing, important others are disappointed.

______ 5. When I am failing, I worry about what others think about me.

Sport Competition Anxiety Test (SCAT)

Assessing Your Anxiety

Read each statement below, decide if you "Rarely", "Sometimes" or "Often" feel this way when competing in your sport, tick the appropriate box to indicate your response.

	Rarely	Sometimes	Often
1. Competing against others is socially enjoyable	☐	☐	☐
2. Before I compete I feel uneasy	☐	☐	☐
3. Before I compete I worry about not performing well	☐	☐	☐
4. I am a good sportsman when I compete	☐	☐	☐
5. When I compete, I worry about making mistakes	☐	☐	☐
6. Before I compete I am calm	☐	☐	☐
7. Setting a goal is important when competing	☐	☐	☐
8. Before I compete I get a queasy feeling in my stomach	☐	☐	☐
9. Just before competing, I notice my heart beats faster than usual	☐	☐	☐
10. I like to compete in games that demands a lot of physical energy	☐	☐	☐
11. Before I compete I feel relaxed	☐	☐	☐
12. Before I compete I am nervous	☐	☐	☐
13. Team sports are more exciting than individual sports	☐	☐	☐
14. I get nervous wanting to start the game	☐	☐	☐
15. Before I compete I usually get uptight	☐	☐	☐

Run 1

9415 pas_neg
Watch Handicapped

1	2	3	4	5
not at all		moderately		extremely

---

2 cog_reap
Decrease

1	2	3	4	5
not at all		moderately		extremely

6410 pas_neg
Watch AimedGun

1	2	3	4	5
not at all		moderately		extremely

---

50 cog_reap
Decrease

1	2	3	4	5
not at all		moderately		extremely

2235 pas_neut
Watch Butcher

1	2	3	4	5
not at all		moderately		extremely

---

71 cog_reap
Decrease

1	2	3	4	5
not at all		moderately		extremely

6250.1 cog_reap
Decrease AimedGun

1	2	3	4	5
not at all		moderately		extremely

Run 1

2102 pas_neut
Watch NeuMan

1	2	3	4	5
not at all		moderately		extremely

6211 pas_neg
Watch Attack

1	2	3	4	5
not at all		moderately		extremely

79 cog_reap
Decrease

1	2	3	4	5
not at all		moderately		extremely

3 pas_neg
Watch

1	2	3	4	5
not at all		moderately		extremely

2485 pas_neut
Watch Man

1	2	3	4	5
not at all		moderately		extremely

1040 cog_reap
Decrease Snake

1	2	3	4	5
not at all		moderately		extremely

83 cog_reap
Decrease

1	2	3	4	5
not at all		moderately		extremely

Run 1

6834 pas_neg
Watch Police
1 2 3 4 5
not at all moderately extremely

---

68 pas_neg
Watch
1 2 3 4 5
not at all moderately extremely

2100 cog_reap
Decrease
1 2 3 4 5
not at all moderately extremely

4532 pas_neut
Watch AttractiveMan
1 2 3 4 5
not at all moderately extremely

---

72 cog_reap
Decrease
1 2 3 4 5
not at all moderately extremely

---

87 pas_neg
Watch
1 2 3 4 5
not at all moderately extremely

2480 cog_reap
Decrease ElderlyMan
1 2 3 4 5
not at all moderately extremely

27 pas_neg
Watch

1	2	3	4	5
not at all		moderately		extremely

53 pas_neg
Watch

1	2	3	4	5
not at all		moderately		extremely

2394 pas_neut
Watch Medicalworker

1	2	3	4	5
not at all		moderately		extremely

2692 cog_reap
Decrease Bomb

1	2	3	4	5
not at all		moderately		extremely

54 pas_neg
Watch

1	2	3	4	5
not at all		moderately		extremely

1026 pas_neg
Watch Snake

1	2	3	4	5
not at all		moderately		extremely

3280 cog_reap
Decrease DentalExam

1	2	3	4	5
not at all		moderately		extremely

9230 pas_neg

Watch OilFire

1	2	3	4	5
not at all		moderately		extremely

2385 pas_neut

Watch Girl

1	2	3	4	5
not at all		moderately		extremely

Run 2

75 pas_neg
Watch

1 2 3 4 5
not at all moderately extremely

2005 pas_neut
Watch AttractiveMan

1 2 3 4 5
not at all moderately extremely

---

62 pas_neg
Watch

1 2 3 4 5
not at all moderately extremely

1052 cog_reap
Decrease Snake

1 2 3 4 5
not at all moderately extremely

4100 pas_neut
Watch MaleDancers

1 2 3 4 5
not at all moderately extremely

6213 pas_neg
Watch Terrorist

1 2 3 4 5
not at all moderately extremely

---

32 pas_neg
Watch

1 2 3 4 5
not at all moderately extremely

Run 2

2110 cog_reap
Decrease AngryFace

1	2	3	4	5
not at all		moderately		extremely

2320 pas_neut
Watch Girl

1	2	3	4	5
not at all		moderately		extremely

---

8 cog_reap
Decrease

1	2	3	4	5
not at all		moderately		extremely

6314 pas_neg
Watch Attack

1	2	3	4	5
not at all		moderately		extremely

---

58 cog_reap
Decrease

1	2	3	4	5
not at all		moderately		extremely

2495 pas_neut
Watch Man

1	2	3	4	5
not at all		moderately		extremely

6840 pas_neg
Watch Police

1	2	3	4	5
not at all		moderately		extremely

73 cog_reap
Decrease
1 2 3 4 5
not at all moderately extremely

2795 cog_reap
Decrease Boy
1 2 3 4 5
not at all moderately extremely

8480 pas_neg
Watch BikerOnFire
1 2 3 4 5
not at all moderately extremely

---

86 pas_neg
Watch
1 2 3 4 5
not at all moderately extremely

2020 pas_neut
Watch Adult
1 2 3 4 5
not at all moderately extremely

---

67 cog_reap
Decrease
1 2 3 4 5
not at all moderately extremely

2312 cog_reap
Decrease Mother
1 2 3 4 5
not at all moderately extremely

Run 2

88	pas_neg			
Watch				
1	2	3	4	5
not at all		moderately		extremely

4621	cog_reap			
Decrease	Harassment			
1	2	3	4	5
not at all		moderately		extremely

60	cog_reap			
Decrease				
1	2	3	4	5
not at all		moderately		extremely

9404	pas_neg			
Watch	Soldiers			
1	2	3	4	5
not at all		moderately		extremely

2191	pas_neut			
Watch	Farmer			
1	2	3	4	5
not at all		moderately		extremely

82	cog_reap			
Decrease				
1	2	3	4	5
not at all		moderately		extremely

2695	cog_reap			
Decrease	Refugees			
1	2	3	4	5
not at all		moderately		extremely

59 pas_neg

Watch

1 2 3 4 5

not at all moderately extremely

9582 pas_neg

Watch DentalExam

1 2 3 4 5

not at all moderately extremely

11 cog_reap
Decrease

1	2	3	4	5
not at all		moderately		extremely

2718 cog_reap
Decrease DrugAddict

1	2	3	4	5
not at all		moderately		extremely

8465 pas_neut
Watch Runner

1	2	3	4	5
not at all		moderately		extremely

6244 pas_neg
Watch AimedGun

1	2	3	4	5
not at all		moderately		extremely

1230 cog_reap
Decrease Spider

1	2	3	4	5
not at all		moderately		extremely

76 pas_neg
Watch

1	2	3	4	5
not at all		moderately		extremely

13 cog_reap
Decrease

1	2	3	4	5
not at all		moderately		extremely

Run 3

2514	pas_neut			
Watch	Woman			
1	2	3	4	5
not at all		moderately		extremely

65	pas_neg			
Watch				
1	2	3	4	5
not at all		moderately		extremely

6555	pas_neg			
Watch	Knife			
1	2	3	4	5
not at all		moderately		extremely

7493	pas_neut			
Watch	Man			
1	2	3	4	5
not at all		moderately		extremely

70	cog_reap			
Decrease				
1	2	3	4	5
not at all		moderately		extremely

9045	pas_neg			
Watch	NativeFem			
1	2	3	4	5
not at all		moderately		extremely

4535	pas_neut			
Watch	Weightlifter			
1	2	3	4	5
not at all		moderately		extremely

Run 3

61 cog_reap
Decrease

1	2	3	4	5
not at all		moderately		extremely

1270 pas_neg
Watch Roach

1	2	3	4	5
not at all		moderately		extremely

78 cog_reap
Decrease

1	2	3	4	5
not at all		moderately		extremely

22 pas_neg
Watch

1	2	3	4	5
not at all		moderately		extremely

2130 cog_reap
Decrease Woman

1	2	3	4	5
not at all		moderately		extremely

51 cog_reap
Decrease

1	2	3	4	5
not at all		moderately		extremely

2749 pas_neut
Watch Smoking

1	2	3	4	5
not at all		moderately		extremely

2491 cog_reap
Decrease SickMan

1	2	3	4	5
not at all		moderately		extremely

55 pas_neg
Watch

1	2	3	4	5
not at all		moderately		extremely

9409 pas_neg
Watch MenW/guns

1	2	3	4	5
not at all		moderately		extremely

4536 pas_neut
Watch AttractiveMan

1	2	3	4	5
not at all		moderately		extremely

80 pas_neg
Watch

1	2	3	4	5
not at all		moderately		extremely

2810 cog_reap
Decrease Boy

1	2	3	4	5
not at all		moderately		extremely

84 pas_neg
Watch

1	2	3	4	5
not at all		moderately		extremely

Run 3

2682 cog_reap

Decrease Police

1	2	3	4	5
not at all		moderately		extremely

9592 pas_neg

Watch Injection

1	2	3	4	5
not at all		moderately		extremely

Run 4

28 cog_reap
Decrease

1	2	3	4	5
not at all		moderately		extremely

2752 cog_reap
Decrease Alcoholic

1	2	3	4	5
not at all		moderately		extremely

1280 cog_reap
Decrease Rat

1	2	3	4	5
not at all		moderately		extremely

---

29 pas_neg
Watch

1	2	3	4	5
not at all		moderately		extremely

2357 pas_neut
Watch Man

1	2	3	4	5
not at all		moderately		extremely

6200 cog_reap
Decrease AimedGun

1	2	3	4	5
not at all		moderately		extremely

---

52 pas_neg
Watch

1	2	3	4	5
not at all		moderately		extremely

Run 4

56 cog_reap
Decrease

1	2	3	4	5
not at all		moderately		extremely

9190 pas_neut
Watch Woman

1	2	3	4	5
not at all		moderately		extremely

2372 pas_neut
Watch Woman

1	2	3	4	5
not at all		moderately		extremely

---

81 pas_neg
Watch

1	2	3	4	5
not at all		moderately		extremely

2271 cog_reap
Decrease Woman

1	2	3	4	5
not at all		moderately		extremely

2635 pas_neut
Watch Cowboy

1	2	3	4	5
not at all		moderately		extremely

---

57 cog_reap
Decrease

1	2	3	4	5
not at all		moderately		extremely

Run 4

6571 pas_neg
Watch CarTheft

1 2 3 4 5
not at all moderately extremely

---

63 cog_reap
Decrease

1 2 3 4 5
not at all moderately extremely

2870 pas_neut
Watch Teenager

1 2 3 4 5
not at all moderately extremely

---

64 cog_reap
Decrease

1 2 3 4 5
not at all moderately extremely

9594 pas_neg
Watch Injection

1 2 3 4 5
not at all moderately extremely

2270 pas_neut
Watch NeutChild

1 2 3 4 5
not at all moderately extremely

5970 cog_reap
Decrease Tornado

1 2 3 4 5
not at all moderately extremely

pas_neg

Run 4

66
Watch

1	2	3	4	5
not at all		moderately		extremely

---

69 pas_neg
Watch

1	2	3	4	5
not at all		moderately		extremely

2730 Watch
Alcoholic NativeBoy

1	2	3	4	5
not at all		moderately		extremely

---

77 pas_neg
Watch

1	2	3	4	5
not at all		moderately		extremely

9440 pas_neg
Watch Skulls

1	2	3	4	5
not at all		moderately		extremely

---

85 cog_reap
Decrease

1	2	3	4	5
not at all		moderately		extremely

1090 pas_neg
Watch Snake

1	2	3	4	5
not at all		moderately		extremely

Run 4

2445 pas_neut

Watch feet

1	2	3	4	5
not at all		moderately		extremely

3022 cog_reap

Decrease Scream

1	2	3	4	5
not at all		moderately		extremely

Appendix C: Task Order and Stimuli

Condition	file	Instructions	Instructional Onset	Picture Onset	Rating Onset	Sample Self Report Scores
pas_neg	9415	Watch	0	2.13	10.009	3.003906
cog_reap	2	Decrease	18.009	20.138	28.018	2.84375
pas_neg	6410	Watch	36.017	38.253	46.026	3.167969
cog_reap	50	Decrease	54.025	56.195	64.034	2.21875
pas_neut	2235	Watch	72.033	74.19	82.042	3.214844
cog_reap	71	Decrease	90.042	92.198	100.051	2.984375
cog_reap	6250.1	Decrease	108.05	110.153	118.059	2.941406
pas_neut	2102	Watch	126.058	128.188	136.067	3.027344
pas_neg	6211	Watch	144.066	146.183	154.075	3.027344
cog_reap	79	Decrease	162.075	164.218	172.084	3.027344
pas_neg	3	Watch	180.083	182.173	190.092	2.941406
pas_neut	2485	Watch	198.091	200.247	208.1	1.96875
cog_reap	1040	Decrease	216.099	218.202	226.108	3.027344
cog_reap	83	Decrease	234.108	236.237	244.117	2.804688
pas_neg	6834	Watch	252.116	254.245	262.125	2.984375
pas_neg	68	Watch	270.124	272.267	280.133	3.0625
cog_reap	2100	Decrease	288.132	290.289	298.141	1.066406
pas_neut	4532	Watch	306.141	308.257	316.15	3.027344
cog_reap	72	Decrease	324.149	326.265	334.158	3.097656
pas_neg	87	Watch	342.157	344.287	352.166	3.050781
cog_reap	2480	Decrease	360.165	362.282	370.174	3.050781
pas_neg	27	Watch	378.174	380.343	388.183	2.875
pas_neg	53	Watch	396.182	398.311	406.191	3.015625
pas_neut	2394	Watch	414.19	416.306	424.199	2.984375
cog_reap	2692	Decrease	432.198	434.301	442.207	2.957031
pas_neg	54	Watch	450.207	452.323	460.216	3.121094
pas_neg	8231	Watch	468.215	470.331	478.224	3.179688
cog_reap	3280	Decrease	486.223	488.339	496.232	3.15625
pas_neg	9230	Watch	504.231	506.348	514.24	3.097656
pas_neut	2385	Watch	522.24	524.343	532.249	1.039063

Condition	file	Instructions	Instructional Onset	Picture Onset	Rating Onset	Sample Self Report Scores
pas_neg	75	Watch	0	2.103	10.009	2.96875
pas_neut	2005	Watch	18.009	20.112	28.018	2.789063
pas_neg	62	Watch	36.017	38.173	46.026	3.15625
cog_reap	1052	Decrease	54.025	56.101	64.034	3.027344
pas_neut	4100	Watch	72.033	74.136	82.042	3.167969
pas_neg	6213	Watch	90.042	92.105	100.051	1.957031
pas_neg	32	Watch	108.05	110.166	118.059	2.761719
cog_reap	2110	Decrease	126.058	128.121	136.067	2.859375
pas_neut	2320	Watch	144.066	146.169	154.075	2.71875
cog_reap	8	Decrease	162.075	164.204	172.084	2.984375
pas_neg	6314	Watch	180.083	182.146	190.092	2.984375
cog_reap	58	Decrease	198.091	200.207	208.1	2.96875

pas_neut	2495	Watch	216.099	218.216	226.108	3.121094
pas_neg	6840	Watch	234.108	236.184	244.117	2.816406
cog_reap	73	Decrease	252.116	254.245	262.125	1.886719
cog_reap	2795	Decrease	270.124	272.227	280.133	2.914063
pas_neg	8480	Watch	288.132	290.262	298.141	2.832031
pas_neg	86	Watch	306.141	308.243	316.15	3.0625
pas_neut	2020	Watch	324.149	326.212	334.158	3.121094
cog_reap	67	Decrease	342.157	344.273	352.166	3.167969
cog_reap	2312	Decrease	360.165	362.295	370.174	2.804688
pas_neg	88	Watch	378.174	380.276	388.183	2.984375
cog_reap	4621	Decrease	396.182	398.285	406.191	3.039063
cog_reap	60	Decrease	414.19	416.306	424.199	3.050781
pas_neg	9404	Watch	432.198	434.328	442.207	3.050781
pas_neut	2191	Watch	450.207	452.336	460.216	3
cog_reap	82	Decrease	468.215	470.331	478.224	3.074219
cog_reap	2695	Decrease	486.223	488.313	496.232	2.96875
pas_neg	59	Watch	504.231	506.334	514.24	3
pas_neg	9582	Watch	522.24	524.342	532.248	3.085938

Condition	file	Instructions	Instructional Onset	Picture Onset	Rating Onset	Sample Self Report Scores
cog_reap	11	Decrease	0	2.13	10.009	2.875
cog_reap	2718	Decrease	18.008	20.058	28.017	2.929688
pas_neut	8465	Watch	36.016	38.159	46.025	1.179688
pas_neg	6244	Watch	54.025	56.114	64.034	3.003906
cog_reap	1230	Decrease	72.033	74.149	82.042	3
pas_neg	76	Watch	90.041	92.158	100.05	2.804688
cog_reap	13	Decrease	108.049	110.179	118.058	3
pas_neut	2514	Watch	126.058	128.174	136.067	3.027344
pas_neg	65	Watch	144.066	146.222	154.075	3.027344
pas_neg	6555	Watch	162.074	164.177	172.083	3.003906
pas_neut	7493	Watch	180.082	182.225	190.092	1.71875
cog_reap	70	Decrease	198.091	200.207	208.1	2
pas_neg	9045	Watch	216.099	218.215	226.108	2.914063
pas_neut	4535	Watch	234.107	236.17	244.116	3.003906
cog_reap	61	Decrease	252.115	254.245	262.124	3.050781
pas_neg	8010	Watch	270.124	272.227	280.133	3.097656
cog_reap	78	Decrease	288.132	290.248	298.141	2.929688
pas_neg	22	Watch	306.14	308.256	316.149	2.234375
cog_reap	2130	Decrease	324.148	326.211	334.157	2.914063
cog_reap	51	Watch	342.157	344.3	352.166	3.050781
pas_neut	2749	Watch	360.165	362.268	370.174	2.75
cog_reap	2491	Decrease	378.173	380.236	388.182	3.121094
pas_neg	55	Watch	396.181	398.298	406.19	2.902344
pas_neg	9409	Watch	414.19	416.333	424.199	2.886719
pas_neut	4536	Watch	432.198	434.261	442.207	2.929688
pas_neg	80	Watch	450.206	452.309	460.215	1.984375

Condition	file	Instructions	Instructional Onset	Picture Onset	Rating Onset	Sample Self Report Scores
cog_reap	2810	Decrease	468.214	470.291	478.223	2.082031
pas_neg	84	Watch	486.223	488.339	496.232	3.015625
cog_reap	2682	Decrease	504.231	506.334	514.24	2.984375
pas_neg	9592	Watch	522.239	524.316	532.248	3.015625
Condition	file	Instructions	Instructional Onset	Picture Onset	Rating Onset	Sample Self Report Scores
cog_reap	28	Decrease	0	2.117	10.01	3.15625
cog_reap	56	Decrease	126.058	128.174	136.067	2.957031
cog_reap	57	Decrease	234.108	236.224	244.117	2.777344
cog_reap	63	Decrease	270.124	272.254	280.133	3
cog_reap	64	Decrease	306.141	308.284	316.15	3.179688
cog_reap	85	Decrease	468.215	470.331	478.224	2.109375
pas_neg	29	Watch	54.025	56.181	64.034	3.167969
pas_neg	52	Watch	108.05	110.206	118.059	2.859375
pas_neg	66	Watch	378.174	380.29	388.183	2.96875
pas_neg	69	Watch	396.182	398.285	406.191	3.109375
pas_neg	77	Watch	432.198	434.301	442.207	3.167969
pas_neg	81	Watch	180.083	182.199	190.092	1.125
cog_reap	1280	Decrease	36.017	38.147	46.026	3.121094
cog_reap	2271	Decrease	198.091	200.154	208.1	1.96875
cog_reap	2752	Decrease	18.009	20.085	28.018	3.085938
cog_reap	3022	Decrease	522.24	524.356	532.249	2.96875
cog_reap	5970	Decrease	360.165	362.282	370.174	3.0625
cog_reap	6200	Decrease	90.042	92.171	100.051	3.132813
pas_neg	2730	Watch	414.19	416.293	424.199	3.132813
pas_neg	6571	Watch	252.116	254.232	262.125	2.859375
pas_neg	8230	Watch	486.223	488.326	496.232	2.109375
pas_neg	9190	Watch	144.066	146.169	154.075	3
pas_neg	9440	Watch	450.207	452.336	460.216	2.109375
pas_neg	9594	Watch	324.149	326.225	334.158	2.96875
pas_neut	2270	Watch	342.157	344.233	352.166	3.003906
pas_neut	2357	Watch	72.033	74.163	82.042	2.941406
pas_neut	2372	Watch	162.075	164.151	172.084	2.566406
pas_neut	2445	Watch	504.231	506.321	514.24	2.886719
pas_neut	2635	Watch	216.099	218.229	226.108	2.929688
pas_neut	2870	Watch	288.132	290.262	298.141	3.039063

References

Adolphs, R. (2002). Neural systems for recognizing emotion. *Curr Opin Neurobiol, 12*(2), 169-177.

Adolphs, R., Damasio, H., Tranel, D., Cooper, G., & Damasio, A. R. (2000). A role for somatosensory cortices in the visual recognition of emotion as revealed by three-dimensional lesion mapping. *J Neurosci, 20*(7), 2683-2690.

Andre, A. (2001). *The value of workload in the design and analysis of consumer products.* Mahwah, NJ: L. Erlbaum.

Arnsten, A. F. (2009). Stress signalling pathways that impair prefrontal cortex structure and function. *Nat Rev Neurosci, 10*(6), 410-422.

Babiloni, C., Del Percio, C., Iacoboni, M., Infarinato, F., Lizio, R., Marzano, N., et al. (2008). Golf putt outcomes are predicted by sensorimotor cerebral EEG rhythms. *J Physiol, 586*(1), 131-139.

Babiloni, C., Del Percio, C., Rossini, P. M., Marzano, N., Iacoboni, M., Infarinato, F., et al. (2009). Judgment of actions in experts: a high-resolution EEG study in elite athletes. *Neuroimage, 45*(2), 512-521.

Babiloni, C., Marzano, N., Infarinato, F., Iacoboni, M., Rizza, G., Aschieri, P., et al. (2010). "Neural efficiency" of experts' brain during judgment of actions: a high-resolution EEG study in elite and amateur karate athletes. *Behav Brain Res, 207*(2), 466-475.

Badre, D., & D'Esposito, M. (2009). Is the rostro-caudal axis of the frontal lobe hierarchical? *Nat Rev Neurosci, 10*(9), 659-669.

Banks, S. J., Eddy, K. T., Angstadt, M., Nathan, P. J., & Phan, K. L. (2007). Amygdala-frontal connectivity during emotion regulation. *Soc Cogn Affect Neurosci, 2*(4), 303-312.

Baumeister, J., Reinecke, K., Liesen, H., & Weiss, M. (2008). Cortical activity of skilled performance in a complex sports related motor task. *Eur J Appl Physiol, 104*(4), 625-631.

Bear, M. F., Connor, B. W., & Paradiso, M. A. (1996). *Neuroscience: exploring the brain*. Baltimore MD: Lippincott Williams and Wilkins.

Beck, A. T., Rush, A. J., Shaw, B. F., & Emery, G. (1979). *Cognitive Therapy of Depression*. New York: Guilford Press.

Beer, J. S., Knight, R. T., & D'Esposito, M. (2006). Controlling the integration of emotion and cognition: the role of frontal cortex in distinguishing helpful from hurtful emotional information. *Psychol Sci, 17*(5), 448-453.

Beer, J. S., Lombardo, M. V., & Bhanji, J. P. (2010). Roles of medial prefrontal cortex and orbitofrontal cortex in self-evaluation. *J Cogn Neurosci, 22*(9), 2108-2119.

Beilock, S. L. (2010). *Choke: What the Secrets of the Brain Reveal about Getting it Right When You Have*. NY, NY: Free Press.

Beilock, S. L., & Carr, T. H. (2001). On the fragility of skilled performance: what governs choking under pressure? *J Exp Psychol Gen, 130*(4), 701-725.

Bell, A. J., & Sejnowski, T. J. (1995). An information-maximization approach to blind separation and blind deconvolution. *Neural Comput, 7*(6), 1129-1159.

Binder, J. R., Desai, R. H., Graves, W. W., & Conant, L. L. (2009). Where is the semantic system? A critical review and meta-analysis of 120 functional neuroimaging studies. *Cereb Cortex, 19*(12), 2767-2796.

Bixby, W., Spalding, T. W., & Hatfield, B. D. (2001). Temporal dynamics and dimensional specificity of the affective response to exercise of varying intensity: Differing pathways to a common outcome. *Journal of Sport and Exercise Psychology, 23*, 171-190.

Bradberry, T. J., Gentili, R. J., & Contreras-Vidal, J. L. (2010). Reconstructing three-dimensional hand movements from noninvasive electroencephalographic signals. *J Neurosci, 30*(9), 3432-3437.

Bright, P., Moss, H., & Tyler, L. K. (2004). Unitary vs multiple semantics: PET studies of word and picture processing. *Brain Lang, 89*(3), 417-432.

Brunet, E., Sarfati, Y., Hardy-Bayle, M. C., & Decety, J. (2000). A PET investigation of the attribution of intentions with a nonverbal task. *Neuroimage, 11*(2), 157-166.

Canli, T., Ferri, J., & Duman, E. A. (2009). Genetics of emotion regulation. *Neuroscience, 164*(1), 43-54.

Carretie, L., Albert, J., Lopez-Martin, S., & Tapia, M. (2009). Negative brain: an integrative review on the neural processes activated by unpleasant stimuli. *Int J Psychophysiol, 71*(1), 57-63.

Cerin, E., & Barnett, A. (2009). Predictors of pre- and post-competition affective states in male martial artists: a multilevel interactional approach. *Scand J Med Sci Sports*.

Chambers, C. D., Bellgrove, M. A., Stokes, M. G., Henderson, T. R., Garavan, H., Robertson, I. H., et al. (2006). Executive "brake failure" following deactivation of human frontal lobe. *J Cogn Neurosci, 18*(3), 444-455.

Chein, J. M., & Schneider, W. (2005). Neuroimaging studies of practice-related change: fMRI and meta-analytic evidence of a domain-general control network for learning. *Brain Res Cogn Brain Res, 25*(3), 607-623.

Chell, B. J., Graydon, J. K., Crowley, P. L., & Child, M. (2003). Manipulated stress and dispositional reinvestment in a wall-volley task: an investigation into controlled processing. *Percept Mot Skills, 97*(2), 435-448.

Conroy, D. E. (2001). Progress in the development of a multidimensional measure of fear of failure: The Performance Failure Appraisal Inventory (PFAI). *Anxiety, Stress, & Coping, 14*, 431-452.

Cox, R. H. (2002). *Sport psychology: Concepts and applications (5th ed.).* Boston: WCB/McGraw-Hill.

Critchley, H. D., Daly, E. M., Bullmore, E. T., Williams, S. C., Van Amelsvoort, T., Robertson, D. M., et al. (2000). The functional neuroanatomy of social behaviour: changes in cerebral blood flow when people with autistic disorder process facial expressions. *Brain, 123 (Pt 11)*, 2203-2212.

Damasio, A. R. (1996). The somatic marker hypothesis and the possible functions of the prefrontal cortex. *Philos Trans R Soc Lond B Biol Sci, 351*(1346), 1413-1420.

Damasio, A. R., Grabowski, T. J., Bechara, A., Damasio, H., Ponto, L. L., Parvizi, J., et al. (2000). Subcortical and cortical brain activity during the feeling of self-generated emotions. *Nat Neurosci, 3*(10), 1049-1056.
Davidson, R. J. (2002). Anxiety and affective style: role of prefrontal cortex and amygdala. *Biol Psychiatry, 51*(1), 68-80.
Davis, M. H., Meunier, F., & Marslen-Wilson, W. D. (2004). Neural responses to morphological, syntactic, and semantic properties of single words: an fMRI study. *Brain Lang, 89*(3), 439-449.
Deeny, S. P., Haufler, A. J., Saffer, M., & Hatfield, B. D. (2009). Electroencephalographic coherence during visuomotor performance: a comparison of cortico-cortical communication in experts and novices. *J Mot Behav, 41*(2), 106-116.
Del Percio, C., Babiloni, C., Bertollo, M., Marzano, N., Iacoboni, M., Infarinato, F., et al. (2009). Visuo-attentional and sensorimotor alpha rhythms are related to visuo-motor performance in athletes. *Hum Brain Mapp, 30*(11), 3527-3540.
Del Percio, C., Babiloni, C., Marzano, N., Iacoboni, M., Infarinato, F., Vecchio, F., et al. (2009). "Neural efficiency" of athletes' brain for upright standing: a high-resolution EEG study. *Brain Res Bull, 79*(3-4), 193-200.
Del Percio, C., Brancucci, A., Vecchio, F., Marzano, N., Pirritano, M., Meccariello, E., et al. (2007). Visual event-related potentials in elite and amateur athletes. *Brain Res Bull, 74*(1-3), 104-112.
Del Percio, C., Infarinato, F., Iacoboni, M., Marzano, N., Soricelli, A., Aschieri, P., et al. (2010). Movement-related desynchronization of alpha rhythms is lower in athletes than non-athletes: a high-resolution EEG study. *Clin Neurophysiol, 121*(4), 482-491.
Del Percio, C., Rossini, P. M., Marzano, N., Iacoboni, M., Infarinato, F., Aschieri, P., et al. (2008). Is there a "neural efficiency" in athletes? A high-resolution EEG study. *Neuroimage, 42*(4), 1544-1553.
Drabant, E. M., McRae, K., Manuck, S. B., Hariri, A. R., & Gross, J. J. (2009). Individual differences in typical reappraisal use predict amygdala and prefrontal responses. *Biol Psychiatry, 65*(5), 367-373.
Driscoll, D., Tranel, D., & Anderson, S. W. (2009). The effects of voluntary regulation of positive and negative emotion on psychophysiological responsiveness. *Int J Psychophysiol, 72*(1), 61-66.
Endler, N. S., & Kocovski, N. L. (2001). State and trait anxiety revisited. *J Anxiety Disord, 15*(3), 231-245.
Eysenck, M. W., & Calvo, M. G. (1992). Anxiety and performance: The processing efficiency theory. *Cognition and Emotion, 6*, 409-434.
Feder, A., Nestler, E. J., & Charney, D. S. (2009). Psychobiology and molecular genetics of resilience. *Nat Rev Neurosci, 10*(6), 446-457.
Fenz, W. (1975). Coping Mechanisms and Performance Under Stress.
Finger, E. C., Mitchell, D. G., Jones, M., & Blair, R. J. (2008). Dissociable roles of medial orbitofrontal cortex in human operant extinction learning. *Neuroimage, 43*(4), 748-755.
Fitts, P. M., & Posner, M. (1967). *Human performance*. Belmont,CA Brooks/Cole.
Fox, S. (2008). *Human Physiology*: McGraw-Hill.

Frewen, P. A., Dozois, D. J. A., Neufeld, R. W. J., Lane, R. D., Densmore, M., Stevens, T. K., et al. (2010). Individual differences in trait mindfulness predict dorsomedial prefrontal and amygdala response during emotional imagery: An fMRI study *Personality and Individual Differences, 49*(5), 479-484

Gallo, I. S., Keil, A., McCulloch, K. C., Rockstroh, B., & Gollwitzer, P. M. (2009). Strategic automation of emotion regulation. *J Pers Soc Psychol, 96*(1), 11-31.

Gentili, R. J., Bradberry, T. J., Oh, H., Hatfield, B. D., & Contreras Vidal, J. L. (2010). Cerebral cortical dynamics during visuomotor transformation: Adaptation to a cognitive-motor executive challenge. *Psychophysiology*.

Ghashghaei, H. T., Hilgetag, C. C., & Barbas, H. (2007). Sequence of information processing for emotions based on the anatomic dialogue between prefrontal cortex and amygdala. *Neuroimage, 34*(3), 905-923.

Goldin, P. R., McRae, K., Ramel, W., & Gross, J. J. (2008). The neural bases of emotion regulation: reappraisal and suppression of negative emotion. *Biol Psychiatry, 63*(6), 577-586.

Gray, J. R., Burgess, G. C., Schaefer, A., Yarkoni, T., Larsen, R. J., & Braver, T. S. (2005). Affective personality differences in neural processing efficiency confirmed using fMRI. *Cogn Affect Behav Neurosci, 5*(2), 182-190.

Greicius, M. D., Krasnow, B., Reiss, A. L., & Menon, V. (2003). Functional connectivity in the resting brain: a network analysis of the default mode hypothesis. *Proc Natl Acad Sci U S A, 100*(1), 253-258.

Grimm, S., Schmidt, C. F., Bermpohl, F., Heinzel, A., Dahlem, Y., Wyss, M., et al. (2006). Segregated neural representation of distinct emotion dimensions in the prefrontal cortex-an fMRI study. *Neuroimage, 30*(1), 325-340.

Gross, J., & Thompson, R. (2007). *Emotion regulation: Conceptual foundations. Handbook of Emotion Regulation*.

Gross, J. J., & John, O. P. (2003). Individual differences in two emotion regulation processes: implications for affect, relationships, and well-being. *J Pers Soc Psychol, 85*(2), 348-362.

Gross, J. R. (1998). The emerging field of emotion regulation: an integrated review. *Review of General Psychology, 2* (3), 271-299.

Gucciardi, D. F., & Dimmock, J. A. (2008). Choking under Pressure in Sensorimotor Skills: Conscious Processing or Depleted Attentional Resources? . *Psychology of Sport and Exercise, 9*, 45 - 59

Haas, B. W., Omura, K., Constable, R. T., & Canli, T. (2007). Is automatic emotion regulation associated with agreeableness? A perspective using a social neuroscience approach. *Psychol Sci, 18*(2), 130-132.

Haier, R. J., Siegel, B., Tang, C., Abel, L., & Buchsbaum, M. S. (1992). Intelligence and changes in regional cerebral glucose metabolic rate following learning. *Intelligence 16* 415–426.

Haines, D. E. (2006). *Fundamental Neuroscience for Basic and Clinical Applications*. Philadelphia, Pa: Churchill Livingstone Elsevier.

Hancock, P., & Szalma, J. L. (2008). *Performance Under Stress*. Burlington VT: Ashgate Publishing.

Hanin, Y. L. (2007). Emotions in Sport. Current Issues and Perspectives. In G. Tenenbaum & R. C. Eklund (Eds.), *Handbook of sport psychology*. New York: Wiley & Sons.

Hardy, J., Hall, C. R., & Alexander, M. R. (2001). Exploring self-talk and affective states in sport. *J Sports Sci, 19*(7), 469-475.

Hatfield, B. D., & Brody, E. B. (2000). The psychology of athletic preparation and performance: The mental management of physical resources. . In B. T. (Ed.), *Essentials of Strength Training and Conditioning (2nd ed.).* . Champaign, IL: Human Kinetics Publishers.

Hatfield, B. D., & Brody, E. B. (2008). The psychology of athletic preparation and performance: The mental management of physical resources. . In B. T. (Ed.), *Essentials of Strength Training and Conditioning (2nd ed.).* . Champaign, IL: Human Kinetics Publishers.

Hatfield, B. D., Haufler, A. J., Hung, T. M., & Spalding, T. W. (2004). Electroencephalographic studies of skilled psychomotor performance. *J Clin Neurophysiol, 21*(3), 144-156.

Hatfield, B. D., & Hillman, C. (2001). The psychophysiology of sport: A mechanistic under standing of the psychology of superior performance. In R. H. Singer, H Janelle, C (Ed.), *Handbook of sport psychology*. New York: Wiley & Sons.

Hatfield, B. D., & Kerick, S. E. (2007). The psychology of superior sport performance; A cognitive and affective neuroscience perspective. In G. Tenenbaum & R. C. Eklund (Eds.), *Handbook of Sport Psychology - 3rd edition* (pp. 84-109): J.C. Wiley Publishers.

Hatfield, B. D., Landers, D. M., & Ray, W. J. (1984). Cognitive processes during self-paced motor performance: An electroencephalographic profile of skilled marksmen. *Journal of Sport Psychology, 6*, 42-59.

Hatfield, B. D., Rietschel, J. C., Costanzo, M. E., Goodman, R. N., Haufler, A. J., Lo, L., et al. (2010). Electrocortical dynamics during competitive psychomotor performance.

Haufler, A. J., Spalding, T. W., Santa Maria, D. L., & Hatfield, B. D. (2000). Neuro-cognitive activity during a self-paced visuospatial task: comparative EEG profiles in marksmen and novice shooters. *Biol Psychol, 53*(2-3), 131-160.

Heinzel, A., Bermpohl, F., Niese, R., Pfennig, A., Pascual-Leone, A., Schlaug, G., et al. (2005). How do we modulate our emotions? Parametric fMRI reveals cortical midline structures as regions specifically involved in the processing of emotional valences. *Brain Res Cogn Brain Res, 25*(1), 348-358.

Hickok, G., & Poeppel, D. (2007). The cortical organization of speech processing. *Nat Rev Neurosci, 8*(5), 393-402.

Huettel, S. A., Song, A. W., & McCarthy, G. (2003). *Functional Magnetic Resonance Imaging*: Sunderland, MA.

Iaria, G., Committeri, G., Pastorelli, C., Pizzamiglio, L., Watkins, K. E., & Carota, A. (2008). Neural activity of the anterior insula in emotional processing depends on the individuals' emotional susceptibility. *Hum Brain Mapp, 29*(3), 363-373.

Izard, C. E. (2009). Emotion theory and research: highlights, unanswered questions, and emerging issues. *Annu Rev Psychol, 60*, 1-25.

Jackson, R. C., Ashford, K. J., & Nosworthy, G. (2006). Attentional focus, dispositional reinvestment and skilled motor performance under pressure. *Journal of Sport and Exercise Psychology, 28*, 49-68.

Jackson, R. C., & Wilson, R. (1999). *Using 'swing thoughts' to prevent paradoxical performance effects in golf putting.* Leeds: Human Kinetics.

Kalisch, R. (2009). The functional neuroanatomy of reappraisal: time matters. *Neurosci Biobehav Rev, 33*(8), 1215-1226.

Kerick, S. E., Douglass, L. W., & Hatfield, B. D. (2004). Cerebral cortical adaptations associated with visuomotor practice. *Med Sci Sports Exerc, 36*(1), 118-129.

Kerick, S. E., McDowell, K., Hung, T. M., Santa Maria, D. L., Spalding, T. W., & Hatfield, B. D. (2001). The role of the left temporal region under the cognitive motor demands of shooting in skilled marksmen. *Biol Psychol, 58*(3), 263-277.

Kilpatrick, L., & Cahill, L. (2003). Amygdala modulation of parahippocampal and frontal regions during emotionally influenced memory storage. *Neuroimage, 20*(4), 2091-2099.

Kinrade, N. P., Jackson, R. C., & Ashford, K. J. (2010). Dispositional reinvestment and skill failure in cognitive and motor tasks. *Psychology of Sport and Exercise, 11*, 312-319.

Koenigsberg, H. W., Fan, J., Ochsner, K. N., Liu, X., Guise, K., Pizzarello, S., et al. (2010). Neural correlates of using distancing to regulate emotional responses to social situations. *Neuropsychologia, 48*(6), 1813-1822.

Kringelbach, M. L. (2005). The human orbitofrontal cortex: linking reward to hedonic experience. *Nat Rev Neurosci, 6*(9), 691-702.

Lam, W. K., Maxwell, J. P., & Masters, R. (2009). Analogy learning and the performance of motor skills under pressure. *J Sport Exerc Psychol, 31*(3), 337-357.

Lang, P. J., Bradley, M. M., & Cuthbert, B. N. (1999). *International affective picture system (IAPS): Technical manual and affective ratings*. Gainesville: University of Florida.

Lawrence, E. J., Shaw, P., Giampietro, V. P., Surguladze, S., Brammer, M. J., & David, A. S. (2006). The role of 'shared representations' in social perception and empathy: an fMRI study. *Neuroimage, 29*(4), 1173-1184.

Lawton, G. W., Hung, T. M., Saarela, P., & Hatfield, B. D. (1998). Electroencephalography and mental states associated with elite performance *Journal of Sport and Exercise Psychology, 20*(1), 35-53.

Lay, B. S., Sparrow, W. A., Hughes, K. M., & O'Dwyer, N. J. (2002). Practice effects on coordination and control, metabolic energy expenditure, and muscle activation. *Hum Mov Sci, 21*(5-6), 807-830.

Lee, T. W., Girolami, M., & Sejnowski, T. J. (1999). Independent component analysis using an extended Infomax algorithm for mixed sub-gaussian and super-gaussian sources. *Neural Computation 11*, 417–441.

Levens, S. M., & Phelps, E. A. (2010). Insula and orbital frontal cortex activity underlying emotion interference resolution in working memory. *J Cogn Neurosci, 22*(12), 2790-2803.

Lieberman, M. D. (2007). Social cognitive neuroscience: a review of core processes. *Annu Rev Psychol, 58*, 259-289.

Lyons, D. M., Parker, K. J., & Schatzberg, A. F. (2010). Animal models of early life stress: Implications for understanding resilience. *Dev Psychobiol, 52*(7), 616-624.

Martens, R., Vealey, R. S., & Burton, D. (1990). *Competitive anxiety in sport.* Champaign, IL: Human Kinetics.

Masters, R. (1992). Knowledge, (k)nerves, and know-how: The role of explicit versus implicit knowledge in the breakdown of a complex motor skill under pressure. *The British Journal of Psychology 31*, 343-358.

Masters, R. S. W., & Maxwell, J. P. (2008). The theory of reinvestment. *International Review of Sport and Exercise Psychology, 1*, 160-183.

Matthews, M. D. (2008). Positive Psychology: Adaptation, Learning and Performance in Exceptional Circumstances. In A. Publishing (Ed.), *Performance Under Stress*. Burlington VT.

Maxwell, J. P., Masters, R. S., & Poolton, J. M. (2006). Performance breakdown in sport: the roles of reinvestment and verbal knowledge. *Res Q Exerc Sport, 77*(2), 271-276.

Maxwell, J. P., Masters, R. S. W., & Eves, F. F. (2000). Explicit versus implicit motor learning: Dissociating selective and unselective modes of skill acquisition via feedback manipulation.
. *Journal of Sports Sciences, 18*, 559.

McRae, K., Hughes, B., Chopra, S., Gabrieli, J. D., Gross, J. J., & Ochsner, K. N. (2010). The neural bases of distraction and reappraisal. *J Cogn Neurosci, 22*(2), 248-262.

McRae, K., Ochsner, K. N., Mauss, I., Gabrieli, J. D. E., & Gross, J. J. (2008). Gender differences in emotion regulation: An fMRI study of cognitive reappraisal. *Group Processes and Intergroup Relations, 11*, 143-162.

Nakata, H., Yoshie, M., Miura, A., & Kudo, K. (2010). Characteristics of the athletes' brain: evidence from neurophysiology and neuroimaging. *Brain Res Rev, 62*(2), 197-211.

Neubauer, A. C., & Fink, A. (2009). Intelligence and neural efficiency. *Neurosci Biobehav Rev, 33*(7), 1004-1023.

New, A. S., Hazlett, E. A., Buchsbaum, M. S., Goodman, M., Mitelman, S. A., Newmark, R., et al. (2007). Amygdala-prefrontal disconnection in borderline personality disorder. *Neuropsychopharmacology, 32*(7), 1629-1640.

Northoff, G., Heinzel, A., Bermpohl, F., Niese, R., Pfennig, A., Pascual-Leone, A., et al. (2004). Reciprocal modulation and attenuation in the prefrontal cortex: an fMRI study on emotional-cognitive interaction. *Hum Brain Mapp, 21*(3), 202-212.

Northoff, G., Richter, A., Gessner, M., Schlagenhauf, F., Fell, J., Baumgart, F., et al. (2000). Functional dissociation between medial and lateral prefrontal cortical spatiotemporal activation in negative and positive emotions: a combined fMRI/MEG study. *Cereb Cortex, 10*(1), 93-107.

Ochsner, K. N., Bunge, S. A., Gross, J. J., & Gabrieli, J. D. (2002). Rethinking feelings: an FMRI study of the cognitive regulation of emotion. *J Cogn Neurosci, 14*(8), 1215-1229.
Ochsner, K. N., & Gross, J. J. (2005). The cognitive control of emotion. *Trends Cogn Sci, 9*(5), 242-249.
Ochsner, K. N., & Gross, J. J. (2008). Cognitive Emotion Regulation Insights From Social Cognitive and Affective Neuroscience. *Current Directions in Psychological Science, 17* (2), 153 – 158.
Ochsner, K. N., Ray, R. D., Cooper, J. C., Robertson, E. R., Chopra, S., Gabrieli, J. D., et al. (2004). For better or for worse: neural systems supporting the cognitive down- and up-regulation of negative emotion. *Neuroimage, 23*(2), 483-499.
Oldfield, R. C. (1971). The assessment and analysis of handedness: the Edinburgh inventory. *Neuropsychologia, 9*(1), 97-113.
Pascual-Marqui, R. D. (2002). Standardized low-resolution brain electromagnetic tomography (sLORETA): technical details. *Methods Find Exp Clin Pharmacol, 24 Suppl D*, 5-12.
Patrick, C. J., & Lavoro, S. A. (1997). Ratings of emotional response to pictorial stimuli: Positive and negative affect. *Motivation and Emotion 21*, 297–321.
Patterson, J. C., 2nd, Ungerleider, L. G., & Bandettini, P. A. (2002). Task-independent functional brain activity correlation with skin conductance changes: an fMRI study. *Neuroimage, 17*(4), 1797-1806.
Paulus, M. P., Simmons, A. N., Fitzpatrick, S. N., Potterat, E. G., Van Orden, K. F., Bauman, J., et al. (2010). Differential brain activation to angry faces by elite warfighters: neural processing evidence for enhanced threat detection. *PLoS One, 5*(4), e10096.
Pessoa, L. (2008). On the relationship between emotion and cognition. *Nat Rev Neurosci, 9*(2), 148-158.
Pessoa, L. (2010). Emotion and cognition and the amygdala: from "what is it?" to "what's to be done?". *Neuropsychologia, 48*(12), 3416-3429.
Pessoa, L., & Adolphs, R. (2010). Emotion processing and the amygdala: from a 'low road' to 'many roads' of evaluating biological significance. *Nat Rev Neurosci, 11*(11), 773-783.
Pessoa, L., McKenna, M., Gutierrez, E., & Ungerleider, L. G. (2002). Neural processing of emotional faces requires attention. *Proc Natl Acad Sci U S A, 99*(17), 11458-11463.
Pfaff, D. W., Kieffer, B. L., & Swanson, L. W. (2008). Mechanisms for the regulation of state changes in the central nervous system: an introduction. *Ann N Y Acad Sci, 1129*, 1-7.
Phan, K. L., Taylor, S. F., Welsh, R. C., Decker, L. R., Noll, D. C., Nichols, T. E., et al. (2003). Activation of the medial prefrontal cortex and extended amygdala by individual ratings of emotional arousal: a fMRI study. *Biol Psychiatry, 53*(3), 211-215.
Phelps, E. A., Delgado, M. R., Nearing, K. I., & LeDoux, J. E. (2004). Extinction learning in humans: role of the amygdala and vmPFC. *Neuron, 43*(6), 897-905.

Phelps, E. A., & LeDoux, J. E. (2005). Contributions of the amygdala to emotion processing: from animal models to human behavior. *Neuron, 48*(2), 175-187.
Posner, M. I., Rothbart, M. K., Sheese, B. E., & Tang, Y. (2007). The anterior cingulate gyrus and the mechanism of self-regulation. *Cogn Affect Behav Neurosci, 7*(4), 391-395.
Quirk, G. J., & Beer, J. S. (2006). Prefrontal involvement in the regulation of emotion: convergence of rat and human studies. *Curr Opin Neurobiol, 16*(6), 723-727.
Ray, R. D., Ochsner, K. N., Cooper, J. C., Robertson, E. R., Gabrieli, J. D., & Gross, J. J. (2005). Individual differences in trait rumination and the neural systems supporting cognitive reappraisal. *Cogn Affect Behav Neurosci, 5*(2), 156-168.
Rietschel, J. C., Goodman, R. N., King, B. R., Lo, L. C., Contreras-Vidal, J. L., & Hatfield, B. D. (2010). Cerebral cortical dynamics and the quality of motor behavior during social evaluative challenge. *Psychophysiology*.
Rodrigues, S. M., LeDoux, J. E., & Sapolsky, R. M. (2009). The influence of stress hormones on fear circuitry. *Annu Rev Neurosci, 32*, 289-313.
Rolls, E. T., & Grabenhorst, F. (2008). The orbitofrontal cortex and beyond: from affect to decision-making. *Prog Neurobiol, 86*(3), 216-244.
Rong, F., & Contreras-Vidal, J. L. (2006). Magnetoencephalographic artifact identification and automatic removal based on independent component analysis and categorization approaches. *J Neurosci Methods, 157*(2), 337-354.
Ruby, P., & Decety, J. (2003). What you believe versus what you think they believe: a neuroimaging study of conceptual perspective-taking. *Eur J Neurosci, 17*(11), 2475-2480.
Rypma, B., Berger, J. S., Prabhakaran, V., Bly, B. M., Kimberg, D. Y., Biswal, B. B., et al. (2006). Neural correlates of cognitive efficiency. *Neuroimage, 33*(3), 969-979.
Sabatinelli, D., Fortune, E. E., Li, Q., Siddiqui, A., Krafft, C., Oliver, W. T., et al. (2010). Emotional perception: Meta-analyses of face and natural scene processing. *Neuroimage*.
Salzman, C. D., & Fusi, S. (2010). Emotion, cognition, and mental state representation in amygdala and prefrontal cortex. *Annu Rev Neurosci, 33*, 173-202.
Scheuerecker, J., Frodl, T., Koutsouleris, N., Zetzsche, T., Wiesmann, M., Kleemann, A. M., et al. (2007). Cerebral differences in explicit and implicit emotional processing--an fMRI study. *Neuropsychobiology, 56*(1), 32-39.
Schmitz, T. W., & Johnson, S. C. (2006). Self-appraisal decisions evoke dissociated dorsal-ventral aMPFC networks. *Neuroimage, 30*(3), 1050-1058.
Schneider, W., & Chein, J. M. (2003). Controlled & automatic processing: behavior, theory, and biological mechanisms. *Cognitive Science, 27*, 525–559.
Selye. (1975). Confusion and controversy in the stress field. *Journal of Human Stress 1*, 37–44.
Senior, C., Russell, T., & Gazzaniga, M. (2006). *Methods in mind*. Cambridge, Mass.: MIT Press.
Shamay-Tsoory, S. G., Lester, H., Chisin, R., Israel, O., Bar-Shalom, R., Peretz, A., et al. (2005). The neural correlates of understanding the other's distress: a

positron emission tomography investigation of accurate empathy. *Neuroimage, 27*(2), 468-472.
Smith, M. A., Brandt, J., & Shadmehr, R. (2000). Motor disorder in Huntington's disease begins as a dysfunction in error feedback control. *Nature, 403*(6769), 544-549.
Spielberger, C. D., Gorsuch, R. L., & Lushene, R. E. (1970). *STAI manual*. Palo Alto, CA: Consulting Psychologists.
St Clair Gibson, A., & Foster, C. (2007). The role of self-talk in the awareness of physiological state and physical performance. *Sports Med, 37*(12), 1029-1044.
Staal, M. A. (2004). *Stress, Cognition, and Human Performance: A Literature Review and Conceptual Framework*.
Straube, T., & Miltner, W. H. (2010). Attention to aversive emotion and specific activation of the right insula and right somatosensory cortex. *Neuroimage*.
Surguladze, S., Russell, T., Kucharska-Pietura, K., Travis, M. J., Giampietro, V., David, A. S., et al. (2006). A reversal of the normal pattern of parahippocampal response to neutral and fearful faces is associated with reality distortion in schizophrenia. *Biol Psychiatry, 60*(5), 423-431.
Tepas, D. I., & Price, J. M. (2001). *What is stress and what is fatigue?.* . Mahwah, NJ: L. Erlbaum.
Van Dillen, L. F., Heslenfeld, D. J., & Koole, S. L. (2009). Tuning down the emotional brain: an fMRI study of the effects of cognitive load on the processing of affective images. *Neuroimage, 45*(4), 1212-1219.
van Galen, G. P., & van Huygevoort, M. (2000). Error, stress and the role of neuromotor noise in space oriented behaviour. *Biol Psychol, 51*(2-3), 151-171.
Venkatraman, V., Rosati, A. G., Taren, A. A., & Huettel, S. A. (2009). Resolving response, decision, and strategic control: evidence for a functional topography in dorsomedial prefrontal cortex. *J Neurosci, 29*(42), 13158-13164.
Vialou, V., Robison, A. J., Laplant, Q. C., Covington, H. E., 3rd, Dietz, D. M., Ohnishi, Y. N., et al. (2010). DeltaFosB in brain reward circuits mediates resilience to stress and antidepressant responses. *Nat Neurosci, 13*(6), 745-752.
Wager, T. D., Davidson, M. L., Hughes, B. L., Lindquist, M. A., & Ochsner, K. N. (2008). Prefrontal-subcortical pathways mediating successful emotion regulation. *Neuron, 59*(6), 1037-1050.
Wan, C. Y., & Huon, G. F. (2005). Performance degradation under pressure in music: An examination of attentional processes. *Psychology of Music, 33*, 155-172.
Waugh, C. E., Hamilton, J. P., & Gotlib, I. H. (2010). The neural temporal dynamics of the intensity of emotional experience. *Neuroimage, 49*(2), 1699-1707.
Wilk, S. L., Desmarais, L. B., & Sackett, P. R. (1995). Gravitation to Jobs Commensurate With Ability: Longitudinal and Cross-Sectional Tests. *Journal of Applied Psychology, 80*, 79-85.
Wright, P., He, G., Shapira, N. A., Goodman, W. K., & Liu, Y. (2004). Disgust and the insula: fMRI responses to pictures of mutilation and contamination. *Neuroreport, 15*(15), 2347-2351.

Yamasaki, H., LaBar, K. S., & McCarthy, G. (2002). Dissociable prefrontal brain systems for attention and emotion. *Proc Natl Acad Sci U S A, 99*(17), 11447-11451.

Yaoi, K., Osaka, N., & Osaka, M. (2009). Is the self special in the dorsomedial prefrontal cortex? An fMRI study. *Soc Neurosci, 4*(5), 455-463.

Yerkes, R. M., & Dodson, J. D. (1908). The Relation of Strength of Stimulus to Rapidity of Habit-Formation. *Journal of Comparative Neurology and Psychology, 18*, 459-482.