Cognitive Bias Modification & Exercise

Charlotte Clarke

A Thesis Submitted For The Degree Of Doctor Of Philosophy

Centre for Brain Sciences

Department of Psychology

University of Essex

August 2018.

Abstract

This doctoral thesis investigates the complex relationship between mental well-being, cognitive bias and physical exercise. The introduction of this thesis begins with a perspective of the relationship between cognitive interpretation bias, physical exercise and mental well-being, specifically anxiety.

The thesis begins with two studies which measure the effect of physical exercise on typical individual's interpretation biases and measures of mental well-being. Study three begins to develop an exercise orientated Cognitive Interpretation Bias Modification (CBM-I) training programme that's positively valanced and incorporating a dual method of CBM-I and exercise training against a rest control group. Study four uses the same methodological paradigm as study three whilst introducing a more robust control condition and recruiting a high anxiety sample. Study four uses a neutral CBM-I training program instead of a rest control condition, along with a positive CBM-I training program and physical exercise and measures the effect of these on interpretation bias and measures of mental well-being. Study five focuses on developing the neutral CBM-I training in direct contrast to the positive CBM-I training over the course of two sessions with a high anxiety sample of participants. Study Six and seven both recruited a high anxiety sample and were the only studies conducted completely online. Study Six consisted of six sessions of positive or neutral CBM-I training over six weeks. Whilst study seven consisted of three sessions of positive CBM-I, positive CBM-I & exercise, exercise or neutral CBM-I training over a three-week period.

The results from these seven studies suggest support for positive CBM-I training which is exercise valanced and physical exercise for reducing self-report anxiety and depression. Implications for mental well-being in cases of sub-clinical anxiety are discussed, limitations addressed and future directions are considered.

Dedication

I would like to dedicate my doctoral thesis to my parents Mark and Cheryl. For giving me every opportunity in life, your support and your unwavering belief in me.

Acknowledgements

Firstly, I would like to acknowledge the most inspiring, dedicated and compassionate person I have ever met, Bundy. You have always had high expectations for me, most of the time of which I believed were unachievable! But I came to realise (far too close to the end of my PhD) that it was because you believed in me and knew where my strengths and weaknesses were, it's your belief in me that has been the biggest support throughout. Bundy has taught me not only everything a great supervisor would, but also patience, having confidence in myself and resilience.

I would like to acknowledge Nick, thank you for your endless support on 'Team Clarke' as you put it so brilliantly. Your advice and encouragement on everything from research to writing to careers and conferences has been invaluable. Your happy infectious personality has had me in fits of laughter and your laid-back attitude has made me calm when things have been stressful. Thank you for all your hard work, keeping me going, being honest and reliable throughout. A thank you also goes to Rick, for all your help during my PhD. I appreciate your fantastic advice on methodology, statistics and data collection, your attention to detail is second to none.

I would also like to thank the Psychology Department at University of Essex for the support and help they have given me throughout my Master's degree and PhD here. Special thanks go to Roger, Elena, Alan and Johnathon for their outstanding skills as technicians and being continually helpful. I would also like to acknowledge the administrative staff in the department for being so approachable, friendly and knowledgeable.

I would also like to acknowledge the Economic & Social Research Council for funding my PhD Research. I have been fortunate enough to be able attend conferences, training courses, purchase equipment and pay many of my participants of which without I would not have been able collect the quantity of data that I have. I am very grateful the financial support I have received and to have carried out my PhD in such a fantastic department in a truly special University.

Lastly, I would like to acknowledge my significant other Tom. You have helped me through my PhD in your own marvellous manner, you keep me laughing, working hard and above all, my happiest self. Thank you for being by my side every step of the way.

Publications & Presentations

- Clarke, S., C., Cooper, N., R. & Mackintosh, B. (2018, September). *Cognitive Bias Modification; An Exercise Focused Interpretation Training Technique for Reducing Anxiety.* Oral Presentation conducted at the European Conference of Mental Health, Split, Croatia.

- Clarke, S., C., Cooper, N., R., Rana, M. & Mackintosh, B. (2018). Cognitive Interpretation Bias: The Effect of a Single Session Moderate Exercise Protocol on Anxiety and Depression. *Frontiers in Psychology,* 9, 1363. doi:10.3389/fpsyg.2018.01363.

- Clarke, S., C. (2018). *Is Exercise The Answer For Anxiety?* Under Review, Cognitive Therapy & Research.

- Clarke, S., C., Mackintosh, B. & Cooper, N. R. (2018). *Can Multi-Session Cognitive Bias Modification alleviate Anxiety?* (Manuscript in preparation).

- Clarke, S., C., Mackintosh, B. & Cooper, N. R. (2017, July). *Interpretation Bias & Exercise Training.* In S. Clarke (Chair). Symposium; Understanding Psychosis. Oral Presentation conducted at British Association for Behavioural & Cognitive Psychotherapies Conference, Manchester, England.

- Clarke, S., C., Mackintosh, B. & Cooper, N. R. (2017, March). *Two Session Cognitive Bias Modification Training; Exercise Interpretation Bias.* Poster session presented at the International Convention of Psychological Science, Vienna, Austria.

- Clarke, S., C. & O'Gorman, R. & Mackintosh, B. (2016, June). *Cognitive Bias Modification Training & Exercise: For Alleviating Depression, Anxiety & Stress Related Disorders.* Poster session presented at The ESRC North West Doctoral Training Centre Conference 2016, Liverpool, UK.

Foreword

This doctoral thesis is written concisely for the purposes of trying to reduce repetition for the reader. Each chapter is written in the form of an article for publication, whilst details on methodology are not repeated when previously used and an are therefore signposted as to where more details can be found.

This research is a collection of seven studies surrounding five main themes; measuring interpretation bias, modifying interpretation bias, moderate exercise, developing a neutral interpretation bias training program as a robust control condition and developing an online interpretation bias modification training program.

The thesis begins with two studies which measure the effect of mild to moderate physical exercise on typical individual's interpretation biases and measures of mental well-being. Study one investigated the effect of a walking exercise protocol on interpretation biases and anxiety and found a significant reduction in trait anxiety in the walking exercise condition relative to control condition, but no effect on interpretation bias. Study two investigated the effect of single session of moderate exercise on a static bicycle and found a significant reduction in interpretation biases, state and trait anxiety, depression and perceived stress measures in the exercise condition compare to the control condition.

Study three begins to develop an exercise orientated Cognitive Interpretation Bias Modification (CBM-I) training programme that's positively valanced and incorporating a dual method of CBM-I and exercise training against a rest control group. This is investigated over two sessions of positive CBM-I training, combined CBM-I and exercise, exercise and a rest control condition. Results suggested that there was a significant reduction in perceived stress, which was driven by the combined CBM-I & exercise condition and the neutral CBM-I condition. There was a significant reduction in self-report depression which was drive by the exercise condition and the combined CBM-I & exercise condition, whilst there was no significant effect on cognitive interpretation bias measures.

Study four uses the same methodological paradigm as study three and seven whilst introducing a more robust control condition and recruiting a high anxiety sample. Study four uses a neutral CBM-I training program instead of a rest control condition, along with a positive CBM-I training condition, a combined CBM-I & exercise condition and physical exercise condition over three sessions and measures the effect of these on interpretation bias and measures of mental well-being. Results suggest a significant reduction in trait anxiety driven by the combined CBM-I & exercise condition and the exercise condition, whilst there were no significant effects on state anxiety, depression, psychological stress, or interpretation bias.

Study five focuses on developing the neutral CBM-I training in direct contrast to the positive CBM-I training over the course of two sessions with a high anxiety sample of participants. The results suggested that trait anxiety reduced in the positive CBM-I group and there was a significant effect on interpretation biases also. There was a significant correlation between trait anxiety and interpretation biases in the positive CBM-I group.

Study six recruited a high anxiety sample and was the first study conducted completely online. Study six consisted of six sessions of positive or neutral CBM-I training over six consecutive weeks. The amount of physical activity and exercise was measured throughout the study, but participants were not encouraged nor discouraged from exercising. There was a significant reduction in trait anxiety in the positive CBM-I condition relative to the control condition. There was also a significant reduction in negative interpretation bias in the positive CBM-I condition compared to the control condition.

Whilst study seven consisted of three sessions of positive CBM-I, positive CBM-I & exercise, exercise or neutral CBM-I training over a three-week period. Although the paradigm of this study is similar to that of study three and four, study seven required participants in the exercise and CBM-I & exercise conditions to complete six sessions of moderate exercise (30 minutes at their required heart rate, as calculated) twice per week of the study. Furthermore, study seven introduced an amended Scrambled Sentences Test (SST; measured both cognitively loaded and non-loaded) which had been used in each study previous, to measure cognitive interpretation bias. The amended SST was an exercise adjusted version, which implemented exercise orientated sentences to unscramble alongside the original sentences, which echoes the exercise orientated CBM-I training programs. The results from study seven suggested that there was a significant effect on state anxiety however this seemed to be due to an increase in the neutral CBM-I condition. There was a significant reduction in self-report depression, which was driven by the positive CBM-I condition and the combined CBM-I & exercise condition. Also, there was first reported a significant effect relative of session, condition and cognitive loading and this was a significant reduction in the negative interpretation biases in the positive CBM-I condition and the exercise training condition.

The results from this collection of seven studies suggest a strong support for the use of positive CBM-I training and moderate intensity physical exercise for decreasing negative cognitive interpretation biases and in turn, self-report anxiety and depression.

Table of Contents

Table of Tables

Table of Figures

Chapter 1 Introduction

1.1 Overview

Primarily research has focused on the benefit of exercise on alleviating depression. However, attention is also starting to focus on the positive benefits of exercise for alleviating symptoms of anxiety disorders. Although there are recommendations from healthcare providers for how much exercise we should participate in to benefit from these positive affects for our wellbeing, a staggering amount of us fall short of these recommendations. This perspective article provides an overview of the psychological and physiological mechanisms that underlie the anxiolytic effects of exercise. This article focuses on anxiety, addresses the associated health risks and synthesizes pertinent research regarding the effects of exercise on anxiety disorders. Additionally, cognitive interpretation bias mechanisms of anxiety will be addressed and whether exercise can affect these cognitive mechanisms will also be discussed. Further implications of exercise as a subjunctive treatment for anxiety are discussed.

Chapter 1 is currently under review for publication at the Journal of Cognitive Therapy & Research (please see Appendix A).

1.1.1 Cognitive Interpretation Bias & Physical Exercise

Anxiety disorders are pervasive mental health conditions and are currently the leading cause of global years lived with disability (Baxter, Scott, et al., 2014). Anxiety disorders (American Psychiatric Association, 2013; Stonerock, Hoffman, Smith, & Blumenthal, 2015), such as generalized anxiety disorder, panic disorder, phobias, as well as closely related stress-related disorders such as post-traumatic stress disorder, are associated with a considerable range of detrimental effects on the individual, including lower quality of life (Mendlowicz & Stein, 2000; Rebar, Stanton, & Rosenbaum, 2017) and a host of comorbid mental health illnesses (Scott et al., 2007) and negative symptoms; low self-esteem, lack of self-efficacy, and self-criticalness (Rebar et al., 2017; Sowislo & Orth, 2013). Increases in both psychological (fear, apprehension) and physiological (trembling, racing heart rate) symptoms are all common criteria of anxiety disorders. Both psychological and physiological symptoms can be debilitating for the individual, causing a host of consequential issues for them in their work, family and social environments (Chisholm et al., 2016; Mennin, Fresco, Ritter, & Heimberg, 2015).

Most concerning is the finding that cardiovascular disease is three times more prevalent in individuals with anxiety disorders (Tolmunen, Lehto, Julkunen, Hintikka, & Kauhanen, 2014; Vogelzangs et al., 2010) and which is associated to premature mortality (Batelaan, Seldenrijk, Bot, van Balkom, & Penninx, 2016). The societal and financial impacts of anxiety on healthcare are profound across the Western and Developing World (Chisholm et al., 2016) not only does it impact our health costs (McCrone, Dhanasiri, Patel, Knapp, & Lawton-Smith, 2008), but is the most common of mental health issues and holds the most risks to our health and wellbeing (Baxter, Vos, Scott, Ferrari, & Whiteford, 2014).

Interest has primarily focused on the benefits of exercise for treatment of depression, whilst there is comparably less interest into the benefits exercise has for anxiety (Krogh, Nordentoft, Sterne, & Lawlor, 2011). Currently, the treatments offered for individuals with anxiety disorders are pharmacotherapy treatments such as selective serotonin reuptake inhibitors (SSRIs) (Bartley, Hay, & Bloch, 2013). Whilst these are arguably effective, they are not without some negative side effects such as sexual dysfunction, sedation, nausea, insomnia and withdrawal symptoms (Fava, Gatti, Belaise, Guidi, & Offidani, 2015). Relying on pharmacotherapy also introduces a higher risk of relapse after the treatment ceases and is not a long term reliable treatment for anxiety disorders (Hoffman, Dukes, & Wittchen, 2008). Psychotherapy treatments, such as cognitive behavioral therapy, are also not without difficulties considering the high cost in implementing the treatment, the lack of access to qualified therapists and at times patient resistance to psychotherapy (Kessler & Greenberg, 2002). Furthermore, up to a third of all patients with clinical anxiety disorders do not respond to SSRI's or cognitive behavioral psychotherapy treatment (de Vries, de Jonge, van den Heuvel, Turner, & Roest, 2016; Stubbs, Vancampfort, et al., 2017).

When we address the therapeutic benefits of exercise, there are many mental health disorders that are responsive as a treatment, including and not limited to depression, anxiety, eating and addictive disorders. Exercise also reduces a range of systems of chronic pain disorders (Geneen et al., 2017), age-related cognitive decline, the severity of Alzheimer's disease (Paillard, 2015), and some symptoms of schizophrenia (Dauwan, Begemann, Heringa, & Sommer, 2016). Endurance exercise specifically has been shown to protect against cognitive decline in older adults, in particular improving executive function and working memory (Barnes, Yaffe, Satariano, & Tager, 2003).

A large population study by De Moor and colleagues investigated the association between personality traits, exercise, anxiety and depression (De Moor, Beem, Stubbe, Boomsma, & De Geus, 2006). As predicted they found individuals who frequently exercised were less anxious and depressed compared to controls. Most interesting were the personality differences in the exercisers': they were less neurotic, more extraverted, higher in adventure seeking traits and higher in disinhibition, all of which considered positive personality traits for resistance from mental ill health. However, the casualty of exercise participation and personality traits must be speculated. It is difficult to establish whether certain personality traits such as extraversion increase how much exercise an individual participates in, or whether regular exercise affects an individual's personality traits and attitudes.

When exercise becomes pathologically compulsive there is an adverse effect on mental health. Research by Weinstein and colleagues investigated compulsive exercise behaviour in recreational and professional athletes. They found that professional athletes reported higher levels of depression than recreational athletes. Furthermore, neither professional nor recreational athletes presented an association between compulsive exercising and trait anxiety (Weinstein, Maayan, & Weinstein, 2015). This area of research sheds light on a growing gap in our understanding of this field; when it comes to mental health benefits of exercise specifically for anxiety, what is the ideal type, duration, intensity and frequency for optimum benefits?

An insightful meta-analysis revealed that depression was significantly more reduced when individuals participated in high intensity exercise in comparison to low intensity (Conn, 2010). Furthermore, Conn found that depression reduced even more so when conducted in a fitness facility and supervised in comparison to exercise conducted at home and unsupervised. This seems to suggest that motivation plays an important role when it comes to exercise, if we are to assume that supervised exercise and exercise in a specific fitness facility promote more intensive and rigorous activity, and therefore the intensity of the exertion is responsible for the anxiety reduction. However an extensive review conducted by Salmon (Salmon, 2001) would suggest that exercise is only beneficial to mood enhancement when it is performed at a manageable level to the individual. Specifically, for individuals who have a sedentary lifestyle, being encouraged to exercise can be unfamiliar, uncomfortable and anxiety provoking in itself.

The introduction of research investigating supervised/unsupervised exercise and exercise in fitness facilities versus exercise at home, poses a fundamental question of causality. Could this positive effect of exercise on mental wellbeing be caused by extraneous variables which are being overlooked? The behavioural activation aspect of exercise encourages social interaction and therefore interrupts social withdrawal, which is common in anxiety disorders (Asmundson et al., 2013; Salmon, 2001). Applying this could have substantial effects on reported levels of anxiety after supervised exercise or exercise in a fitness facility, especially within fitness groups (e.g. running clubs, group exercise classes) where social interaction and group support is especially high. It is well established that changing an individual's self-perpetuating patterns such as social withdrawal and inaction is crucial to therapeutic benefit (Barlow, Allen, & Choate, 2016). Behavioural activation is understood as an effective treatment mechanism in the treatment of some anxiety disorders such as post-traumatic stress disorder (Jakupcak, Wagner, Paulson, Varra, & McFall, 2010). Exercise may offer individuals with anxiety an opportunity to engage in a distracter activity, which draws their attention away from negative thoughts that provoke their anxiety (Chalder et al., 2012; Salmon, 2001; Strohle, 2009). There are some limitations to looking at exercise as merely a distractor behaviour, for example, if the therapeutic effects of exercise are primarily a function of interoceptive exposure, then use of exercise as distraction could diminish the overall effectiveness of exercise as an anxiolytic. Although good methodological practice would include reminding participants to focus on bodily sensations during exercise as to receive full benefit of interoceptive exposure, it would be beneficial to establish whether this actually produces stronger gains than if participants were to be instructed toward a distraction.

Rose and Parfitt conducted a study using nineteen women in a twenty-minute treadmill exercise bout at different intensities (Rose & Parfitt, 2007). These were below lactate threshold (LT), at LT and above LT. Affective valence and activation were monitored before, during and after exercise. Participants were also asked about why they felt the way they did during each level of intensity. Results suggested that affect was least positive during the above LT condition and the most positive during the self-selected and below LT states. This study thus demonstrated that factors such as focus of concentration, ability perceptions, exercise intensity and outcomes underpin an effective response to exercise, contributing to the individual differences in emotional responses to exercise.

The positive effects of exercise are undeniable, but what is it about exercise that produces these anxiolytic affects? Proposed physiological mediators include changes in serotonin metabolism, improved sleep, as well as endorphin release and consequent "runner's high" (Deslandes et al., 2009; Stathopoulou & Powers, 2006). Psychological factors include enhanced self-efficacy and self-esteem, reduced interruption of negative thoughts and less rumination (Dowd, Vickers, & Krahn, 2004), and perhaps the breakdown of muscular armour, the chronic psychosomatic muscle tension patterns that express emotional conflicts and are a focus of somatic therapies (E. Smith, 2000). Neural factors are especially intriguing. Exercise increases brain volume (both grey and white matter), vascularization, blood flow, and functional measures (Erickson, Leckie, & Weinstein, 2014; Talukdar et al., 2017). Studies suggest that exercise induces changes in the hippocampus including increased neuronogenesis, synaptogenesis, neuronal preservation, interneuronal connections, and brain-derived neurotrophic factor, which is the same neurotrophic factor that antidepressants up-regulate (Hall, 2016). Therefore, this could mean that frequent moderate exercise not only increases positive mood in the brain but can also improve our cognitive functioning.

In a study using magnetic resonance imaging (MRI) to examine brain volume, fifty-nine people aged sixty and seventy-nine were randomly assigned to aerobic or non-aerobic exercise groups (1 hour, three times a week for 6 months). Adults exercising aerobically showed increased brain volume in frontal lobe regions implicated in higher order processing, attentional control and memory (Colcombe et al., 2006). Given these neural effects, it is not surprising that exercise can also produce significant cognitive benefits (Ploughman, 2008). Hillman and colleagues (Hillman, Erickson, & Framer, 2008) argue that physical activity during childhood may optimize cortical development promoting lasting changes in brain structure and function in adulthood. Which suggests even more importance should be placed on children's physical activity levels, to aid cognitive development, mental and physical wellbeing into adulthood.

Although anxiety disorders are often differentiated by the specific symptoms of fear and worry, the basic foundation of vulnerability and general mechanisms of these disorders are common (Haller, Cramer, Lauche, Gass, & Dobos, 2014). Emotional 'vulnerability' is an individual's perception of self that is subjected to internal and external dangers over which they have no or little control to provide a sense of safety (Beck & Haigh, 2014). The cognitive dimension in anxiety focuses on this notion of vulnerability (Clark & Beck, 2011). In the last three decades or so, cognitive models of anxiety disorders (and depression) have greatly highlighted the crucial role of selective information processing in the development and maintenance of emotional psychopathology (Beck & Clark, 1997).

In this context, clinical and subclinical levels of anxiety are associated with biases in the predominant and automatic strategic stages of attention (Bar-Haim, Lamy, Pergamin, Bakermans-Kranenburg, & van IJzendoorn, 2007), whilst depression is associated with cognitive biases in the later stages (Gotlib et al., 2004; Hallion & Ruscio, 2011; Joormann & D'Avanzato, 2010). Depression and anxiety are highly comorbid (Brown, Campbell, Lehman, Grisham, & Mancill, 2001). Smith investigated the role of moderate exercise on emotional affect and found that moderate exercise reduced levels of state anxiety (Smith, 2013). Smith concluded that moderate exercise has anxiolytic effects and, furthermore, could build resilience to emotionally arousing threat or negative stimuli, having implications for how positive mood could be potentially protected by moderate exercise even when individuals are presented with negative imagery. This effect of emotional resilience had also been reported by Smith (2013) and O'Connor (O'Connor & Shimizu, 2002). The studies did not investigate any mediating factors between moderate exercise and emotion, suggesting that this research rested on physiological theory of the physiological response. This is problematic as there is not enough evidence to establish cause and effect from these methods and there is no explanation of what occurs in between, in Smith's study (J. C. Smith, 2013).

Anxiety is also characterised by a negative cognitive interpretation bias (Hallion & Ruscio, 2011; Mathews & MacLeod, 2005) although evidence for a link between lack of positive imagery and anxiety is mixed (Morina, Deeprose, Pusowski, Schmid, & Holmes, 2011). Furthermore, the psychotherapy interventions in place for these anxiety disorders are grounded in cognitive theory that rest heavily on the assumption that cognitive biases are causally related to symptoms. These assumptions have been demonstrated and a strong relationship between anxiety, depression and a variety of negative cognitive biases (attentional, interpretational and memory) is becoming established in the literature (Mathews & MacLeod, 2005; Vrijsen et al., 2014). Therefore individuals who suffer with anxiety are therefore likely to have negative cognitive interpretation biases (Richards, 2004; Richards & French, 1992).

1.1.2 Current Limitations In The Field

An increasing body of research suggests that physical activity is a moderately effective treatment for anxiety and depression with an effect size of 0.72 (Mutrie & Faulkner, 2003) but much less than the most powerful medications and psychotherapies. Studies on the management of anxiety disorder’s through physical activity, however, have been criticized for involving non-clinical volunteers, brief follow-ups, inadequate experimenter blinding, and an absence of appropriate statistical analyses, all of which may all have led to an exaggeration of the effectiveness of exercise as a treatment for anxiety and depression disorders (Lawlor & Hopker, 2001). However, these limitations arise in most studies on the management of mental illness as they involve volunteers and there are certain unavoidable confounds such as participant availability heuristics. Thus, it is likely that volunteers in these studies tend to be positively inclined towards physical activity, because otherwise they would not choose to participate (Babyak et al., 2000). It is not clear to what extent the results of these studies generalize to settings and populations where patients may be less motivated to participate in exercise programs to address their mental health problems. Effectiveness studies in community settings and, of course, in countries that do not have these resources in place are needed to understand the extent to which the results of these trials have external validity and global applicability.

1.1.3 Implications

However, despite the many mental and physical benefits of exercise, only some 10% of mental health clinicians recommend it. Such clinicians are unsurprisingly more likely to frequently exercise themselves (McEntree & Halgin, 1996). A recent review by Way and colleagues provides evidence for this. They surveyed three-hundred-and-seventy-five mental health professionals on attitudes to prescribing exercise to patients (Way, Kannis-Dymand, Lastella, & Lovell, 2018). They found that 70% of mental health professionals reported they often prescribed exercise for patients suffering the anxiety, stress and depression, but not for conditions such as schizophrenia, bipolar disorder or substance abuse disorders. Whether mental health professionals prescribed exercise to patients with anxiety, stress and depression, largely relied on their understandings of the patients' physical barriers to exercise and perspectives, and even the practitioners' knowledge of such interventions. Mental health professionals expressed a lack of training in these interventions, and that barriers such as disinclination of patients and disorganization prevented them for implementing these interventions (Way et al., 2018).

1.2 Conclusion

Despite the understanding of the positive impact that frequent exercise can have on our bodies, relationships, cognitive development, mental wellbeing and society in general, only a mere thirty per cent of western populations engage in regular exercise (Salmon, 2001) and this declines rapidly over the lifespan (De Moor et al., 2006). Furthermore, once an exercise program in initiated by an individual for whatever purpose, attrition is high, around thirty per cent dropping off within three to six months (Conn, 2010; Salmon, 2001). To conclude, there is still scope for research in the field of mental health and exercise. Future research needs to investigate exercise motivation, accessibility, exercise setting, frequency, duration, intensity and different variations of exercise to establish the most efficient exercise techniques for modulating cognitive bias mechanisms and improving our mental wellbeing.

Chapter 2 Cognitive Interpretation Bias; The Effect Of A Single Session Moderate Exercise Protocol On Anxiety And Depression.

2.1 Overview

Research conducted within the Cognitive Bias Modification (CBM) paradigm has revealed that cognitive biases such as negative cognitive interpretation biases contribute to mental health disorders such as anxiety (Beard, 2011). It has been shown that exercise reduces anxiety (Ensari, Greenlee, Motl, & Petruzzello, 2015). Exercise has also been found to reduce negative cognitive attention biases (Tian & Smith, 2011), however no research to date has investigated the effect of exercise on cognitive interpretation bias. The key aims of the current project is to investigate whether moderate exercise reduces self-reported symptoms of anxiety, depression and stress. Additionally, to establish which intensity of exercise is required to achieve anxiety reduction and reduce an individual's negative cognitive interpretation biases.

Study one recruited a healthy sample of adult participants who were randomly assigned to one of two conditions: a walking exercise protocol or a control condition (n=2x12). Participants completed anxiety and cognitive interpretation bias measures before and after the walking exercise or control condition. Those in the walking exercise condition presented less symptoms of trait anxiety on a measure of state and trait anxiety inventory (STAI), compared to controls relative to baseline measures following the intervention.

Study two recruited frequent exercisers who were assigned to an exercise or control condition (n=2x24). Participants completed anxiety, depression, psychological stress and cognitive interpretation bias measures before and after the exercise or control condition. Following the intervention, negative interpretation biases decreased in the exercise condition and stayed stable in the control condition. The exercise condition also had significantly decreased anxiety, depression and stress measures after the exercise condition, whilst controls did not. The research concludes that CBM holds promise for the management of mood disorders and exercise is an effective accompaniment to psychotherapy.

Chapter 2 is published in the Journal Frontiers in Psychology (Please see Appendix A).

2.2 Introduction

The beneficial effects of acute and chronic exercise on healthy individuals and those with sub-clinical or clinical anxiety and depression have been well established (Herring, Lindheimer, & O'Connor, 2014; Stubbs, Koyanagi, et al., 2017) and exercise has been advocated as a treatment for maladaptive mood and emotional problems (Barbour & Blumenthal, 2005; Otto et al., 2007; Paluska & Schwenk, 2000; Penedo & Dahn, 2005). Health care providers such as the National Health Service (NHS) in the UK have advocated exercise interventions independent or in conjunction with psychological and/or pharmacological therapies for affective emotional problems (Daley, 2018; Fox, 1999; Saxena, Van Ommeren, Tang, & Armstrong, 2009). Benefits of physical exercise in a range of physical disorders including diabetes, renal disease and osteoporosis, has been clearly established (Fentam, 1994). There is also a strong body of evidence regarding the physiological benefits of regular physical exercise on the human body (Asmundson et al., 2013;

Salmon, 2001), as well as improved psychological wellbeing (Fox, 1999). Exercise is arguably not a panacea for mental health problems, however, it can reduce the symptoms of the less severe cases of anxiety, chronic stress and depression, and in turn could reduce rising health costs nationally and internationally (McCrone et al., 2008).

Although anxiety disorders are often differentiated by the specific symptoms of their fears, the basic foundation of vulnerability and general mechanisms of these disorders are common to all (Mineka, Watson & Clark, 1998). Study of the cognitive dimension of anxiety focuses on this notion of vulnerability (Clark & Beck, 2011). According to Beck, Emery & Greenberg (2005), 'vulnerability' is an individual's perception of self that is subjected to internal and external dangers over which they have little or no control to provide a sense of safety. Also, in the last three decades or so, cognitive models of anxiety disorders and depression have greatly highlighted the crucial role of selective information processing (so-called 'cognitive bias') in the development and maintenance of emotional psychopathology (Beck & Clark, 1997). However, the effects of exercise on the processing of threat-related cognitive biases in people with high levels of anxiety and anxiety disorders are less well understood (Cooper & Tomporowski, 2017).

Physical activity and physical exercise are terms generally used interchangeably, however they are different concepts. Physical activity is any bodily movement resulting in expending energy whereas physical exercise is a subset of physical activity that is regular and structured with an objective to improve health and fitness (Casperson, Powell & Christenson, 1985). Research has generally focused on formal exercise programmes in terms of its psychological benefits, though recently cross-sectional studies have consistently shown high self-reported levels of habitual physical activity to be associated with better mental health (Salmon, 2001). Research into the effects of exercise on emotion is predominantly focussed on self-reported measures of anxiety, stress and depression symptoms or on clinical psychological assessment scales, to evaluate the effects of exercise after a single bout of exercise, a training programme or affective responses during exercise (Ekkekakis, 2013; Williams et al., 2008). These experiments have undoubtedly given insights on benefits of exercise on alleviating moods and there is substantial evidence for this relationship to be considered as a therapeutic approach in the treatment of anxiety disorders (Fox, 1999). Previous research by (Hansen, Stevens, & Coast, 2001) and (Salmon, 2001) suggest that exercise is emotion enhancing when it is performed at a 'manageable level' for the individual that is engaged in the activity.

Clinical and subclinical levels of anxiety are associated with biases in the predominant and automatic strategic stages of attention (Bar-Haim, Lamy, Pergamin, Bakermans-Kranenburg & van IJzendoorn, 2007), whilst depression is associated with cognitive biases in the later stages (Gotlib et al., 2004; Hallion & Ruscio, 2011; Joormann & D'Avanzato, 2010). However depression and anxiety are highly comorbid (Brown, Campbell, Lehman, Grisham & Mancill, 2001) and anxiety has also been associated with negative cognitive interpretation bias as well as attentional biases. (Hallion & Ruscio, 2011; Mathews & MacLeod, 2005). This proposes another understanding of anxiety, perhaps it is characterised by attentional bias, the tendency to search for high risk, threatening or danger to the self, and also interpretation biases which is a tendency to evaluate present and past situations in negative, rather than benign or positive, manner. Whilst depression may only be characterised by interpretation biases, which would explain why individuals with depression commonly ruminate about situations from the past (Krahé, Mathews, Whyte, & Hirsch, 2016). Furthermore, the psychotherapy interventions in place for anxiety and depression disorders are grounded in cognitive theory that rest heavily on the assumption that cognitive biases are causally related to symptoms. These assumptions have been demonstrated and a strong relationship between anxiety, depression and a variety of negative cognitive biases (attentional, interpretational and memory) is becoming established in the literature (Mathews & MacLeod, 2005; Vrijsen et al., 2014). Individuals who suffer with anxiety or depression are therefore likely to have negative cognitive interpretation biases (Richards, 2004; Richards & French, 1992).

Cognitive models of anxiety suggest that there are biased ways of basic information processing running within the cognitive system that probably are not consciously accessible and these play a crucial role in experiencing unwarranted manifestation of anxiety (Mathews & MacLeod, 2005). It is seen that people with anxiety and depression tend towards the negative aspect of ambiguous situations and are also inclined to interpret such conditions negatively instead of positively. Negative mood states are frequently related to negative cognitive biases of attention and interpretation (Rose & Parfitt, 2007). Individuals who suffer with clinical disorders such as anxiety, stress and depression, frequently exhibit a preferential response towards negative relative to positive or benign/neutral information and have a tendency to interpret ambiguous situations and environments negatively rather than positively. There is evidence to suggest that cognitive biases are rooted in psychological processes in clinical populations; suggesting that anxiety and stress-related symptoms could be considerably reduced in vulnerable populations if we could reduce their tendency to make negative cognitive biases and thereby improve mood state (Brosan, Hoppitt, Selfer, Sillence, & Mackintosh, 2011; Mackintosh, Mathews, Yiend, Ridgeway, & Cook, 2006). In terms of cognitive bias, depression and anxiety are associated with difficulty in disengaging one's attention from mood-congruent (negative) self-relevant stimuli. This may be coupled with attentional avoidance to positive stimuli. Together, these lead to a decrease in positive mood and increase in negative depressive symptoms (Gotlib et al., 2004; Mathews & MacLeod, 2005).

According to Salmon (2001), attention to aerobic exercise has outweighed focus given to non-aerobic exercises where muscle activity is brief, intense and cannot be maintained. Aerobic exercise can be defined as an activity involving large muscles, increased heart rate and respiration, such as swimming, running and aerobic dancing. According to a meta-analysis, there were no significant differences between the various types of aerobic exercise, the only significant differences was aerobic having a more positive effect on mood than non-aerobic exercises (Petruzzello et al, 1991). These studies generally show an improvement in mood after participating in an aerobic exercise routine. However, a study by Netz & Lidor (2003) demonstrated that non-aerobic mindful activities can also have positive mood changes. They investigated the effectiveness of four different physical activity modes (dance aerobics, Feldentrais, swimming and yoga) on changes in mood. Physical activity modes were compared with a non-activity computer class, they found that there was an enhancement in positive mood through these low exertion activities in a single session of exercise. This would suggest that level of exertion is not solely responsible for improvement and therefore reduction in anxiety and depressive symptoms. Similarly, Gupta, Khera, Venupati, Sharma & Bijlani (2006) investigated the effect of a short-term yoga programme on individuals with various diseases, specifically anxiety. Results indicated a significant reduction in both state and trait anxiety scores after measuring anxiety scores on the first and last day of the programme.

Smith investigated the role of moderate exercise on emotional affect, using an exercise protocol and the perceived rated level of exertion scale (PRE; Smith, 2013) to achieve a moderate amount of exercise enough to be deemed beneficial. Smith found that moderate exercise reduced levels of state anxiety and concluded that moderate exercise has anxiolytic effects and, furthermore, could be resistant to emotionally arousing negative/threatening stimuli. This has implications for how positive mood could be potentially protected by moderate exercise even when individuals are presented with negative imagery. This effect of emotional resilience has also been reported by O'Connor et al. (2000).

Research into the effects of exercise training on cognitive interpretation biases in anxiety, depression and stress related disorders is sparse and the insight it could lend to our understanding of the cognitive mechanisms could be valuable. The key aims of the present study is to establish at which intensity of exercise is required to achieve anxiety reduction and whether this is related to changes in an individual's negative cognitive interpretation biases. Furthermore, it will investigate whether moderate exercise reduces self-reported symptoms of depression and stress. These research aims will be addressed with two experimental studies. The hypothesis of study one is that there will be significant decrease in negative interpretation bias whilst under a cognitive load (remembering a 6-digit number during the task; please see page 19) compared to when not under a cognitive load and a reduction in anxiety measures in the walking exercise condition relative to the control condition.

2.3 Study One

2.3.1 Methodology

Participants

Twenty-four participants were recruited to take part in this study from the University of Essex, Colchester U.K, please see participant demographic information by condition in Table 2.1. To be eligible, healthy individuals who were regularly physically active as ascertained by self-report were included. Study requirements were that individuals did not exercise for twelve hours prior to participating and must be fluent in spoken and written English. Participants were told they would be required to complete a series of questionnaires, and they may or may not be required to undertake a walking exercise protocol. Ethical approval was granted from the University of Essex Ethics Committee.

Materials

State and Trait Anxiety

The state and trait components of the State Trait Anxiety Inventory (STAI; Spielberger, 1983) questionnaire were used to assess global and transient levels of anxiety (please see appendix B). The STAI assesses apprehension, tensions, nervousness and worry in twenty questions on a 4-point Likert scale. The first part measures state anxiety; which is an immediate measure of the participant's current state of anxiety. The second part is the trait anxiety scale, which measures an individual's predisposition for personal anxiety. This scale has been identified as a reliable tool for assessing anxiety and an individual's aggregate. Reliability scores of this scale range from 0.65

to 0.86 for the trait version and 0.16 to 0.62 for the state version (Barnes, Coombes, Armstrong, Higgins, & Janelle, 2010).

Cognitive Interpretation Bias

The scrambled sentences test (SST; Rude, Wenzlaff, Gibbs, Vane, & Whitney, 2002; Standage, Ashwin, & Fox, 2010) was used to measure negative cognitive interpretation bias (please see appendix F). The SST involves unscrambling a list of twenty sentences, this is done in cognitively non-loaded and cognitively loaded conditions, where the participant is subject to a simultaneous cognitive load task or not (e.g. remembering a six-digit number). Participants firstly, had the task explained to them by the researcher and then were asked to complete three practice questions, which were scored before the participant completed the SST to ensure they understood the task correctly, the practice question scores were not recorded for further analysis. For the loaded and non-loaded trials, only those during which the participant correctly recalled the six-digit number were included for analysis. Participants had four minutes to complete as many of scrambled sentences as possible. The score of negative or positive responses to the cognitive interpretation bias tasks were then collected and recorded. This method aims to investigate the tendency of each individual to interpret ambiguous information either positively or negatively and was measured before and after the intervention. From the data gathered, a negative interpretation bias score was calculated, using the formula in Figure 2.1. The SST has been suggested to be reliable at establishing the existence of a cognitive bias (Rude et al., 2002).

$$\text{SST} = 100 \ \text{X} \ \frac{\textit{Negative}}{\textit{Correct}}$$

Figure 2.1 Equation For Negative Cognitive Interpretation Bias Score.

Design

Anxiety measures are assessed using a 2x2 mixed factorial design in which the within-subjects factor is Time (Session 1 and 2) and the between-subjects factor is condition. The SST data is analysed with a mixed measures 2x2x2 factorial design: SST-type (Load/NonLoad) x Session (S1/S2) x Intervention (walking exercise/control condition). The within-subjects variables are SST-type, and Session, whilst the between-subjects factor is the intervention (walking exercise) or control condition.

Procedure

Participants were randomly assigned to one of the two conditions: exercise condition (n=12), and the control condition (n=12). The experiment was split into session one and session two, in-between the sessions the participants either completed the moderate walking exercise or had thirty minutes to relax (control condition). The order in which the SST's were administered were counterbalanced (load or non-load).

Session One: All participants completed the state and trait versions of the STAI to measure self-reported anxiety before the experimental and control condition to establish an accurate baseline. All participants then did the practice SST and completed the first and second measures of interpretation bias (SST) both cognitively loaded and non-loaded which they had four minutes to do each set of twenty sentences.

Intervention:

Participants in the exercise condition spent thirty minutes walking at a brisk pace around the University grounds, and then were invited back into the experiment lab. Participants in the control condition spent the thirty-minute period in the experiment lab, the only stipulation was to refrain from internet use, social media, and not use their mobile phones.

Session Two: All participants then completed different versions of the SST (loaded and non-loaded) followed by the STAI. Once completed each participant was thanked for their participation and debriefed.

2.3.2 Results

Preliminary Analysis

Before the full analysis was conducted, preliminary analysis of the data was conducted to investigate the assumptions of parametric tests; the assumptions of parametric data were not violated. A One-Way ANOVA was conducted to investigate whether participant's gender, age, baseline SST and STAI scores were significantly different between conditions. There were no significant differences between conditions, therefore one can assume homogeneity between the conditions, and therefore any difference observed are unlikely due to individual differences between conditions at the start of the experiment.

Main Effects

The hypothesis was that individuals in the walking exercise condition would decrease in anxiety (STAI) and negative interpretation bias (SST) measures. There was a significant effect of time on state anxiety measures F (1)=10.17, p<.005, ηp^2= .316, but no significant interaction effect of time x condition F (1)=2.87, p=.10, ηp^2= .116. The interaction between time x condition was statistically significant for trait anxiety, F (1) =5.02, p <.05, ηp^2=.186 (for means and standard deviations please see Table 2.1). A paired samples t-test was used to further investigate this effect, which revealed that participants in the walking exercise condition significantly decreased in trait anxiety measures from baseline (M=44.0, SE=3.97) to post-intervention (M=40.41, SE=4.53), t (11) = 3.54, p< .005, r = .72, which suggests a large significant effect size. The achieved power of this analysis was 1-ß = .92. Whilst the control condition remained stable from baseline (38.50, SD=9.51) to post condition (M=38.16, SD=11.18) t (11) = .32, p=.75. There was no significant effect of condition on interpretation bias scores (SST) F (1)=.379, p=.54. The data analysis of the results suggest that there was a significant reduction in trait anxiety in the walking exercise condition in comparison to the control condition, however there was no effect on interpretation bias.

Table 2.1 Participant Demographic Information, Mean & Standard Deviation For STAI & SST By Condition, Study 1.

	Baseline; Session 1 Post condition; Session 2	***N***	***Mean, Range & SD Age***	***Gender Ratio M:F***	***Walking Exercise Condition Mean (SD)***	***Control Condition Mean (SD)***
STAI- S	Session 1	12	Walking Exercise Condition Mean:29.50 Range: 21-40 SD: 7.03 Control Condition Mean: 28.58 Range: 22-38 SD: 5.45	Walking Exercise Condition 4:20 Control Condition 8:16	**37.58** (9.22)	**33.25** (9.88)
	Session 2				**30.50** (8.74)	**31.08** (9.41)
STAI- T	Session 1	12			**44.0** (13.78)	**38.5** (9.51)
	Session 2				**40.41** (15.69)	**38.16** (11.18)
SST Cognitively Loaded	Session 1	12			**30.87** (27.67)	**19.64** (19.74)
	Session 2				**31.18** (28.08)	**14.96** (13.81)
SST Cognitively Non-Loaded	Session 1	12			**26.58** (23.19)	**19.50** (15.37)
	Session 2				**31.16** (29.08)	**22.56** (21.91)

2.3.3 Discussion

The findings from study one suggest a significant decrease in self-reported trait anxiety measures when participants underwent a single session walking exercise protocol. However, the hypothesis is only partially supported, because there was no significant effect of walking exercise on state anxiety measures relative to the control condition. Furthermore, walking exercise had no significant effect on negative interpretation bias measures, both cognitively loaded and non-loaded, relative to the control condition. The decline in trait anxiety scores post exercise is positive, although effect of the change was not as significant as seen in state anxiety scores. The control condition, as predicted did not show significant changes on anxiety responses, suggesting that being in a state of rest in comparison with engaging in physical exercise, does not affect mood states. These findings suggest that as little as thirty minutes of low intensity exercise such as walking can have a positive effect on mental wellbeing, by reducing self-reported trait anxiety. However, it would seem that more moderate cardiovascular exercise is required to affect an individual's cognitive interpretation biases.

2.4 Study Two

2.4.1 Introduction

Research has previously investigated the role of cognitive interpretation biases in stress reactivity (Joormann, Waugh, & Gotlib, 2015; Mackintosh, Mathews, Eckien, & Hoppitt, 2013). However, research to date has not investigated the effect of cognitive interpretation bias on perceived psychological stress as an independent factor, despite their being support for a link between clinical depression and perceived stress (Joormann & Quinn, 2014; Joormann et al., 2015) .Indeed, our understanding of which psychological mechanisms mediate stress and how they affect mental health has been unclear (Creswell et al., 2005). Stress is a physiological disruption caused by tangible or subjective threats, which disrupt an individual's physical or psychological state and may be caused by a single or combined physical, physiological and psychosocial conditions (Iwasaki, 2006; Sapolsky, 2004). The stress response through the Hypothalamic-Pituitary-Adrenal axis is thought to be a major physiological mechanism in which stress influences one's health and cognition (Cohen, Janicki-Deverts, & Miller, 2007; Norman et al., 2011). Previous research has also found that increased perceived psychological stress correlates with depression (Hammen, 2005; Mazure, 1998). Perceived levels of stress are suggested to be an important factor when studying the effects of exercise on cognitive biases (Salmon, 2001). Kajtna, Stukovnik and Groselj (2011) investigated the effect of mood states on experienced levels of stress, they found no significant correlation between high experienced levels of stress and negative mood-states. This suggests that the physiological effect of stress has no effect on negative emotions and perhaps no effect on cognitive biases. This suggests support for the concept that mood enhancement; of which elicited form exercise will not affect an individual's cognitive bias, whilst there is also support to the contrary (Hallion & Ruscio, 2011). Furthermore various studies have found support for the notion that those who suffer with clinical depression preferentially encode threatening interpretations (Mogg & Bradley, 2006; Mogg & Bradley, 2016). However, the evidence is not clear-cut and others have found no such evidence of negative interpretation bias in depressed individuals (Bisson & Sears, 2007).

Research into the effects of exercise training on cognitive interpretation biases in anxiety, depression and stress related disorders is sparse and the insight it could lend to our understanding of the cognitive mechanisms could be valuable. The key aims of the present study is to establish at which intensity of exercise is required to achieve anxiety reduction and whether this is related to changes in an individual's negative cognitive interpretation biases. Furthermore, it will investigate whether moderate exercise reduces self-reported symptoms of depression and stress. These research aims will be addressed with two experimental studies. The second study hypothesises is that there will be significant decrease in negative interpretation bias whilst cognitively loaded, and a reduction in depression, stress, and anxiety measures in the moderate exercise condition relative to the control condition.

2.4.2 Methodology

Participants

Forty-eight participants were recruited to participate in the study and randomly assigned to either an exercise or non-exercise (control) condition, for participant demographic information by condition please see

Table 2.2. Participants were recruited from and the experiment was conducted in, a private members gym in Colchester, U.K. Eligibility requirements were that individuals must refrain from cardiovascular exercise twelve hours prior to the experiment (regardless of the intensity) and they must be fluent in spoken and written English. Participants had to be over eighteen years old and be regular gym users (twice a week or more) in order to be eligible. Participants were made told that the research had no affiliation with the gym, nor was there any obligation for them to participate. Ethical approval was granted from the University of Essex Ethics Committee.

Materials

State and Trait Anxiety and Cognitive interpretation bias (SST) were measured the same as in study one, please see section 2.3.1.

Depressive symptoms

The revised Beck Depression Inventory (BDI-II; Beck, Steer, & Brown, 1996) was used in this research because it measures attitudes, characteristics and symptoms associated with depression. It is a twenty-one item inventory measured with a 4-point Likert scale (please see appendix D).

The BDI-11 score is calculated by totaling the answers from each questionnaire and scores of above 30 are indicative of severe depression.

Perceived Psychological Stress

The Perceived Stress Scale (PSS; Cohen, Kamarck, & Mermelstein, 1983) was used to measure how stressed the participant perceived themselves as being over the past two months (please see appendix C). Responses on the fourteen-point scale are given on a rating of one (never) to four (always). The PSS contains questions such as “How often in the past two months have you dealt successfully with irritating life hassles?” and is used to measure an individual’s perception of how they are coping with stressors. Furthermore, this suggests that due to current circumstances an individual’s perception of their level of coping with stressors can change sporadically.

Design

This experiment used a mixed measures 2x2x2 factorial design; which will be used to analyse the data collected to investigate hypothesis one; Load/NonLoad X Exercise/Control condition X Session1/Session2. The within-subjects variable is the cognitively loaded or non-loaded SST, and session one/session two, whilst the between-subjects factor is the exercise/control condition. The data analysis approach will use a 2X2 mixed factorial design; in which the within-subjects factor is Session1/Session2 (before & after experimental/control condition), and the between-subjects factor is exercise/control condition. The Dependent variables are the self-report measures of anxiety (STAI), stress (PSS), depression (BDI-II, and interpretation bias (SST).

Procedure

Participants were randomly assigned to the intervention condition (n=24) or the control condition (n=24) the experiment was split into session one and session two, in-between the sessions the participants either completed the moderate intensity exercise protocol or had forty minutes to relax.

Session one- Participants completed the STAI, BDI-II, and PSS. They then had four minutes to complete each SST (the order of which were counter balanced between subjects). Although participants were for the majority randomly assigned to conditions, a running tally was kept of gender and the state and trait anxiety scores (STAI) from session one, to allow for a homogenized sample in both the experimental and control condition.

Intervention: Participants were assigned to either the intervention condition (a moderate exercise protocol) or the control condition, in which the participants had forty minutes to relax until the second session of the experiment. The exercise protocol was compliant to current health and safety regulations as set out by the gym being used. The duration and intensity used was similar to previous research (e.g. Hansen et al., 2001; Russell et al., 2003), and based on findings that advocates that 85% of the cardiovascular aerobic heart rate reserve of each individual should be maintained for 20 to 30 minutes to achieve the desired benefits of aerobic activity (R. T. Barnes et al., 2010), which was relevant for the aims of this research. This research used a static cycle machine (York- Fitness-Model-110) in the gymnasium, as this reduces impact on joints and is safest for the participant, as they remain seated. The static- cycle machine was used to measure heart rate so that the desired aerobic heart rate that is necessary for the experiment can be monitored and adhered to respectively. This provided participants with continuous feedback of their heart rate reserve and when to increase/decrease their aerobic intensity. Heart rate monitors are recognised to be a reliable and valid measure of measuring exercise intensity and rate of exertion during aerobic exercise (Janz, 2002). Aerobic heart rate reserve was calculated using the formula in Figure 2.2 (Uth, Sørensen, Overgaard, & Pedersen, 2004) . The exercise protocol consisted of a light warm up of low-intensity; which is 20% of heart rate reserve for 5 minutes, and then increased to 80% heart rate reserve for 30 minutes, then concluded with a ‘cool down’ which was low-intensity pedaling for 5 minutes using 20% heart rate reserve.

$$HR\ reserve = HR\ resting - HR\ maximum$$

$$Z = 80\%\ of\ HR\ reserve$$

$$Z + HR\ resting = Aerobic\ Heart\ Rate$$

Figure 2.2 Equation For Calculation Of Aerobic Heart Rate (HR=heart rate)

Session two: Participants were invited back into the private consultation room to complete the third and fourth SSTs (counterbalanced between subjects) followed by the STAI, BDI-II and PSS questionnaires. Once completed each participant was thanked for their participation and debriefed.

Data Analytic approach

A mixed measures 2x2x2 mixed factorial ANOVA was used to analyse the data collected to investigate hypothesis one; Load/No Load X Exercise/No Exercise X Session1/Session2. The within-subjects variable is whether the SST was cognitively loaded/non-loaded, and session one/session two, whilst the between-subjects factor is the moderate exercise/control condition. A 2x2 ANOVA was used to measure the effect of moderate intensity exercise on anxiety, depression and perceived levels of psychological stress. The within-subjects factor is session one/session two, whilst the between subjects factor is the exercise/control condition. Post-Hoc analyses in the form of Sidaks's adjustment for pairwise comparisons and paired samples T-Tests were performed on significant effects and the effect size *r* calculated (Rosnow & Rosenthal, 2009). Observed power was calculated for significant Post-Hoc analyses in the form of Apriori power analyses using 'G*Power' Software.

2.4.3 Results

Preliminary analysis

Before analysis was conducted, preliminary analysis of the data was conducted to investigate the assumptions of parametric tests; the assumptions of parametric data were not violated so statistical analysis could be performed. A One-Way ANOVA was conducted to investigate whether participant's gender, age, baseline STAI, BDI-II, PSS and SST scores were significantly different between conditions. There were no significant differences between conditions, therefore one can assume homogeneity between the conditions, and therefore any difference observed are unlikely due to individual differences between conditions at the start of the experiment.

Main Effects

Individuals who participated in the exercise condition decreased in both state and trait anxiety measures, whilst the control condition remained stable from session one to session two (see table 2). This was exemplified by a significant interaction between time x condition reducing state anxiety measures, F (1, 46) = 43.78, p<.005, ηp^2= .488, and reducing trait anxiety measures, F (1, 46) = 39.54, p<.005, ηp^2= .462 (see table 2). Paired samples T-Tests revealed that participants in the exercise condition significantly decreased in state anxiety measures from baseline (M=46.33, SE=2.55) to post intervention (M=31.04, SE=1.56), t (23) = 6.56, p <.05, r =.80, suggesting a large effect. Observed power was calculated to investigate this effect size and found 1-ß =.96. They also decreased significantly in trait anxiety measures from baseline (M=44.42, SE=2.15) to post intervention (M=33.33, SE=2.18), t (23) = 6.05, p <.001, r =.78, suggesting a large effect. Observed power was calculated to investigate this effect size and found 1-ß =.95.

Likewise, there was a significant decrease in self-report stress measures in the exercise condition relative to the control condition (see table 2). Paired samples T-Tests suggest a decrease in stress measures from baseline (M=31.75, SE=1.04) to post exercise (M=22.29, SE=1.12), t (23) = 6.99, p < .005, r =.82, suggesting a large significant effect in the exercise condition. Observed power was calculated to investigate this effect size and found 1-ß =.97. Participants who underwent the moderate exercise protocol also decreased in self-report depression measures (please see

Table 2.2). Paired samples T-Tests suggest a significant decreased in depression measures from baseline (M=17.63, SE=1.52) to post exercise (M=6.58, SE=.78), t (23) = 7.81, p > .001, r =.84 suggesting a large significant effect. Observed power was calculated to investigate this effect size and found 1-ß =.97.

There was a non-significant effect on interpretation bias scores in either the exercise or control condition, regardless of whether the SST was cognitively loaded or non-loaded (see

Table 2.2). Considering the main effect is not vastly distant from being statistically significant, the SST was then analyzed combining both cognitively loaded and non-loaded versions of the measure using a paired samples T-Test. Furthermore, this suggested that for individuals who participated in moderate intensity exercise, there was significant decrease in negative interpretation bias from baseline (M= 62.36, SE=3.66), to post exercise (M= 27.03, SE= 3.58), t

(21) = 6.04, $p < .005$, $r = .79$, suggesting a large significant effect. Observed power was calculated to investigate this effect size and found 1-ß =.95.

Table 2.2 Participant Demographic Information, Mean & Standard Deviation For STAI, PSS, BDI-II & SST Measures By Condition, Study 2.

	Baseline; Session 1 Post condition; Session 2	**N**	**Mean, Range & SD Age**	**Gender Ratio M:F**	**Moderate Exercise Condition Mean (SD)**	**Control Condition Mean (SD)**
STAI- S	Session 1	24	Exercise Condition Mean:27.79 Range: 20-47 SD: 7.30 Control Condition Mean: 25.66 Range: 19-42 SD: 6.22	Exercise Condition: 10:14 Control Condition: 9:15	**46.33** (12.49)	**38.75** (6.74)
	Session 2	24			**31.04** (7.6)	**39.58** (5.61)
STAI- T	Session 1	24			**44.42** (7.87)	**38.42** (7.87)
	Session 2	24			**33.33** (10.70)	**40.00** (6.20)
PSS	Session 1	24			**31.75** (5.11)	**25.21** (6.46)
	Session 2	24			**22.29** (4.51)	**22.54** (5.70)
BDI-II	Session 1	24			**17.63** (7.44)	**12.46** (5.70)
	Session 2	24			**6.58** (3.85)	**11.88** (5.60)
SST Cognitively Loaded	Session 1	20	Exercise Condition N=8 Mean:30.12 Range: 20-47 SD: 10.65 Control Condition N=12 Mean: 26.91 Range: 19-38 SD: 5.88	Exercise Condition: 1:3 Control Condition: 5:7	**46.66** (16.63)	**45.37** (16.97)
	Session 2	20			**42.77** (33.13)	**52.92** (22.38)
SST Cognitively Non- Loaded	Session 1	20			**79.27** (17.39)	**52.18** (25.75)
	Session 2	20			**14.53** (6.47)	**45.29** (20.01)

2.4.4 Discussion

The findings from study two suggest that individuals who underwent the moderate exercise protocol reported significantly lower on both state and trait anxiety measures, relative to those in the control condition. Furthermore, participants in the moderate exercise condition also reported a significant decrease in depression and stress related symptoms relative to those in the control condition. Participants who underwent the moderate exercise protocol also reduced in negative interpretation bias scores relative to controls, however this was not specific to the cognitively loaded condition, which was specified in the hypothesis. When both cognitively loaded and non-loaded conditions were analyzed combined, it suggested that participants in the moderate exercise condition presented less negative cognitive interpretation biases from baseline measures, relative to participants in the control condition.

2.5 General Discussion

The purpose of study one was to further investigate the functions of exercise and mood enhancement, with a focus of anxiety. The aim was to further our understanding of the relationship between exercise regimes and self-report anxiety. The interest primarily was to investigate whether one single session of exercise is sufficient to produce the anxiolytic effects that is well founded. Furthermore, to investigate whether less intense exercise such as walking can produce the same mood enhancing effects as a more intense cardiovascular exercise session. The present research also investigated whether a cognitive load manipulation could have an effect on individual's interpretation biases, and whether this produced a more positive or negative representation of an individual's interpretation biases. Study two aimed to investigate, whether moderate intensity physical exercise was necessary to effect cognitive interpretation biases and whether this could perhaps reduce reported symptoms of stress and depression, as well as anxiety. Study two also employed a cognitive load manipulation to measure whether individual's cognitive biases could in fact be affected by a single bout of moderate physical exercise.

Needless to say, there is an abundance of research focusing on the longer-term effects of physical exercise for reducing self-report anxiety however the results of this present study do highlight some mood enhancing effects after a single session of physical exercise, these effects seem to be more so with moderate intensity exercise compared to light intensity physical exercise. The investigation of cognitive interpretation biases was made using the SST, which is administered both cognitively loaded and non-loaded. It takes concentration to remember the six-digit number, which decreases the amount of concentration an individual has whilst performing the task, therefore their attention is distracted from these threat-engaging thoughts which provoke negative interpretation biases. The underlying logic of this cognitive loading manipulation being that individuals would find it difficult to suppress these negative thoughts and interpretations during the cognitive load manipulation, and therefore the cognitive load measure would be a more accurate representation of an individual cognitive interpretation bias in comparison to the non-cognitively loaded measure. However, the cognitive load manipulation did not significantly affect whether the participants presented more positive or negative interpretation biases in either study one or study two.

Both studies together lend valuable insights from multiple perspectives. They offer further understanding into the relationship between physical exercise and anxiety reduction on the ground that regardless of the mode of exercise employed (physical activity, physical aerobic exercise), there is arguably growing support for the connection between physical exercise and mood enhancement. It is however, worthy to question what value these single-session intervention studies can inform us of the benefit of extended exercise programs to clinical patients. The nature of the methodological design of these two studies (within-subjects) provided sufficient statistical rigor for the purpose of these two studies. These studies were designed as analogue studies, so it becomes important for the betterment of our understanding to replicate these studies with a clinical or subclinical sample, as currently this cannot be generalized to a wider population. There could be a greater improvement in these individuals as the scope for reduction in anxiety and depression could be increased. Whether future research employing similar methodology to that of these two studies are able to replicate these findings or larger sample sizes differ in responses across conditions could become more pronounced, remains to be resolved.

In conclusion, the present studies have built upon the current literature and have lent support to claims that moderate intensity walking and aerobic exercise ameliorate the symptoms of anxiety, depression and psychological stress. In study two, there were signs that SST (interpretation) could also be changed. However, the present research investigated a non-clinical sample that have no previously diagnosed mental health conditions, therefore to what extent this research can be applied holds promise, but indeed is limited. Given the exciting potential for the use of exercise and cognitive bias modification in the clinical interventions, more research into this emerging field is clearly warranted.

Chapter 3 Developing a CBM-I & Exercise Dual Treatment

3.1 Overview

This chapter synthesises two studies which both investigate the effect of a physical exercise protocol, cogntive interpretation bias training both seperately and as a combined intervention for improving mood state. Study three recruited a sample of eighty individuals from a general population sample and uses a control conditon of rest for thirty minuets. Whilst the fourth study recruited a moderate anxiety sample of eighty participants, to measure whether those who are more anxious are more reactive to physical exercise training and cogntive bias modification training. The control condition uses a neutral valenced cogntive bias modification training program. Both studies suggest promising benefits of combining physical exercise and cognitive bias modfication training for improving mood state.

3.2 Introduction

There are fundamental cognitive biases that affect anxiety and depression, specifically negative cognitive interpretation biases; this is a tendency to evaluate an ambiguous situation in an aversive manner making it negative (Butler et al., 2015; Rude et al., 2002). Cognitive theories suggest that negative cognitive biases, or a tendency to process negatively valenced stimuli/events, is fundamental to the role in the onset and maintenance of anxiety (and depression) (Beck, 2008; Beck & Clark, 1997; Beck & Haigh, 2014; Mathews & MacLeod, 2005; Rapee & Heimberg, 1997). Such cognitive theories suggest that negative cognitive biases increase the intensity, frequency and variety of these negative thoughts, which negatively impact emotions; consequently, causing the negative symptoms of anxiety and depression to increase (Clark, & Steer, 1996). There is vast interest in the current literature to modify these cognitive biases to minimize the symptoms of depression and anxiety which could be applied to a clinical setting to improve mental health of the population respectively (Hertel & Mathews, 2011; MacLeod & Mathews, 2012; Smith, 2013).

Negative mood states are frequently related to negative cognitive biases of attention and interpretation (Rose & Parfitt, 2007). Furthermore, individuals who suffer with clinical disorders such as anxiety and depression, frequently exhibit a preferential response towards negative relative to positive, or benign/neutral information. They also tend to interpret ambiguous situations and environments negatively rather than positively. Thus, there is vast evidence to suggest that cognitive biases are rooted in functions of those who experience anxiety and stress-related symptoms and these could be considerably reduced in vulnerable populations (Brosan, Hoppitt, Selfer, et al., 2011; Mackintosh et al., 2006)

The implications of research within the CBM paradigm is that it holds promise for an innovative addition to treatment for anxiety, depression and stress disorders (MacLeod & Mathews, 2012). Furthermore, research into aerobic exercise and its immediate effect of mood enhancement proposes a promising accompaniment to treatment of anxiety and depression (Daley, 2018).

This second experimental chapter aims to investigate the interaction of physical exercise and cognitive bias modification training together in improving mood state using both studies three and four. The third study implores a single session positive CBM-I condition, a rest control condition, a physical exercise condition and a combined positive CBM-I and physical exercise condition.

Study three predicts that participants in the CBM-I & Exercise condition will have a greater decrease in measures of STAI-State, STAI-Trait, BDI-II, PSS, and SST from baseline than the exercise condition, and CBM-I condition, minimal reduction in questionnaire measures for control (resting) condition.

Study four investigates a three sessions positive CBM-I and exercise as both separate conditions and an accumulative condition. Study four also introduces a more robust control condition; a neutrally valenced CBM-I training condition. Study four follows on to implore a new research design, in which both the ameliorating effects of moderate exercise and CBM-I being observed on cognitively loaded, and non-loaded SST, depressive and anxiety symptoms, and perceived psychological stress. Study four predicts that the combined condition of positive CBM-I and exercise will be the most effective at reducing negative interpretation bias, measures of STAI, BDI-II, PSS than the other conditions.

3.3 Study Three

3.3.1 Methodology

Participants

Eighty participants were recruited from an Undergraduate student population from the University of Essex. Participants were recruited using an online participation and accreditation system 'SONA". Participants age, gender and aerobic fitness is detailed in Table 3.1 by condition.

Table 3.1 Participant Demographic Information By Condition, Study 3.

Condition	N	Age	Gender Ratio M: F	Resting HR	Aerobic HR Reserve
CBM Positive	20	Mean:18.98 Range:18-22 SD: 0.97	5:15	Mean:73.95 Range:60-94 SD: 10.57	Average 165-175 Range 155-180
Physical Exercise	19	Mean:18.57 Range:18-22 SD: 1.97	7:12	Mean:79.21 Range:66-108 SD:11.08	Average 163-175 Range 140-181
CBM + Exercise	21	Mean:18.56 Range:18-21 SD: 2.86	5:16	Mean:78.90 Range:64-94 SD:8.53	Average 165-177 Range 160-180
Control Condition	20	Mean:18.76 Range: 18-21 SD: 2.22	8:12	Mean:75.2 Range:65-89 SD:7.73	Average 165-175 Range 159-178

Ethics

Participants were recruited though the 'SONA' system, where they voluntarily attended a study appointment which was convenient to their schedule. The Participants were informed of their role in the study before they consented. They were told they would be required to complete a series of four questionnaires twice, and they may or may not be required to undertake a moderate intensity exercise protocol and a computer task. They were also informed of their right to withdraw from the study at any time. Ethical considerations of the health and safety of the participant and researcher in respect of using exercise equipment were considered and minimized by using a static bicycle for the exercise protocol. Ethical approval was granted from the Psychology Ethics Committee, under the terms of University of Essex's Policy and code of practice for the conduct of research with Human participants.

Materials

Participants were required to attend one session. Participants completed the State-Trait Anxiety Inventory (STAI; Spielberger, 1983) revised Beck Depression Inventory, BDI-II; (Beck et al., 1996), and the Perceived Stress Scale PSS; (Cohen et al., 1983) before and after the CBM-I positive/Physical exercise/CBM-I & Exercise /Rest Control programme before the intervention at baseline and after post condition. Four Scrambled Sentences Test, two before and two after were administered. The STAI was the same as used for study one (please see chapter two, section 2.3.1). The scrambled sentences test (SST; Rude et al., 2002) (please see chapter two, section 2.3.1) was the same as used for study one and two and the equation used to calculate the score was also the same (please see Figure 2.1). The BDI-II was the same as used in study two (please see chapter two, section 2.4.2). The PSS was the same as used in study two (please see chapter two, section 2.4.2).

Participants were assigned to either to CBM-I condition, physical exercise condition, CBM-I & exercise condition, or to the control condition in which the participants had forty minutes to relax until the second part of the experiment.

Cognitive Bias Modification Interpretation Training Condition

The program was developed from a previous CBM-I training program (Mathews & Mackintosh, 2000). On the basis of Mathews and Mackintosh (2000), each scenario had the final word missing and was emotionally ambiguous up to this point (e.g., "As you are walking down a crowded street in Cambridge/Essex, you see your new flatmate on the other side. You call out but your flatmate does not answer. You think that this was because they were—"). The final word always resolved the ambiguity in a benign way and was presented in an incomplete form on the screen after the participant had read the preceding scenario (e.g., pr—c-upi-d— "preoccupied"). Participants were asked to imagine themselves in the situation and to use their image to identify what the incomplete word was (pressing the down-arrow key as soon as they new). They were then prompted to type in the first missing letter of this word before the correct complete word (e.g., "preoccupied") was presented, and a comprehension question asked them to confirm the interpretation of the scenario (e.g., "Did your flatmate deliberately ignore your call to her in the street?"). Participants used the arrow keys to answer yes or no to this question, and they were given feedback (a "Correct" or an "Incorrect" message) that reinforced a positive interpretation. The next scenario then followed.

Five sets of ten ambiguous scenarios (fifty total), which are trained to be interpreted positively for the session. The training program gives immediate feedback to participants to ensure the ambiguous scenarios are interpreted positively. In each set of ten; six focused on exercise anxiety, two on social anxiety and two on physical anxiety.

Physical Exercise Protocol

The exercise protocol was compliant to current health and safety regulations as set out by the approved ethics. The duration and intensity used was similar to previous research in order to assume that the predicted effects will occur from the moderate amount of exercise (Brosan, Hoppitt, Shelfer, Sillence, & Mackintosh, 2011; Hansen et al., 2001), whilst still aiming to minimize the amount of inconvenience or fatigue to the participants as much as possible. According to previous research that (Barnes et al., 2010) advocates that 85% of the cardiovascular aerobic heart rate reserve of each individual should be maintained for 20 to 30 minutes to achieve the desired benefits of aerobic activity, which was relevant for the aims of this research. This research used a static cycle machine in the sports labs; (Monark Ergonomic Testing Bicycle 874E) as this reduces impact on joints and is safest for participants as they remain seated. The static-cycle machine was also used to measure heart rate so that the desired aerobic heart rate that is necessary for the experiment can be monitored and adhered to respectively. The exercise protocol consisted of a light warm up of low-intensity; which is 20% of heart rate reserve for 5 minutes, and then increased to 80% heart rate reserve for 30 minutes, then concluded with a 'cool down' which was low-intensity pedaling for 5 minutes using 20% heart rate reserve. Aerobic heart rate reserve was calculated using the formula in Figure 2.2 (Uth, Sorensen, Overgaard, & Pedersen, 2004). Heart rate monitors are suggested to be a reliable and valid measure of measuring exercise intensity (American College of Sports and Medicine, 2006).

Participant's in the Exercise and CBM-I & Exercise condition underwent the physical exercise protocol and CBM-I training program previously detailed in this methodology section.

Design

Independent measures design, The Independent Variable is experimental condition; CBM-I, Exercise, CBM-I & Exercise or Control condition. The Dependent variables are baseline and post condition for STAI-State, STAI-Trait, BDI-II PSS, SST cognitively Loaded, and SST Non-Loaded.

Procedure

Participants were greeted by the researcher and escorted to labs in the University of Essex Psychology Department. The experiment was conducted in groups of four participants per session. Participants were sat in a single computer booth each and did not communicate with each other throughout. The study was explained to them, and their role clearly defined to them by the researcher. Participants were then given an information sheet to read and a consent form to sign.

The experiment was split into session one and session two, all on the same day, which one of the four conditions each participant was indicated their activity between session one and session two. The order in which the SST were administered were counterbalanced to minimize any effects of the differences between the four versions of the tests may have on the dependent variables, which would not otherwise be accounted for.

Session one- Participants completed the first STAI, BDI-II, and PSS. They then had four minutes to complete each SST. The first two SST's, which were either first SST loaded, second SST not loaded, or the participant first SST not loaded, second SST loaded, this was randomly assigned and counterbalanced.

To investigate the effects of loading a participant's memory with a six-digit number, on whether their performance in the SST. Although participants were for the majority randomly assigned to conditions, a running tally was kept of gender and the state and trait anxiety scores (STAI) from session one, to allow for a homogenized sample in both the experimental and control condition, so more reliable inferences could be made from any effects found from the experimental condition and a more accurate representative sample of the wider population.

Post intervention participants were invited back into the private consultation room to complete the third and fourth SST, in the same sequence as before (loaded then not loaded, or not loaded then loaded). The participant then was asked to complete the second STAI, BDI-II and PSS. Once completed the participant was thanked for their participation in the study and the nature and aims of the study were then explained. Participants were then given a debrief form which outlined the questionnaires they had completed and the researchers contact details, in case they had any further questions or would like to withdraw. Therefore, the process of informed consent was adhered to and the participant was given the right to withdraw, fulfilling the requirements of informed consent.

Data analytic approach

A 4x2 ANOVA was used to analyse the questionnaires, CBM-I/Exercise/CBM-I & Exercise/Control, by Session one/Session two. A 4x2x2 mixed factorial ANOVA was also used for the SST. The within-subjects variable is the load/no load, and baseline/post intervention, whilst the between-subjects factor is the CBM-I/Exercise/CBM-I & Exercise/Control. Post-Hoc analyses in the form of paired samples T-tests were performed on significant effects. Observed power was calculated for significant Post-Hoc analyses in the form of Apriori power analyses using ‘G*Power’ Software.

3.3.2 Results

Preliminary analysis

Before analysis was conducted, preliminary analysis of the data was conducted to investigate whether assumption of parametric tests had been violated. Assumptions were not violated; therefore, parametric analysis was conducted. A One-Way ANOVA was conducted to investigate whether participant's resting heart rate, age, baseline STAI, PSS, BDI-II scores were significantly different between conditions. A Chi-Square test was also conducted to investigate whether gender was significantly different between groups. These analyses showed there was a significant difference between the conditions for baseline PSS scores F (3,76)=4.20, p<.01 and baseline BDI scores F (3,76)=2.81, p<.05. There were no significant differences between conditions for STAI, SST, gender, age or HR Rest, therefore one can assume homogeneity between the conditions with exception to PSS and BDI measures please see Table 3.1 for participant demographic information detailed by condition.

Main Effects

This study predicted participants in the CBM-I & Exercise condition will have a greater decrease in STAI-State, STAI-Trait, BDI-II, & PSS from baseline to post intervention than the exercise condition or CBM-I condition alone. Furthermore, the three experimental conditions STAI, BDI-II & PSS will decrease from baseline to post intervention, whilst the control condition scores will remain stable from baseline to post intervention. There was a reduction in state anxiety from baseline to post intervention (please see Table 3.2), which was statistically significant $F(1,73)=7.28$, $p<.05$, $\mu^2=.09$. However the effect of condition effect was not significant, $F(3,73)$, $p=1.75$. There was no statistically significant reduction in trait anxiety measures from baseline to post intervention (please see Table 3.2) $F(1,73)$, $p=.61$, nor was there an effect of condition $F(3,73)$, $p=.20$.

Table 3.2 Mean & Standard Deviation For STAI, BDI-II, PSS & SST Measures By Condition, Study 3.

	Baseline; Post condition;	N	CBM-I	Exercise	CBM-I & Exercise	Control
STAI- S	Session 1	77	**40.60** (10.59)	**43.9** (16.59)	**49.88** (15.33)	**40.57** (9.31)
	Session 2		**35.6** (9.33)	**37.3** (8.31)	**40.88** (10.87)	**42.42** (9.61)
STAI- T	Session 1	77	**46.3** (10.62)	**45.6** (6.33)	**45.83** (11.99)	**48.73** (11.17)
	Session 2		**44.75** (11.3)	**45.1** (7.18)	**43.55** (11.05)	**49.10** (13.0)
PSS	Session 1	77	**11.2** (2.85)	**8.4** (1.63)	**9.5** (3.03)	**10.21** (2.57)
	Session 2		**10.95** (2.89)	**8.75** (2.44)	**7.88** (3.08)	**9.73** (2.64)
BDI-II	Session 1	77	**16.65** (9.01)	**13.85** (5.28)	**22.66** (10.32)	**19.68** (13.44)
	Session 2		**14.55** (7.47)	**11.8** (5.33)	**16.5** (11.49)	**19.26** (10.25)
SST Cognitively Loaded	Session 1	76	**30.87** (19.90)	**34.42** (26.43)	**39.44** (24.32)	**38.15** (23.72)
	Session 2		**27.99** (19.72)	**30.36** (19.53)	**38.13** (20.70)	**37.90** (22.81)
SST Cognitively Non- Loaded	Session 1	76	**29.47** (20.81)	**33.17** (21.76)	**39.90** (23.48)	**41.13** (31.89)
	Session 2		**29.04** (22.73)	**33.32** (20.50)	**28.29** (19.91)	**37.22** (26.13)

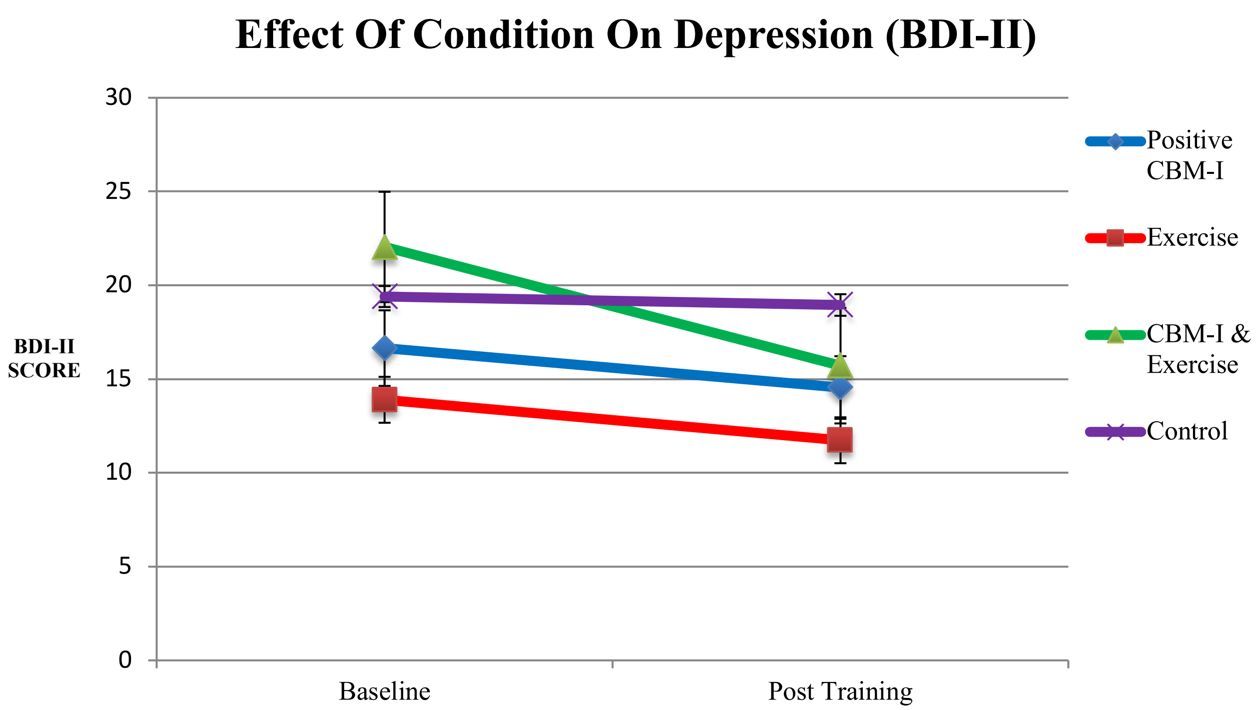


Figure 3.1 Effect Of Condition On Depression (BDI-II), Study 3.

There was a decrease in depression measures (BDI-II), this was a significant interaction between time x condition (please see Table 3.2, Figure 3.1) F (3,73)=6.27, p<.001, μ^2=.20. Post-Hoc analyses in forms of paired samples T-Tests suggest a significant decrease in BDI-II measures in the physical exercise condition t (19) =3.93, p<.001, r =.66, which suggest a significantly large effect size, observed power was calculated to investigate this effect size and found 1-ß =.77. There was a significant decrease in the CBM-I and exercise combined condition t (17) =4.11, p<.001, r =.70, suggesting a large significant effect, observed power was calculated to investigate this effect size and found 1-ß =77.

There was a decrease in self-report stress (PSS) and this was a significant interaction effect of time x condition (please see Table 3.2, Figure 3.2), F(3,73)=3.95, p<.05, μ^2=.12. Paired samples T-Test suggest a significant reduction in PSS measures in the CBM-I & Exercise condition t(17) =3.10, p<.005, r =.60, observed power was calculated to investigate this effect size and found 1-ß =.64. There was also a significant effect on the control condition t(18) =2.45, p<.05, r =.50, suggesting a significant moderate effect.

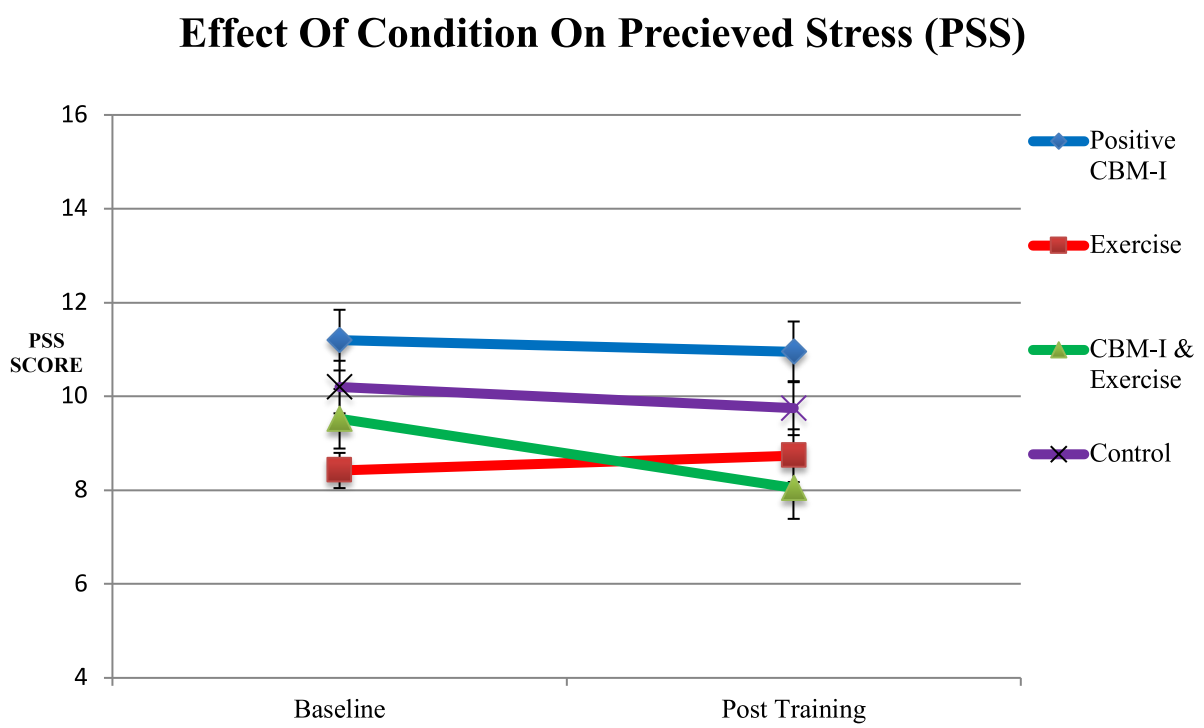


Figure 3.2 Effect Of Condition On Perceived Stress (PSS), Study 3.

It was hypothesised that participants in the CBM-I and the CBM-I & Exercise conditions will have a greater decrease in SST cognitively loaded scores, than non-loaded scores from session one to session two, than participants in the Exercise condition or Control condition.

There was no significant interaction effect between time x condition x cognitive loading, $F(3,72)=1.31$, $p=.27$ (please see Table 3.2). There was also no significant effect of time $F(1,72)=1.90$, $p=.17$, condition $F(3,72)=1.67$, $p=.18$, or cognitive loading $F(1,72)=.69$, $p=.40$.

3.3.3 Discussion

The results suggest there was no reduction in state or trait anxiety measures (STAI) relative to condition as was predicted, there was a significant state effect reducing anxiety overall. There was significant reduction in self-report depression (BDI-II) relative to condition, and this effect is driven by the combined CBM-I & Exercise condition and the Exercise condition. This combination of physical exercise training and positively valenced CBM-I training suggests a significant reduction in individuals' depressive symptoms after just one session. Similarly, there is a significant reduction in self-report psychological stress (PSS), this effect is also driven by the combined positive CBM-I training and physical exercise condition. This suggest that depressive self-report measures can be significantly reduced in a general population sample after just two sessions of positive CBM-I and physical exercise training. Furthermore, there was no significant reduction in individuals negative bias when they completed a cognitively loaded or non-loaded SST relative to condition.

3.4 Study Four

3.4.1 Introduction

Study three investigates cognitive interpretation bias and exercise as both separate conditions and an accumulative condition, as well as a rest control condition. The cognitive bias modification programme was developed in study three and developed to be exercise orientated CBM-I (as opposed to social and physical anxiety). The cognitive interpretation bias modification training programme (CBM-I) aims to adapt an individual's interpretation biases, so that ambiguous scenarios are interpreted positively rather than negatively.

Whilst study three investigated the effect of one session of positive cognitive bias modification training, physical exercise training, positive training and exercise combined, or a rest control condition, on negative bias, self-reported anxiety, depression and stress measures. Study four will investigate a similar research paradigm, however it implores three sessions of positive cognitive bias modification training, physical exercise, positive CBM-I training and exercise combined, or a neutral valanced CBM-I training as a more appropriate control condition.

The hypothesis of the fourth study predicts that participants in the positive CBM-I and the CBM-I & exercise condition will have a greater decrease in SST cognitively loaded scores, than non-loaded scores from session one to session three, than participants in the exercise condition or neutral CBM-I condition. Furthermore, individuals undertaking the positive training and exercise will have a greater decrease in self report anxiety, stress and depression measures over the three independent sessions.

3.4.2 Methodology

Participants

Eighty participants were recruited from an Undergraduate student population from the University of Essex. Participants were recruited using an online participation and accreditation system 'SONA". Participants age, gender and aerobic fitness is detailed in Table 3.3 by condition. Participants were deemed eligible for the study if they scored six or over on the GAD-7 scale, suggesting they had a moderate anxiety, as ascertained by self-report.

Table 3.3 Participant Demographic Information By Condition, Study 4.

Condition	N	Age	Gender Ratio M:F	Resting HR	Aerobic HR Reserve
CBM-I Positive	20	Mean:19.3 Range:18-26 SD: 2.10	10:10	Mean: 76.05 Range: 61-96 SD: 11.50	Average 162-175 Range 150-179
Physical Exercise	20	Mean: 19.85 Range:18-27 SD:2.66	9:11	Mean: 77.65 Range:60-108 SD: 11.90	Average 163-175 Range 140-181
CBM-I & Exercise	20	Mean:19.6 Range:18-26 SD: 2.37	12:8	Mean:79.75 Range: 69-98 SD: 8.47	Average 165-175 Range 155-180
CBM-I Neutral	20	Mean:20.30 Range: 18-27 SD: 2.20	9:11	Mean: 79.25 Range:6 4-94 SD: 8.60	Average 161-174 Range 155-180

Ethics

Participants were recruited thought the 'SONA' system, where they voluntarily signed up to a timeslot, which was convenient to their schedule. The Participants were informed of their role in the study before they consented. They were told they would be required to complete a series of four questionnaires twice, and they may or may not be required to undertake a moderate intensity exercise protocol. They were also informed of their right to withdraw from the study at any time. Ethical considerations of the health and safety of the participant and researcher in respect of using exercise equipment were considered and minimized by using a static bicycle for the exercise protocol. Ethical approval was granted from the Psychology Ethics Committee (CODE), under the terms of University of Essex's Policy and code of practice for the conduct of research with Human participants.

Materials

Participants were required to attend three sessions. Participants completed the State-Trait Anxiety Inventory (STAI; Spielberger, 1983) revised Beck Depression Inventory (BDI-II; Beck et al., 1996), and the Perceived Stress Scale (PSS; Cohen et al., 1983) at session one, before the intervention. They then completed the measures again after session one post condition, after session two post condition and session three post condition. Cognitive interpretation bias (SST) was measured at baseline previous to condition, and at session three post condition. Participants were required to complete the Generalised Anxiety Disorder Questionnaire (GAD-7; Spitzer, Koroenke, Williams, & Lowe, 2006) to initially screen anxiety level of participants, which was an eligibility criteria (please see appendix E).

Please see chapter one, sections 2.3.1 and 2.4.2 for extensive description of STAI, BDI-II, PSS and SST measurements.

CBM- I Positive Interpretation Training

The program was developed and extended from study three to consist of three exercise orientated CBM-I scenarios (sixty total per session), which are trained to be interpreted positively for each session. The training program gives immediate feedback to participants to encourage the ambiguous scenarios are interpreted positively. In each set of ten; six focused on exercise anxiety, two on social anxiety and two on physical anxiety (sixty total per session). Three individual CBM-I training programs were developed for use in this research; one for each training session.

CBM-I Neutral Training

The CBM-I Neutral training program was developed for the purposes of the study and is also used in the next chapter. Similarly, to the positive training, each session consists of six sets of ten ambiguous yet neutral scenarios (Sixty total per session), which the participants are trained to interpret, but are not given any feedback to reinforce a positive or negative interpretation. In each set of ten; six focused on exercise anxiety, two on social anxiety and two on physical anxiety. Three neutrally valenced CBM programs were developed for use in this research; one for each of the three training sessions. Similarly, to the positive CBM-I positive training, the neutral training sessions were each unique to ensure participants couldn’t remember scenarios from the previous neutral pseudo training session.

Physical Exercise Protocol

Moderate exercise protocol was that of the same used in study three (please see study three, section 3.3.1).

Participant's in the physical exercise and exercise and positive CBM-I training condition used the static bicycles in the sports labs; (Monark Ergonomic Testing Bicycle 874E). This provided participants with continuous feedback of their heart rate reserve and when to increase/decrease their aerobic intensity. Heart rate monitors are suggested to be a reliable and valid measure of measuring exercise intensity (Janz, 2002). Aerobic heart rate reserve was calculated using the formula in Figure 2.2 (Uth et al., 2004).

Design

Independent measures design, The Independent Variable is experimental condition; Positive CBM-I, Exercise, Positive CBM-I & Exercise, Neutral CBM-I condition. The Dependent variables are self-report measures conducted at session one (baseline), session two and session three for STAI-State, STAI-Trait, BDI-II & PSS. Interpretation bias was measured at session one (baseline) and session three using SST cognitively Loaded, and SST Non-Loaded.

Procedure

Participants were asked to complete the GAD-7 Questionnaire via email, to measure if they were eligible for the study. Participants were greeted by the researcher and escorted to labs in the University of Essex Psychology Department. The experiment was conducted in groups of two participants per session. Participants were sat in a single computer booth each and did not communicate with each other throughout. The study was explained to them, and their role clearly defined to them by the researcher. Participants were then given an information sheet to read and a consent form to sign.

The experiment was split into session one, session two and session three, there was a week break between each session. The order in which the SST were administered were counterbalanced to minimize any effects of the differences between the four versions of the tests may have on the dependent variables, which would not otherwise be accounted for.

Session one- Participants completed the first STAI, PSS, and BDI-II. They then had four minutes to complete each SST. The first two SST's, which were either first SST loaded, second SST not loaded, or the participant first SST not loaded, second SST loaded.

As before, the memory effect was monitored by a digit number, before and afterward, in the loaded condition. Although participants were for the majority randomly assigned to conditions, a running tally was kept of gender and the state and trait anxiety scores (STAI) from session one, to allow for a homogenized sample in both the experimental and control condition, so more reliable inferences could be made from any effects found from the experimental condition and a more accurate representative sample of the wider population.

Post intervention participants were invited back into the private consultation room to complete the third and fourth SST, in the sequence of loaded then not loaded, or not loaded then loaded depending on which they were assigned. The participant then was asked to complete the second STAI, PSS and BDI-II. Once completed the participant was thanked for their participation in the study and the nature and aims of the study were then explained. Participants were then given a debrief form which outlined the questionnaires they had completed and the researchers contact details, in case they had any further questions or would like to withdraw.

Data analytic approach

A 4x3 ANOVA was used to analyse Positive CBM-I/Exercise/CBM-I & Exercise/Neutral CBM-I, by Session one/Session two/Session three measures of STAI, PSS, BDI-II. A 4x2x2 mixed factorial ANOVA was also used. The within-subjects variable is the SST load/non-load, and session one/session three, whilst the between-subjects factor is the Positive CBM-I/Exercise/CBM-I & Exercise/Neutral CBM-I. Post-Hoc analyses in the form of Sidaks' adjustment for pairwise comparisons and paired samples T-Tests were performed on significant effects and the effect size *r* calculated (Rosnow & Rosenthal, 2009). Observed power was calculated for significant Post-Hoc analyses in the form of Apriori power analyses using 'G*Power' Software.

3.4.3 Results

Preliminary analysis

Before analysis was conducted, preliminary analysis of the data was conducted to investigate whether assumption of parametric tests had been violated. Assumptions were not violated; therefore, parametric analysis was conducted. A One-Way ANOVA was conducted to investigate whether participants resting heart rate, gender, age, baseline STAI, BDI-II, PSS scores were significantly different between conditions. These analyses showed no significant differences therefore one can assume homogeneity between the conditions, and therefore any difference observed are unlikely due to individual differences between conditions at the start of the experiment. Post-Hoc analyses in the form of Sidaks' adjustment for pairwise comparisons and paired samples T-Tests were performed on significant effects and the effect size *r* calculated (Rosnow & Rosenthal, 2009).

Main Effects

Individuals in the positive CBM-I and physical exercise condition decreased the most in state anxiety over the three training sessions (please see Table 3.4), however this interaction of time x condition was not statistically significant $F(9,77)=1.81$, $p=0.67$. However there, was a significant reduction of state anxiety over time $F(3,77)=22.79$, $p<.005$, $\mu^2=.23$.

Similarly participants who underwent the positive CBM-I training and physical exercise intervention decreased in trait anxiety measures over the three sessions the most and this effect was a statistically significant interaction of time x condition, $F(9,77)=3.50$, $p<.005$, $\mu^2=.12$ (please see Table 3.5,

Figure **3.3**). Post-Hoc tests were performed in the form of Sidak's adjustment for multiple comparisons, which revealed there was a significantly greater reduction in trait anxiety in the CBM-I & exercise condition in comparison to the neutral CBM-I condition, (Mean Difference=5.27, SE=1.92) $p<.05$. There was also significantly greater reduction in trait anxiety in the CBM-I & exercise condition in comparison to the exercise condition (Mean Difference=5.51, SE=1.90) $p<.05$. The findings suggest that there was no effect on state anxiety measures, however there was a decrease in trait anxiety measures over the three training sessions relevant to experimental condition. Specifically driven by a substantial decrease in trait anxiety reported by individuals in the combined CBM-I and exercise condition.

Table 3.4 Mean & Standard Deviation For STAI-State By Condition, Study 4.

Condition	N	Baseline Pre-Training	Post-Training Session one	Post-Training Session two	Post-Training Session three
Positive CBM-I	20	**38.45** (7.39)	**31.15** (6.08)	**29.30** (6.17)	**29.95** (11.99)
Exercise	20	**38.1** (10.78)	**34.90** (9.59)	**32.1** (6.90)	**31.65** (6.57)
CBM-I & Exercise	20	**40.45** (7.97)	**34.15** (7.81)	**33.42** (4.92)	**25.66** (4.27)
Neutral CBM-I	20	**38.80** (8.16)	**36.95** (7.15)	**35.75** (6.61)	**34.15** (7.91)

Table 3.5 Mean & Standard Deviation For STAI-Trait By Condition, Study 4.

Condition	N	Baseline Pre-Training	Post-Training Session one	Post-Training Session two	Post-Training Session three
Positive CBM-I	20	**45.20** (8.31)	**36.1** (8.13)	**37.10** (9.07)	**36.05** (10.76)
Exercise	20	**45.40** (8.36)	**44.15** (7.79)	**41.45** (6.65)	**36.45** (8.63)
CBM-I & Exercise	20	**46.55** (4.34)	**37.40** (8.21)	**34.36** (7.12)	**28.5** (6.14)
Neutral CBM-I	20	**45.1** (8.92)	**41.7** (6.25)	**40.75** (6.15)	**38.36** (7.27)

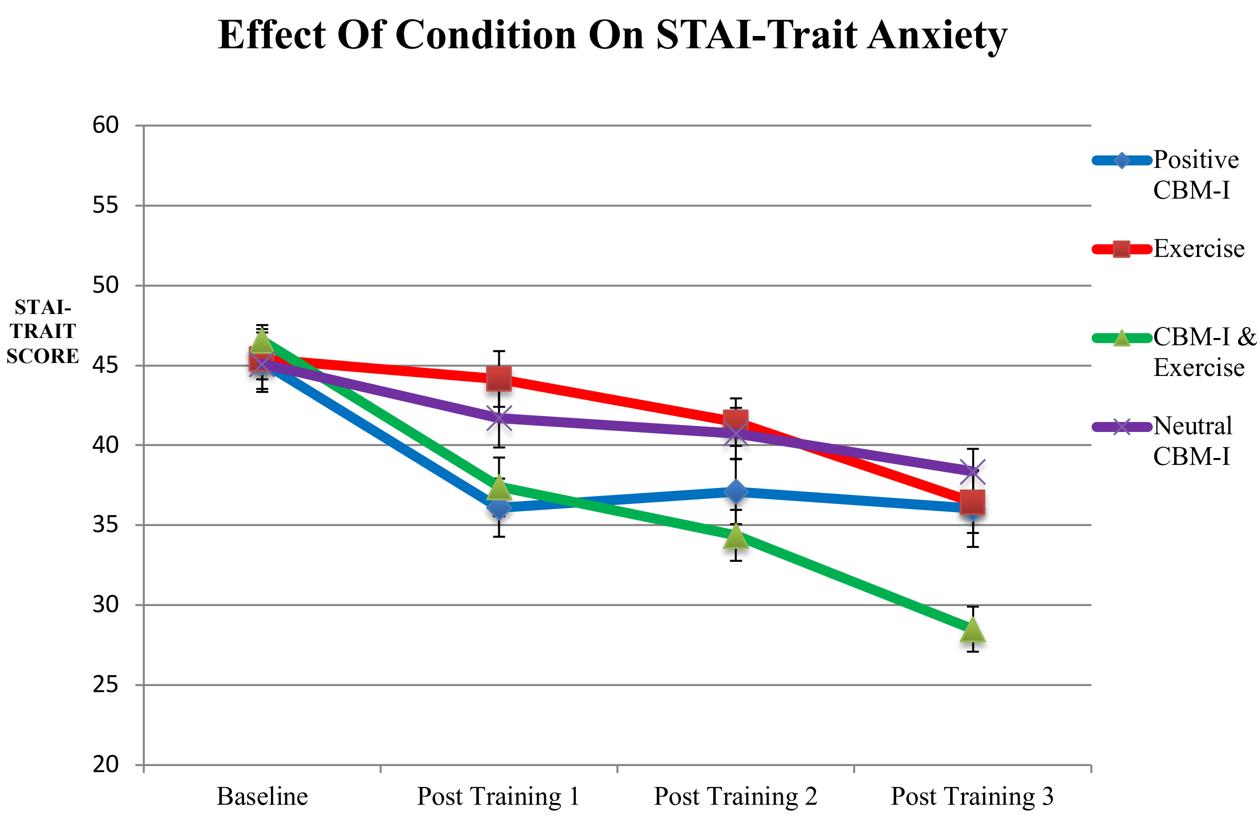


Figure 3.3 Effect Of Condition On Trait Anxiety (STAI), Study 4.

There was a significant decrease in self-reported depression (BDI-II) over the three sessions $F(3,77)=9.04$, $p<.005$, $\mu^2=.10$, however this was not a significant time x condition interaction $F(3,77)=.40$, $p=.93$ (please see Table 3.6). Similarly, there was a significant decrease in self-report stress (PSS) over the three sessions, this was a significant effect of time $F(3,77)=16.33$, $p<.005$, $\mu^2=.18$, however there was no significant effect of condition $F(3,77)=1.29$, $p=.24$ and no significant interaction effect of time x condition $F(9,77)=1.20$, $p=.24$ (please see Table 3.7).

Therefore, all participants decreased in self-report stress and depression measures, and this was a significant effect of time, however there was no significant effect of condition on these measures.

Table 3.6 Mean & Standard Deviation For BDI-II By Condition, Study 4.

condition	N	Baseline Pre-Training	Post-Training Session one	Post-Training Session two	Post-Training Session three
Positive CBM-I	20	**12.8** (8.21)	**11.25** (8.94)	**8.65** (6.49)	**9.4** (9.48)
Exercise	20	**12.95** (6.41)	**13.2** (6.27)	**9.55** (9.07)	**9.25** (8.91)
CBM-I & Exercise	20	**9.25** (5.07)	**8.2** (6.78)	**6.1** (3.75)	**4.85** (3.88)
Neutral CBM-I	20	**11.2** (5.27)	**8.85** (4.58)	**8.85** (4.58)	**8.25** (5.79)

Table 3.7 Mean & Standard Deviation For PSS By Condition, Study 4.

Condition	N	Baseline Pre-Training	Post-Training Session one	Post-Training Session two	Post-Training Session three
Positive CBM-I	20	**9.85** (2.10)	**8.7** (3.07)	**8.80** (2.82)	**7.65** (4.45)
Exercise	20	**10.65** (1.66)	**8.85** (3.40)	**8.45** (1.84)	**7.7** (3.06)
CBM-I & Exercise	20	**10.35** (1.46)	**8.4** (1.56)	**8.26** (1.59)	**6.88** (2.34)
Neutral CBM-I	20	**9.25** (1.99)	**9.05** (3.79)	**9.55** (3.21)	**8.15** (2.24)

There was no significant interaction effect of time x condition x cognitive load, on individuals interpretation bias (SST) scores, $F(1,76)=1.31$, $p=.27$, nor time $F(1,76)=.24$, $p=.62$, condition $F(3,76)=1.31$, $p=.27$ or load $F(3,76)=1.66$, $p=.18$ (please see Table 3.8). The data analysis suggests there was no effect of positive CBM-I, exercise, CBM-I & exercise, or Neutral CBM-I on interpretation bias measures.

Table 3.8 Mean & Standard Deviation For SST Cognitively Loaded And Non-Loaded By Condition, Study 4.

Condition	N	SST Loaded Baseline	SST Loaded Post-Training	SST Non-Loaded Baseline	SST Non-Loaded Post-Training
Positive CBM-I	20	**32.24** (26.27)	**27.90** (21.44)	**33.85** (18.88)	**33.47** (30.52)
Exercise	20	**19.53** (23.64)	**23.61** (21.67)	**20.58** (19.78)	**21.36** (22.36)
CBM-I & Exercise	20	**35.67** (25.78)	**33.34** (24.15)	**31.77** (25.86)	**40.97** (29.72)
Neutral CBM-I	20	**38.8** (27.5)	**29.38** (25.61)	**37.09** (30.33)	**31.7** (31.58)

3.4.4 Discussion

The results from study four suggest neither exercise nor positive interpretation bias training separately or accumulatively effect an individual's interpretation biases, which contradicts that of study three. However, what one can suggest from these results is that there is a significant interaction effect of time and experimental condition on self-report trait anxiety measures, driven by the combined CBM-I & exercise training condition.

3.5 General Discussion

Cognitive interpretation biases are a useful element to investigate as by understanding their functions we can theoretically, train and modify them to decrease symptoms of disorders such as depression, anxiety and stress related disorders (Hertel & Mathews, 2011). The efficacy of CBM-I is supported by the characteristics of depression; such as the inability to generate positive cognitive processes about the future (Holmes, Lang, & Shah, 2009; Holmes, Mathews, Dalgleish, & Mackintosh, 2006; Holmes et al., 2008; Morina, Deeprose, Pusowski, Schmid, & Holmes, 2011). CBM theoretically overcomes this gap by imagining a scenario visually is a powerful method in which to resolve ambiguous scenarios which would usually be evaluated with a negative outcome, allowing them to visualise it with a positive outcome (Holmes et al., 2009). Depression in particular is characterised by a sense of hopelessness and an inability to generate positive images, whilst CBM-I forces a positive visualisation, which aids the individual into interpreting ambiguous scenarios in a positive manner (Beck, 2008). There is growing support for the effectiveness of CBM-I; but are adamant that visualisation of positive imagery is important for its effectiveness in adapting individuals cognitive interpretation biases (Holmes et al., 2009; Holmes et al., 2006; Holmes et al., 2008; Lang, Blackwell, Harmer, Davison, & Holmes, 2012).

It is well established in the literature that anxiety and depression are highly comorbid (Brown et al., 2001) therefore, it is unlikely that depression and negative bias are not significantly related and one can speculate that this was due to an unrepresentative sample and possible flaws in the current study's methodology. These two studies lend little support to the concept of physical exercise having a positive affect for cognitive interpretation bias and mental wellbeing however there is an abundance of literature advocating exercise as a treatment of maladaptive mood or emotional problems (Barbour & Blumenthal, 2005; Blumenthal et al., 2007; Otto et al., 2007; Paluska & Schwenk, 2000; Penedo & Dahn, 2005). Previous research by Hansen, Stevens, and Coast, (2001) and Salmon (2001) suggest that physical activity is emotion enhancing when it is performed at a 'manageable level' for the individual that is engaged in the activity. These ameliorating effects of exercise on mood and consequently stress, depression and anxiety have many different proposed explanations (Hansen et al., 2001; Salmon, 2001)

Chapter 4 Two-Session Cognitive Bias Modification Training; Exercise Valenced Interpretation Bias

4.1 Overview

In recent years there has been exponential growth in developing and employing Computerised Cognitive Bias Modification (CBM) procedures in the field of experimental psychopathology. Cognitive theories suggest that negative cognitive biases of interpretation are key to the onset and maintenance of psychological disorders; such as anxiety and depression. Therefore, these training programs are rapidly evolving in the field of experimental treatments to attempt to modify these maladaptive biases in interpretation. A cognitive interpretation bias training program was developed which was exercise orientated, and either positively or neutrally valenced dependent on experimental condition. Cognitive Bias Modification Interpretation (CBM-I) training was used to see whether it had the impetus to reduce negative interpretation biases and decrease symptoms of anxiety in two sessions over the course of one week. Whilst previous studies have been used in conjunction with other pharmaceutical treatments, exercise and Cognitive Behavioral Therapy (CBT).

Forty-eight participants recruited from a general population sample, that underwent the CBM-I Positive Training or CBM-I Neutral Training (control condition). Self-reported measures of state and trait anxiety and interpretation bias was gathered before and after the intervention. Both conditions presented a steady decrease in self-reported trait anxiety over the two training sessions, whilst the positive CBM-I condition showed a greater decline in trait anxiety than the neutral training condition. Both positive and neutral CBM-I training had an effect on measures of state anxiety, with a significant decrease from baseline to post-training but no effect of condition. Participants who underwent the positive training in comparison to neutral training showed a significant decrease in negative cognitive interpretation biases (as measured by the scrambled sentences task; SST).

These results suggest that CBM-I positive training effectively guides individuals to interpret scenarios in a more positive manner and this positively influences mental state; in turn decreasing trait anxiety. Thus, a multiple-session study may alter individuals' cognitive interpretation biases, causing them to interpret and evaluate situations more positively, improving mood state and alleviating symptoms of anxiety. The implications of research within the cognitive bias modification paradigm is that it holds promise for an innovative new treatment for anxiety.

4.2 Study Five

4.3 Introduction

Cognitive theories suggest that negative cognitive biases are key to the onset and maintenance of anxiety and depression (Beck, 2008; Clark, & Beck, 2010; Mathews & MacLeod, 2005; Rapee & Heimberg, 1997). Such theories suggest that these cognitive biases increase the variety, frequency, and intensity of negative thoughts and processes, which in turn negatively impacts emotion and symptoms of anxiety (Clark & Beck, 2010; Everaert, Mogoase, David, & Koster, 2015; Hallion & Ruscio, 2011). Furthermore, individuals with anxiety disorders typically report particularly threatening thoughts, which can begin, sustain and intensify already present symptoms of anxiety. These negative thoughts are argued to originate from negative interpretation and attentional cognitive biases (Ghahramanlou-Holloway, Wenzel, Lou, & Beck, 2007).

Clinical and subclinical levels of anxiety are associated with biases in the early and automatic strategic stages of attention (Bar-Haim, Lamy, Pergamin, Bakermans-Kranenburg, & van IJzendoorn, 2007; Wiers et al., 2007), whilst depression is associated with the cognitive biases in the later stages (Gotlib et al., 2004; Hallion & Ruscio, 2011; Joormann & D'Avanzato, 2010). Anxiety is also characterised by a tendency to interpret events, actions and behavior in a negative way which leads to a negative cognitive interpretation bias (Hallion & Ruscio, 2011; Mathews & MacLeod, 2005).

There is a strong relationship between negative cognitive interpretation biases and an inability to generate positive images. This association between positive imagery and cognitive bias is most commonly seen in depression, whilst evidence for a link between lack of positive imagery and anxiety is mixed (Morina et al., 2011). The effects of biases related to attention include negative self-evaluation, heightened arousal, and increased anxiety symptoms (Rapee & Heimberg, 1997). From this it would seem that negative cognitive interpretation biases can be attributed to the process of onset and maintenance of anxiety (Richards, 2004; Richards & French, 1992).

Cognitive bias modification lends insight into causal relationships between cognition and emotion, which progresses our understanding of how cognition affects mental health. CBM is unique in this context as to conclusively understand which cognition are responsible for particular thought processes and behaviours, CBM manipulates and shapes these cognitions (MacLeod & Mathews, 2012). This is methodologically a powerful way to determine the cause an effect of cognitive biases and which disorders they influence. An important purpose of any research within the field of CBM is the interest to evaluate the potential therapeutic properties of CBM, in the interest to improve and influence the treatment strategies currently used to treat mental health of individuals in the wider population. This is a topic of debate within CBM research, as some research supports CBM treatment for sub-syndromal cases (Almeida et al., 2014), whilst some research boasts its effectiveness for severe cases of anxiety (Salemink, van den Hout, & Kindt, 2009) and depression (Joormann & D'Avanzato, 2010) . Furthermore some research suggests CBM training creates a resistance to threatening situations and stimuli, or an increased resilience (de Voogd et al., 2016), which equates to CBM being a preventative treatment for mental health issues (Hoppitt et al., 2014). It is noteworthy to mention that the ability to modify certain processes comes with it the opportunity to begin to understand the mechanisms which underpin these processes. The development and evaluation of CBM techniques and methodologies has allowed researchers to uncover the fundamental information-processing mechanisms that dictate the patterns of anxiety linked cognitive bias (MacLeod & Mathews, 2012).

Cognitive Bias Modification (CBM-I) is an intervention aimed at reducing an individual's cognitive bias and can be defined as the direct manipulation of a target bias by extensive exposure to task contingencies that encourage predetermined patterns of processing selectivity (Cristea, Kok, & Cuijpers, 2015; MacLeod & Mathews, 2012). Put simply, CBM-I aims to train individuals interpretation from the negative to the positive. Following this there has been an exponential growth of developing and employing CBM-I procedures in the field of experimental psychopathology treatment (MacLeod & Mathews, 2012) with considerable interest in the literature to modify cognitive biases to minimize the symptoms of anxiety and to apply them to a clinical setting to improve mental health of the population (Hertel & Mathews, 2011; MacLeod & Mathews, 2012; Smith, Summers, Dillon, Macatee, & Cougle, 2016).

The literature on CBM-I training to reduce negative interpretations is mainly focused on its effectiveness for populations with high levels of anxiety and depression, whereas research into individuals with subclinical levels of anxiety is lacking. Thus, a study by Khalli-Torghabeh and colleagues found that a highly socially anxious sample who undertook multiple sessions of CBM-I training became less socially anxious and exhibited more positive and therefore less negative interpretation biases relative to a control condition, who were also high in social anxiety (Khalili-Torghabeh, Salehi Fadardi, Mackintosh, Reynolds, & Mobini, 2014). Participants in the study underwent two sessions of CBM-I per week, over a fortnight. The benefit of this investigation was formulating the effectiveness of intensity, duration and frequency of these CBM-I training sessions.

Research conducted by (Lisk, Pile, Haller, Kumari, & Lau, 2018) investigated the effect of multiple sessions of CBM training on self-report anxiety. Participants completed four CBM-I and four CBM-A (attentional bias training) training sessions over a two-week period, participants presented a significant reduction in social anxiety measures in the CBM-I phase. Furthermore, even though the CBM-I training was completed over four sessions in the first week, participants reported the CBM-I training was most beneficial for their mental health than the CBM-A training in the later week. This study holds promise for the paradigm of a multiple session approach for CBM-I training for anxiety reduction.

Research suggests that moderate and intense exercise can improve accuracy and response time to threat and non-threat related cognitive biases (Smith & O'Connor, 2003). These finding indicate that these emotion-processing networks are activated and responsive to external stimuli during high intensity exercise. This contradicts what was previously argued by (Dietrich & Audiffren, 2011) that emotion networks are inhibited during physical exercise. Furthermore, given the reductions in anxiety that occur from modifying threat-related biases through training, it would be of interest to investigate whether exercise is accompanied by more positive biases. Research conducted by Tian and Smith (Tian & Smith, 2011) lends support to the concept that exercise-focused CBM-I can change negative cognitive biases to positive cognitive biases and improve mental state. Tian and Smith suggest that exercise is accompanied by a reduction in negative attentional biases, and therefore a positive mood enhancement. This poses the question of whether interpretation bias is modifiable in this way, and whether exercise focused interpretation bias training is a promising venture (Tian & Smith, 2011). Furthermore, research has shown that the specificity of the training targets affects the outcome in CBM-I training, particularly interpretation bias. This has been demonstrated by Mackintosh and colleagues (Mackintosh et al., 2013) the importance of matching the topic focus of the CBM-I training to the intended target for modification and have implications for transferring CBM-I method from the laboratory setting to clinical settings. Only when the CBM-I training involved both the topic focused content achievement/threat and benign appraisals for failure, was the CBM-I training successful. This supports the notion that CBM-I training should focus on relevant topics that respond to relative biases, an example being social anxiety focused CBM-I training, which successfully reduces measures of social anxiety (Hoppitt et al., 2014; Salemink, Kindt, Rienties, & van den Hout, 2014).

The first hypothesis is that participants in the positive CBM-I training program will show a decrease on anxiety measures after session one of training and then again following the second training. Participants in the neutral CBM-I training will not show a decline, or not show as great a decrease as the positive CBM-I training condition. The second hypothesis is that participants in the positive training will show a decrease in negative cognitive interpretation biases (SST) when cognitively loaded, and not in the non-cognitively loaded task. Participants in the neutral training will show no difference between sessions, or a difference between cognitively non-loaded SST tasks but not the loaded, before and after the training.

4.4 Methodology

Participants

Forty-eight participants were recruited from the general population over a period of four weeks, to participate in a two-part study and randomly allocated to one of two conditions, (random thus balanced for sex and GAD-7 anxiety score) please see Table 4.1 for participant demographics by condition. University of Essex Ethical Approval was granted. Participants were deemed eligible for the study if they scored six or over on the GAD-7 scale, suggesting they had a moderate anxiety, as ascertained by self-report.

Materials

Participants were required to attend two sessions. Participants completed the State-Trait Anxiety Inventory (STAI;Spielberger, 1983) before and after the CBM-I Positive/Neutral programme at the beginning of session one, after training in in session one, before training in session two and then after the training in session two (week gap between session one and two).

Table 4.1 Participant Demographic Information By Condition, Study 5.

Condition	**N**	**Age**	**Gender Ratio M:F**	**Pre-screen GAD-7**
Positive CBM-I	24	Mean: 27.53 Range: 19-68 SD: 10.01	10:14	Mean: 11.81 Range: 6-21 SD: 4.02
Neutral CBM-I	24	Mean: 27.45 Range: 19-62 SD: 9.94	9:15	Mean: 11.73 Range: 6-19 SD: 3.85

The STAI was the same as used for study one (please see chapter two, section 2.3.1). The Generalized Anxiety Disorder Questionnaire (GAD-7; Spitzer et al., 2006) was used to initially screen anxiety level of participants, which was an eligibility criteria (please see appendix E). The scrambled sentences test (SST; Rude et al., 2002) was used to measure negative interpretation bias before training in session one and after training in session two. The SST was the same as used for study one (please see chapter two, section 2.3.1). The equation that was used to calculate an overall negative interpretation score, which is suggested to reflect each individual's cognitive interpretation biases, can be seen in Figure 2.1.

Cognitive Bias Modification - Positive Interpretation Training

The program was developed from a previous CBM-I training program (Mathews & Mackintosh, 2000). Five sets of ten ambiguous scenarios (fifty total) are used and trained to be interpreted positively for each session. The training program gives immediate feedback to participants to ensure the ambiguous scenarios are interpreted positively. In each set of ten, six focused on exercise anxiety, two on social anxiety and two on physical anxiety. Two positive CBM-I training programs were developed for use in this research: one for the first training session and the other for the second training session.

Cognitive Bias Modification - Neutral Interpretation Training

The neutral training program was developed for the purposes of the study. There were five sets of ten ambiguous scenarios (fifty total) per session which were randomised before programmed into each of the sessions. During the CBM-I training participants were trained to interpret each scenario but are not given any feedback to reinforce a positive or negative interpretation. In each set of ten, six focused on exercise anxiety, two on social anxiety and two on physical anxiety. Two neutral training programs were developed for use in this research: one for the first training session, and the other for the second training session, to ensure participants would not be able to remember scenarios from the previous neutral training program used in the previous week.

Procedure

Participants were asked to complete the GAD-7 Questionnaire via email, to measure if they were eligible for the study.

Session one: Participants completed the first of four STAI. Then they had a practice SST, and after that, two SST tasks, counterbalanced for load/no load. They had four minutes to complete each SST

Participants then undertook either the positive training program or neutral training program, which lasted approximately 30-40 minutes. Afterwards participants completed the second STAI.

Session two: Participants completed the third STAI, they then undertook the second positive/neutral CBMI-I training, which lasted approximately 30-40 minutes. Afterwards participants completed the second SST, counterbalanced as before, and then after their fourth STAI. Participants were then thanked for their participation, paid for their time and debriefed.

Design and Data Analytic Approach

Independent measures design; the independent variable was Training condition; CBM-I positive training and CBM-I neutral training (control condition). The Dependent variables for the questionnaires were Time: session 1, (baseline and post-training) and session 2 (pre-and post-training). The Dependent variables for the SST were Time (baseline session 1, and after Positive/Neutral Training session 2) and cognitive load (loaded, and non-loaded).

Pairwise comparisons using Sidak's correction were performed in terms of Post-Hoc tests on significant effects. A 2x2x2 mixed ANOVA was also used to analyse the effect on SST measures; the within-subjects variables were cognitive load (load/non-load), and session whilst the between-subjects factor was condition. Post-Hoc analyses in the form of paired samples T-Tests were performed on significant effects and the effect size *r* calculated (Rosnow & Rosenthal, 2009). Observed power was calculated for significant Post-Hoc analyses in the form of Apriori power analyses using 'G*Power' Software.

4.5 Results

Preliminary Analysis

Preliminary analyses were conducted to ensure parametric assumptions were not violated. A 2x2 ANOVA was used to analyse the data for the first hypothesis: Training condition (positive vs neutral) x Time (session one x session two). A 2x2x2 mixed factorial ANOVA was used to analyse the data for the second hypothesis: Training condition (positive vs neutral) x Time (session one x session two) x Cognitive Load (loaded vs non-load). A One-Way ANOVA was conducted to investigate whether participant's gender, age, baseline SST and STAI scores were significantly different between conditions. There were no significant differences between conditions, therefore one can assume homogeneity between the conditions, and therefore any difference observed are unlikely due to individual differences between conditions at the start of the experiment.

Main Effects

The first hypothesis investigated was whether participants in the CBM-I positive training will show a decrease in anxiety measures from baseline before the first training session, after session one of training, before training in session two and then again following the second training. Participants in the neutral training condition will not show as great a decrease as the positive training.

There was a significant effect of time on state anxiety $F(1, 38) = 3.28$, $p < .05$, $\mu^2 = .51$, but no significant effect of condition $F(1, 41) = .64$, $p = .42$, or time x condition interaction $F(3, 38) = .18$, $p = .90$. For trait anxiety, there was a significant interaction between time x condition $F(3, 43) = 3.14$, $p < .05$, $\mu^2 = .19$ (please see Table 4.2, Figure 4.1). Post-Hoc analyses in the form of paired samples T-Tests where used to further investigate the interaction effect and revealed a significant reduction in trait anxiety for both the positive CBM-I training condition $t(23) = 3.18$, $p < .005$, $r = .55$ and the CBM-I neutral condition $t(23) = 2.58$, $p < .05$, $r = .46$, which suggests a significant moderate effect size. Observed power was calculated to investigate this effect size and found 1-ß =.55.

Table 4.2 Mean & Standard Deviation For STAI- State & Trait Anxiety By Condition, Study 5.

Condition	*N*	*STAI State Anxiety*				*STAI Trait Anxiety*			
Session		1.0	1.5	2.0	2.5	1.0	1.5	2.0	2.5
Positive CBM-I	21	**38.85** (10.23)	**31.57** (7.28)	**35.47** (12.2)	**33.66** (11.49)	**46.23** (11.47)	**43.62** (11.42)	**43.61** (12.67)	**40.76** (11.92)
Neutral CBM-I	22	**40.31** (11.67)	**33.91** (7.89)	**37.13** (11.02)	**37.00** (11.57)	**46.72** (13.83)	**45.14** (13.46)	**44.31** (12.66)	**44.27** (12.97)

Table 4.3 Mean & Standard Deviation For SST Cognitively Loaded & Non-Loaded By Condition, Study 5.

Condition	*N*	*SST Cognitively Loaded*		*SST Cognitively Non-Loaded*	
Session		*Session 1*	*Session 2*	*Session 1*	*Session 2*
Positive CBM-I	24	**36.58** (26.65)	**32.52** (25.96)	**34.50** (27.79)	**35.84** (27.05)
Neutral CBM-I	24	**27.10** (23.06)	**29.28** (25.03)	**30.35** (19.81)	**23.66** (23.69)

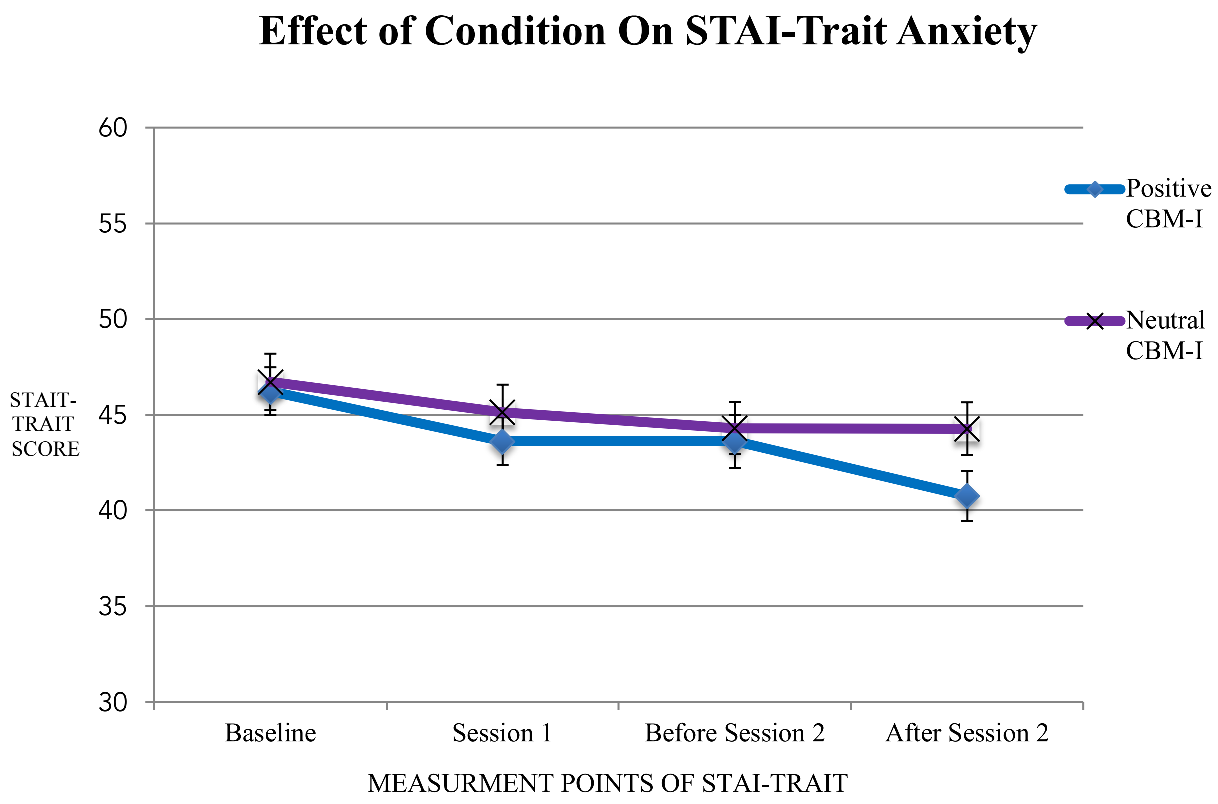


Figure 4.1 Effect Of Condition On Trait Anxiety (STAI), Study 5.

The second hypothesis investigated was whether participants in the positive training condition would show a decrease in negative cognitive interpretation biases (SST) when cognitively loaded, and not in the non-cognitively loaded task. Participants in the neutral training condition should show no difference between sessions, or a difference between cognitively non-loaded SST tasks but not the loaded, before and after the training.

There was a significant interaction between time x condition x cognitive loading $F(3, 46) = 4.86$, $p>.05$, $\mu^2 =.09$. Participants who underwent the positive training in comparison to the neutral training showed a significant decrease in negative cognitive interpretation biases SST measurements, when the SST was cognitively loaded (please see Table 4.3, Figure 4.2), relative to those who underwent the neutral training. Unpicking the condition effect, participants in the positive CBM-I training condition showed no significant decrease in cognitive interpretation bias measures before and after the training when cognitively loaded t (23)=.98, p=.33, or cognitively non-loaded t (23)=.25, p=.80 (please see Figure 4.3). Similarly, the neutral CBM-I training condition showed no significant decrease in cognitive interpretation bias measures before and after the training when cognitively loaded t (23)=.50, p=.62, or cognitively non-loaded t (23)=1.45, p=.16. To further understand the interaction effect correlation analyses were performed. In the CBM-I positive condition, baseline measures of trait anxiety were significantly correlated with cognitively loaded SST r=.61, p<.001, and non-loaded SST r=.53, p<.05. As were post training measures of trait anxiety correlated with cognitively loaded SST r=.66, p<.001 and non-loaded SST r=.81, p<.001. This suggests that there is a significant reduction in negative interpretation bias in the positive CBM-I training condition and this is could be reducing trait anxiety measures.

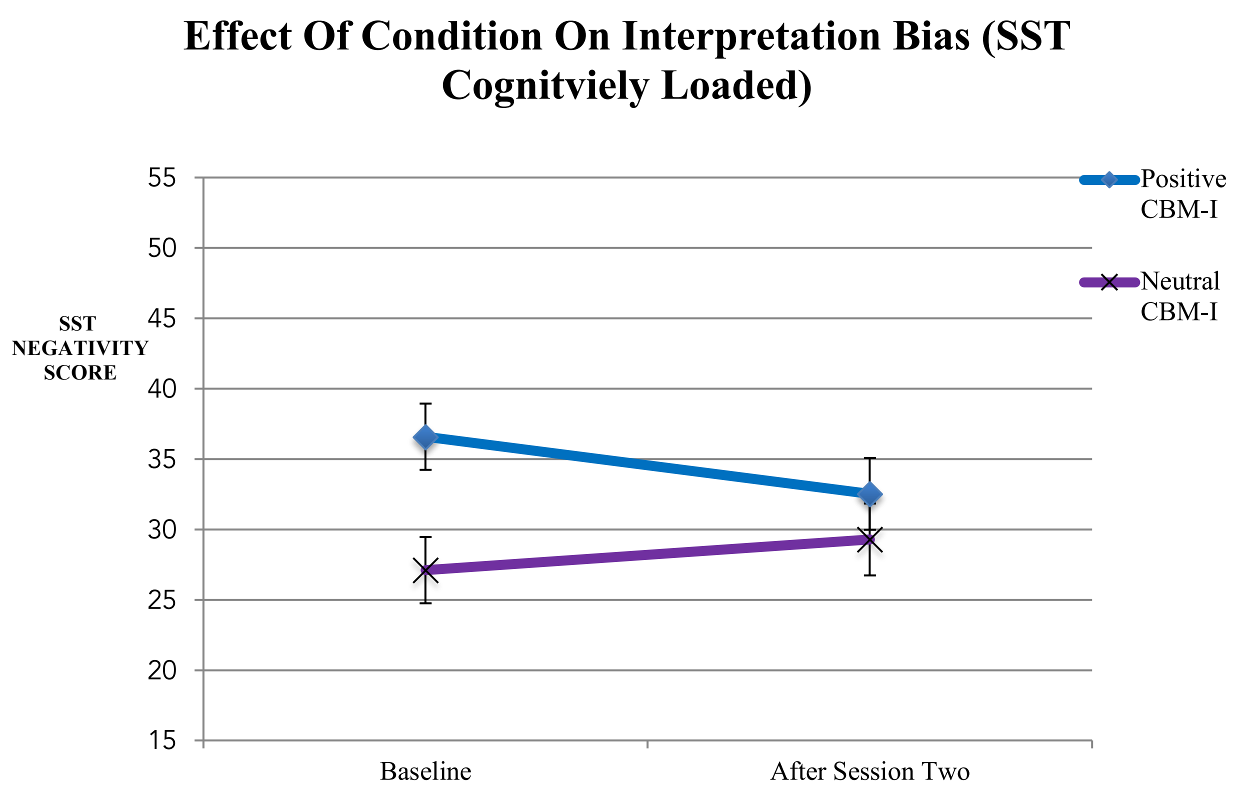


Figure 4.2 Effect Of Condition On Interpretation Bias (SST Cognitively Loaded), Study 5.

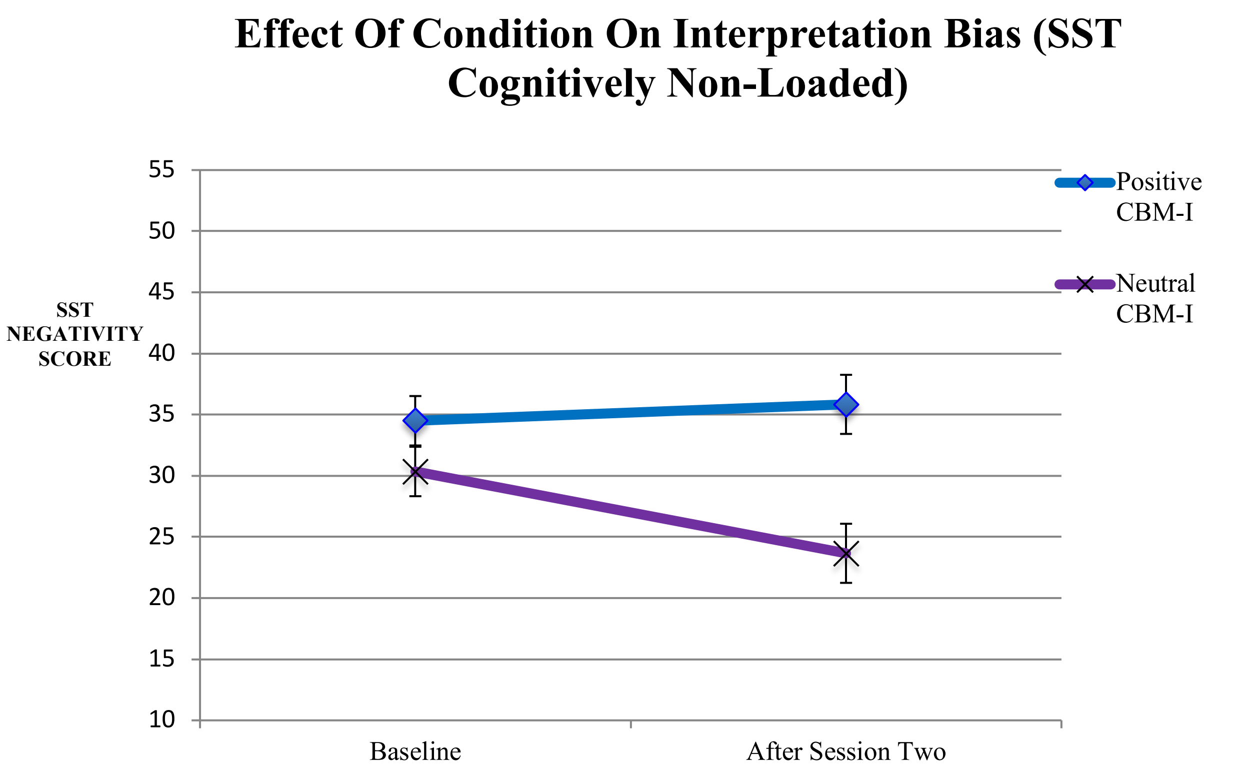


Figure 4.3 Effect Of Condition On Interpretation Bias (SST Cognitively Non-Loaded), Study 5.

4.6 Discussion

This study aimed to investigate the effect of two-session positive CBM-I training in comparison to neutral training on cognitive interpretation biases and self-report anxiety. The results suggest that positive CBM-I training significantly decreases trait anxiety relative to neutral CBM-I training. Cognitive load during the SST had an interesting effect on interpretation biases. It was found that participants in the positive CBM-I training condition, presented a greater decrease in negative interpretation biases when the SST was cognitively loaded than non-loaded, relative to the reverse effect when they had neutral training. There was a significant decrease of self-report state anxiety measures by time, although the effect of condition was not significant.

Bowler, Mackintosh, Dunn, Mathews et al. (2012) used the cognitive loaded and non-loaded SST, found that social anxiety and trait anxiety were reduced in the loaded SST condition (Bowler et al., 2012). Whilst the current study also lend support for this finding. The current study found that loaded SST, which measured cognitive interpretation biases, decreased in the positive training condition, and trait anxiety also significantly decreased, relative to the neutral training. Bowler et al., (2012) using both a CBT and CBM conditions, whilst the current study aimed to investigate a difference between a positive CBM-I and an adequate control, hence the implementation of a neutral CBM-I. The cognitive load SST would, therefore, suggesting automatic processing of cognitive interpretation biases therefore supporting the role of CBM for the treatment of anxiety and depression. Bowler et al., (Bowler et al., 2012) conclude that both CBM and CBT conditions decreased anxiety and depressive symptoms in a clinical sample however as the effect of cognitive loading was significant one can assume that CBM is an automatic effect. Furthermore, an explanation for why the current study couldn’t further support Bowler’s findings, which could be due to their use of a non-clinical sample of individuals with high social anxiety, whilst the current study used a general sample of individuals that presented to be high in anxiety pre-participation.

These results lend support to (Gortner, Rude, & Pennebaker, 2006; Tian & Smith, 2011) findings, which found a strong relationship between anxiety, and negative cognitive biases. This could be due to methodological differences between this study and that of Mathews and MacLeod (Mathews & MacLeod, 2005) and above others. Research by Hirsch and colleagues (Hirsch, Meeten, Krahé, & Reeder, 2016; Krahé et al., 2016) is now supported by the present research, as they also found that individuals with clinical and subclinical levels of anxiety are determined by preferential attention, furthermore, preferential interpretation of threatening information, which leads to negative bias. Whilst (Khalili-Torghabeh et al., 2014) found a positive relationship between anxiety and cognitive interpretation biases, which also supports the present study's findings.

It is noteworthy to speculate why the present study didn't find a significant decrease in depression in response to the positive over neutral training. This could be due to depression frequently characterised by cognitive attentional biases, although previously thought to be attributed to anxiety (Bar-Haim et al., 2007), as depression is primarily associated with the cognitive biases in the later interpretation stages (Bisson & Sears, 2007; Joormann & D'Avanzato, 2010; Joormann & Quinn, 2014; Joormann et al., 2015; Mathews & MacLeod, 2005). Another explanation of this could also be explained by the attentional avoidance to positive stimuli, this decreases positive mood and increases depressive symptoms (Mathews & MacLeod, 2005; Mogg & Bradley, 2006). Therefore, this suggests that attentional cognitive biases could be at the root of ameliorating depressive symptoms rather than interpretational cognitive biases.

From the results found, one can suggest that positive CBM-I training effectively trains individuals to interpret scenarios in a more positive manner and this positively influences mental state, in turn decreasing trait anxiety. Future research would benefit from the development of CBM-I paradigms that incorporate interpretational cognitive biases; that investigate positive, neutral and negative biases; no research as of yet has investigated all of these. This would be most efficiently conducted using interpretational cognitive biases should be measured with comprehension tasks, because they are more complex and require cognitive effort, yet must still be a fairly automatic response to still be a genuine instantaneous cognitive bias.

Furthermore, the results provide support for the specificity effect of CBM-I training (Mackintosh et al., 2013). That being, the results suggest that exercise focused positive CBM-I training, effects individual's interpretation biases in a similar way to physical exercise, therefore reducing negative bias and improving mood state. This is turn reduced trait anxiety. Following on from this one can suggest that future research focuses appreciates the effectiveness of exercise focused CBM-I training within the CBM framework.

This research has investigated the role of two sessions of CBM-I training on negative bias, and the effect this has on state and trait anxiety, perceived stress, and depression. The positive CBM-I training has specifically focused on exercise due to the ameliorating effect exercise has on mental state. The results suggested that over the two sessions trait anxiety decreased in the positive CBM-I condition but not as much in the neutral CBM-I training control condition. The results are discussed in relevance to previous research in the field and implications of this research within the current CBM framework and clinical setting are discussed. Future directions will focus on increased frequency of CBM training sessions; increased to three or four over a six-week period.

Specificity to other focuses will be explored and the nature of cognitively loading whilst measuring cognitive interpretation biases will be investigated.

Chapter 5 Developing an Online CBM-I Program

5.1 Overview

This chapter synthesizes two studies, which developed the use of a fully online cognitive bias modification training program (CBM-I). Both studies focus completely on reducing negative interpretation biases and in turn reducing self-report anxiety and in study seven, depression also. Studies six and seven recruited a high anxiety (sub-clinical) sample from a general population using the GAD-7.

Study six implements a six session CBM-I training model, participants are randomly allocated to either positive or neutral training conditions. Participants complete the STAI at week one, three and six and the GAD-7 before training session one and then after each training session every week. SST measures are taken both cognitively loaded and non-loaded at week one pre-training and week six post-training. Study seven implements a three session CBM-I & Exercise training model, participants are randomly allocated to either a positive CBM-I condition, a combine CBM-I & Exercise condition, a neutral CBM-I condition or Exercise condition. Participants completed the STAI and BDI-II at week one pre-training and week 3 post-training. SST measures are taken both cognitively loaded and non-loaded at week one pre-training and week three post-training. Both studies results presented a decrease in negative interpretation bias lead by the positive CBM-I condition and the exercise condition. Study six showed a significant decrease in trait anxiety measures (STAI-T) over the six-week study. Whilst study seven showed a significant reduction in BDI-II measures of depression over the three-week study, which was driven by the positive CBM-I condition and the combined CBM-I & Exercise condition.

This adds growing support to the premise that positively valenced CBM-I training that is exercise orientated decreases neagative bias. In both studies this decrease in negtive bias has a knock-on effect for self report trait anixtey in study six and self-report depression in study seven. The results from these two studies lend support to a growing field of online CBM-I research. The research endorses the CBM-I paradigm alongside moderate physcial exercise protocols for reducing negative cognitive interpretation bias and in turn improving mental well-being.

5.2 Introduction

Cognitive bias modifcation training for adapting interpretation biases is advocated for decreasing negative bias and improving mental wellbeing as an adjunctive treatment (White et al., 2018). These CBM training programs for attentional bias and interpretation bias have become ameanble in an online format to be used by individuals at home (Salemink et al., 2014) and even in school settings (Fitzgerald, Rawdon, & Dooley, 2016). As previosuly mentioned these cognitive biases are deeply rooted in cognitive funtioning. These cognitive biases manifest as a greater allocation of attention to threatening or negative stimuli at involuntary and voluntary levels of processing which is attentional bias (Roy et al., 2008). And a tendancy to interpret ambigious cues in a threatening or negative manner, also to disproprortiantely attribute neagative events as being the fault of oneself due to internal factors and attribute positive events caused by external events or others actions. Computerised cognitive training models which encourage more adaptive style of information processing, specifically interpretation, over repated practice have been developed to reduce these neagtive biases and improve general anxiety and depression (Lisk et al., 2018).

Mutiple studies have invesitgated the effect of cogntive interpretation bias modification on anxiety and thus far have only produced results of weak effect, yet still significant (Lisk et al., 2018) in symptomology changes (Keshavan, Vinogradov, Rumsey, Sherrill, & Wagner, 2014). Reduction in anxiety symptoms are most common unsuprisingly when the cognitive bias modification have been succesful in modifying the interpretational biases (Notebaert, Clarke, Grafton, & MacLeod, 2015) and reduction of symptoms is most efficent when a multiple session paradigm is used (Hallion & Ruscio, 2011).

Research by Krebs and colleagues found that CBM-I had a signifcant moderate effect on on decreasing negative interpretation biases and therefore boosting positive interpretations (Krebs et al., 2018). They also found a small yet significant effect of CBM-I on self-reported anxiety measures immedicaly following training. Thus, whilst CBM-I training paradigms have immense potential for mental wellbeing, there is mixed findings in the impoteous to effect anxiety and depression. Therefore research must shift to invesitgating the improvement and advancing of the CBM-I methodlogical practices for the benefit of reduction of negative cogntive biases and reducton in anxiety and depressive symptoms.

5.3 Study Six

5.3.1 Methodology

Participants

Fifty-nine participants were recruited from a general population sample from the University of Essex. Participants were recruited using an online participation and accreditation system 'SONA" and the study was advertised through an email subscription list for small advertisements. Participants' age, gender and baseline anxiety scores are detailed in Table 5.1 . Participants were deemed eligible for the study if they scored six or over on the GAD-7 scale, suggesting they had a moderate anxiety, as ascertained by self-report.

Table 5.1 Participant Demographic Information By Condition, Study 6.

Condition	N	Age	Gender Ratio M:F	Anxiety Baseline	Average Hrs Active	Average Hrs Aerobic Exercise
CBM-I Positive	28	Mean: 23.87 Range: 18-59 SD: 8.33	7:21	Mean: 11.81 Range: 6-21 SD: 4.02	Mean: 4.1 Range:1-11 SD: 2.69	Mean: 2.17 Range: 0-6 SD: 1.36
CBM-I Neutral	31	Mean: 25.13 Range: 18-58 SD: 8.39	11:20	Mean: 11.73 Range: 6-19 SD: 3.85	Mean: 4.02 Range:1-11 SD: 2.83	Mean: 2.02 Range:0-6 SD: 1.07

Ethics

Ethical considerations were followed the same as within study one (please see chapter two, section 2.3.1). Ethical approval documentation was updated and an amendment submitted to the eithics panel to allow for use of the CBM-I training program in an online format, which was approved.

Materials

Participants were required to complete six online sessions. Participants completed the State-Trait Anxiety Inventory (STAI; Spielberger, 1983) before and after the CBM-I positive/neutral programme in both session one and session six. The STAI was the same as used for study one (please see chapter two, section 2.3.1). The Generalized Anxiety Disorder Questionnaire (GAD-7 Spitzer et al., 2006) was used to initially screen anxiety level of participants (please see chapter four, section 3.4.2), which was an eligibility criteria, and to measure self-reported anxiety after each session of CBM-I positive/neutral training. The scrambled sentences test (SST; Rude et al., 2002) was the same as used for study one and the equation used to calculate the score was also the same (please see chapter two, section 2.3.1).

Participants completed an exercise questionnaire each week of the study at the end of each study. The exercise questionnaire measured how many hours in that week they had engaged in physical activity; low impact movement such as walking, and how many hours that week they had engaged in physical exercise; moderate to intense exercise such as running or cycling, in which the individuals heart rate is elevated.

Cognitive Bias Modification Positive Training Condition

The positive CBM-I training program was developed from previous versions used in chapters three and four. There were six sessions of the CBM-I positive training program. The scenarios were organised into three blocks of ten ambiguous scenarios (thirty per session total), which are trained to be interpreted positively for each session. In each block of ten; six focused on exercise anxiety, two on social anxiety and two on physical anxiety. The training program gives immediate feedback to participants to ensure the ambiguous scenarios are interpreted positively. Six CBM-I training programs were developed for use in this research; one for each training session, six sessions in total.

Cognitive Bias Modification Neutral Training Condition

The neutral CBM training program was developed from chapter four. There were six sessions of the CBM-I neutral training program. Each session contained three blocks of ten ambiguous scenarios (thirty per session total), in each block of ten; six focused on exercise anxiety, two on social anxiety and two on physical anxiety. In the neutral training participants are not provided feedback, therefore this a pseudo-training condition.

Design

This was an independent measures design. The dependent variables were STAI-State and STAI-Trait score, GAD-7 score, SST Cognitive Loaded score and SST non-loaded score. The independent variables were experimental condition: Positive CBM-I, Neutral CBM-I and session: one, three and six for STAI, one, two, three, four, five and six for GAD-7, one and six for SST.

Procedure

Eligible participants were those who scored above five on the GAD-7 pre-screen survey. Once deemed eligible each participant was emailed a summary of the experiment and an information sheet and consent form to sign and return. There were six individual sessions for each participant to complete once per week for six consecutive weeks. Participants were given three days to complete their weekly session and if they failed to complete the session on time they did not continue the study. This was to ensure consistency in when participants completed the sessions whilst remaining flexible for participant to be able to complete each session around their other commitments. After each session participants were emailed to thank them for taking part in the session and to give further instructions for the next session.

STAI measures were conducted before the CBM-I training in session one, and then after CBM-I training in session three and session six. SST measures were conducted before CBM-I training in session one and after CBM-I training in session six. The GAD-7 measures were taken when defining eligibility, and then after CBM-I training in session one, two, three, four, five and six.

After then end of session six, participants were invited to a debrief meeting with the researcher, in which they collected participant payment to compensate them for their time. Participants were also given a debrief form which outlined the questionnaires they had completed, the aims of the study and the researchers contact details, in case they had any further questions or would like to withdraw. Participants had an allocated five minutes to discuss with the researcher any questions or concerns they had about the study. Therefore, the process of informed consent was adhered to and the participant was given the right to withdraw, fulfilling the requirements of informed consent.

Data analytic approach

A 2x6 mixed ANOVA was used to analyse the effect of condition (CBM-I Positive/ CBMI-I Neutral), by session (one, two, three, four, five, six) for the GAD-7 measure. A 2x3 mixed ANOVA was used to analyse the effect of condition (CBM-I Positive/ CBMI-I Neutral), by session (one, three, six) for state and trait anxiety measures. A 2x2x2 mixed ANOVA was also used to analyse the effect on SST measures; the within-subjects variables were cognitive load (load/no load), and session (one, six) whilst the between-subjects factor was condition. Post-Hoc analyses in the form of Sidaks's adjustment for pairwise comparisons and paired samples T-Tests were performed on significant effects and the effect size *r* calculated (Rosnow & Rosenthal, 2009). Observed power was calculated for significant Post-Hoc analyses in the form of Apriori power analyses using 'G*Power' Software.

5.3.2 Results

Preliminary analysis

Before analysis was conducted, preliminary analysis of the data was conducted to investigate whether assumption of parametric tests had been violated. Assumptions were not violated; therefore, parametric analyses were conducted. One-way ANOVA analyses were conducted to investigate if the conditions differed in STAI, GAD-7, SST, exercise level and age at baseline. A Chi-Square test was used to investigate whether gender differed between groups. Analyses suggested the conditions were not significantly different from one another. Correlational analyses investigated whether physical activity and physical exercise per week was related to outcome measures; STAI, GAD-7, and SST. A One-Way ANOVA was also used to investigate whether level of physical activity and level of physical exercise differed by condition, which it did not significantly differ.

Main Effects

There was a significant decrease in state anxiety over the six sessions $F(2, 53) = 5.08$, $p>.05$, $\mu^2 =.09$, however there was no significant interaction effect of time x condition $F(2, 53) = .79$, $p=.45$ (please see Table 5.2). There was however, a significant interaction between time x condition for trait anxiety, $F(2, 53) = 3.57$, $p>.05$, $\mu^2 =.06$. Post-Hoc analyses were performed in the form of paired samples T-Tests, this revealed a significant decrease in the positive CBM-I training condition $t(25) =4.45$, $p<.005$, $r=.66$, suggesting a significant large effect size. Observed power was calculated to investigate this effect size and found 1-ß =.88. However, no significant difference in the neutral CBM-I training condition $t(25) = 1.76$, $p= .08$ (please see Table 5.2, Figure 5.1).

Table 5.2 Mean & Standard Deviation for STAI- State & Trait Anxiety By Condition, Study 6.

Condition	***N***	***STAI State Anxiety***			***STAI Trait Anxiety***		
Session		*Baseline*	*Post Training 3*	*Post Training 6*	*Baseline*	*Post Training 3*	*Post Training 6*
CBM-I Positive	*26*	**51.23 (11.08)**	**47.07 (8.71)**	**47.73 (12.58)**	**56.53 (10.77)**	**54.46 (11.03)**	**49.96 (9.26)**
CBM-I Neutral	*27*	**57.18 (8.47)**	**53.74 (11.47)**	**50.44 (10.07)**	**59.18 (8.0)**	**57.85 (8.03)**	**57.07 (8.53)**

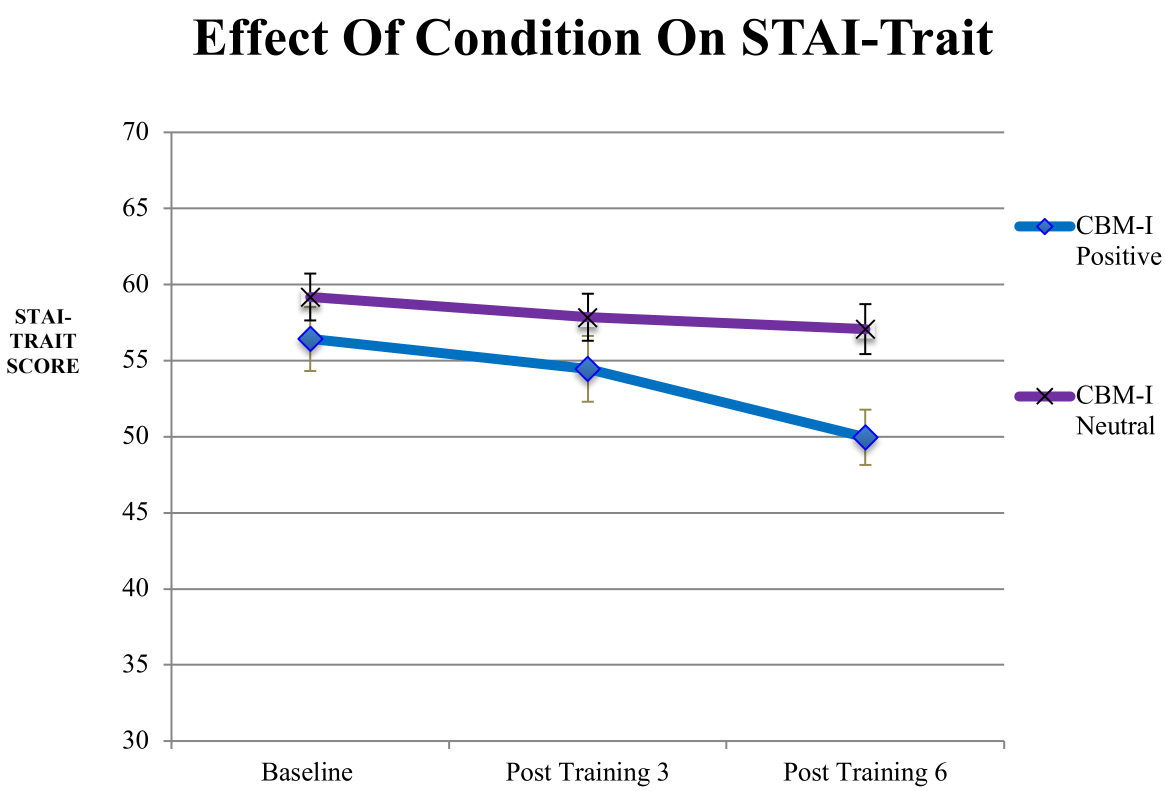


Figure 5.1 Effect of Condition On Trait Anxiety (STAI), Study 6.

There was a significant reduction in self-reported GAD-7 measures over the six sessions, therefore a significant effect of time $F(5, 53) = 3.57$, $p>.05$, $\mu^2 =.06$, but no significant time x condition interaction $F(5, 53) = .89$, $p= .48$ (please see table Table 5.3).

Table 5.3 Mean & Standard Deviation for GAD-7 By Condition, Study 6.

Condition	***N***	***GAD-7***					
Session		*Baseline*	*Post Training 2*	*Post Training 3*	*Post Training 4*	*Post Training 5*	*Post Training 6*
CBM-I Positive	*26*	**12.04 (4.41)**	**9.92 (3.78)**	**7.92 (4.01)**	**8.88 (4.85)**	**8.92 (4.47)**	**9.29 (5.78)**
CBM-I Neutral	*27*	**11.54 (3.32)**	**9.54 (3.55)**	**9.58 (3.34)**	**9.33 (3.51)**	**9.21 (3.21)**	**9.96 (3.66)**

There was a significant interaction between time x condition for SST $F(1, 57) = 14.73$, $p>.005$, $\mu^2 =.20$. There was also a significant interaction between condition x cognitive loading for SST scores $F(1, 57) = 5.29$, $p>.05$, $\mu^2 =.08$. However there was no significant interaction between time x condition x cognitive loading as a whole $F(1, 57) = 0.79$, $p=.77$. Post-hoc tests were performed in the method of Sidak's adjustment for pairwise comparisons of the mean differences between the conditions and found there was a significant difference (MD=8.68, SE=4.09) $p<.05$ (please see Table 5.4, Figure 5.2, Figure 5.3).

Table 5.4 Mean & Standard Deviation For SST Cognitively Loaded & Non-Loaded By Condition, Study 6.

Condition	***N***	***SST Cognitively Loaded***		***SST Cognitively Non-Loaded***	
Session		*Baseline*	*Post Training 6*	*Baseline*	*Post Training 6*
CBM-I Positive	*28*	**61.35 (18.31)**	**20.98 (17.33)**	**54.87 (23.18)**	**17.25 (15.72)**
CBM-I Neutral	*31*	**52.21 (21.76)**	**41.67 (27.89)**	**52.29 (20.20)**	**43.01 (30.17)**

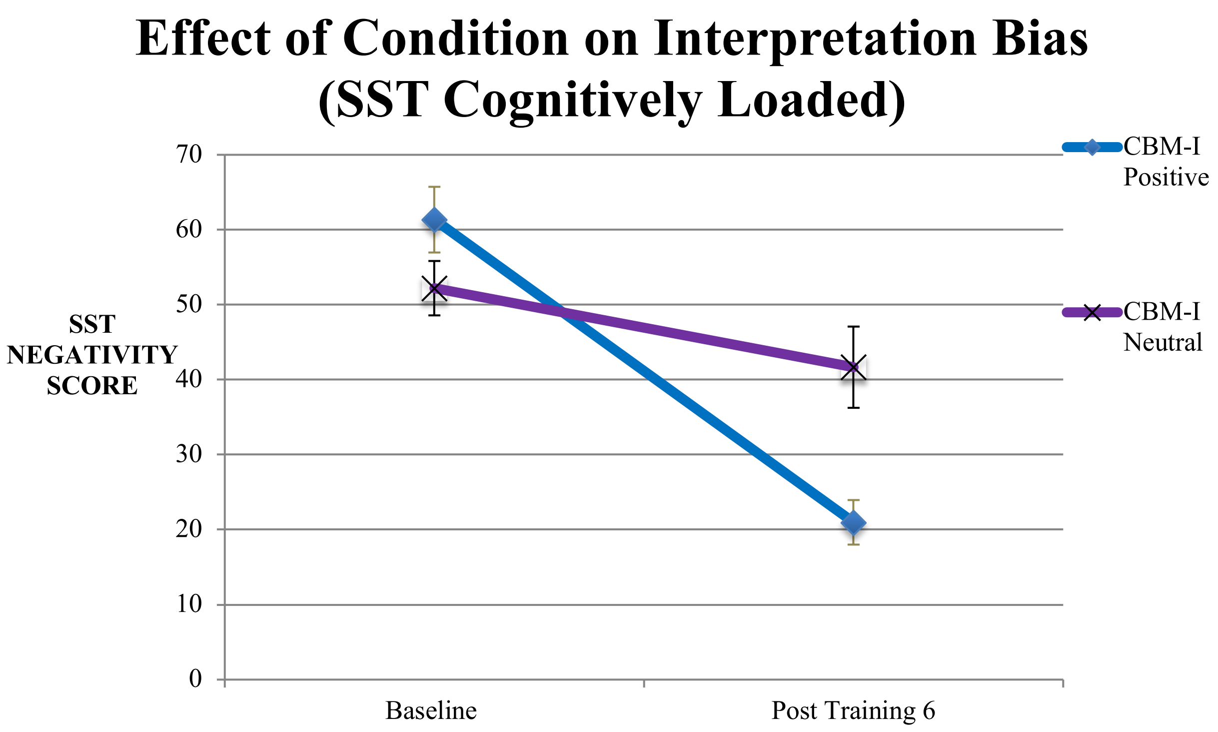


Figure 5.2 Effect Of Condition On Interpretation Bias (SST Cognitively Loaded), Study 6.

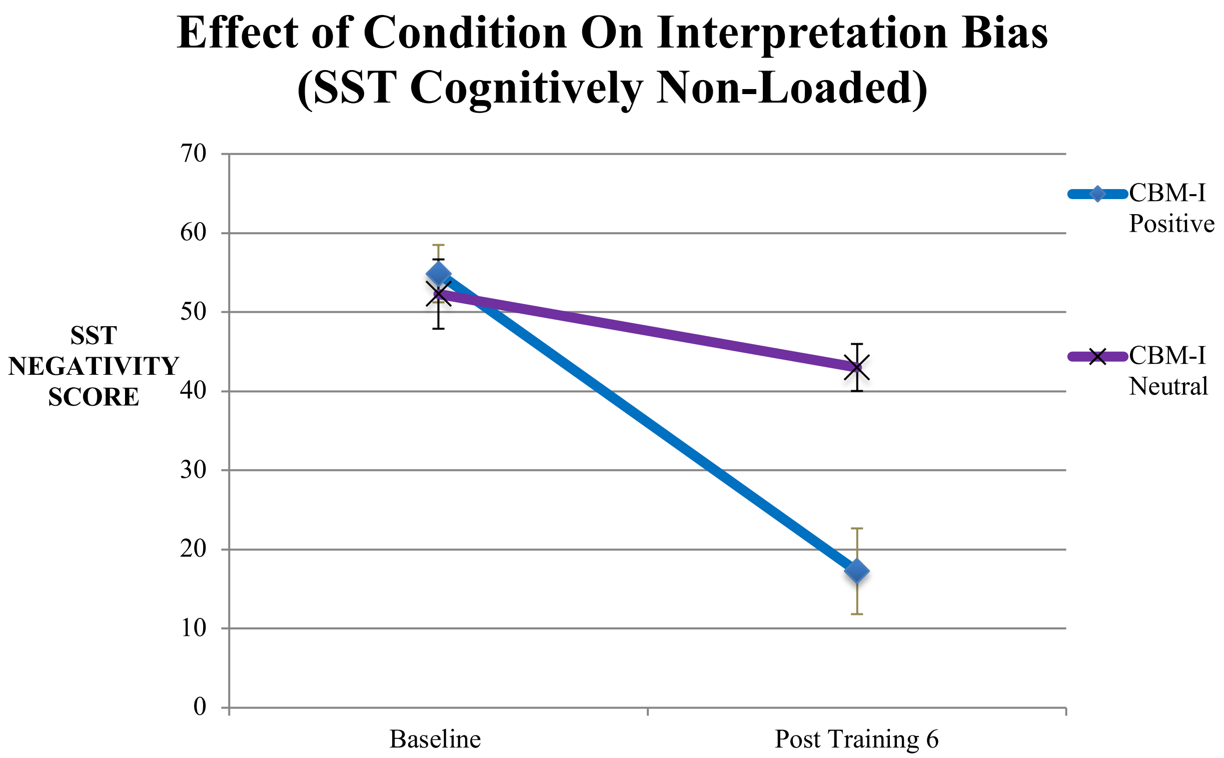


Figure 5.3 Effect Of Condition On Interpretation Bias (SST Cognitively Non-Loaded), Study 6.

5.3.3 Discussion

This study implemented positive CBM-I and neutral CBM-I training program to investigate the effects of CBM-I on individuals with sub clinical anxiety. There was a significant decrease in trait anxiety measures (STAI-T) for participants who underwent the six sessions of positive CBM-I training, relative to the neutral training. Participants who completed the positive CBM-I training decreased in negative interpretation bias measures (SST) relative to the neutral training condition, however this was not dependent on the cognitive loading factor. Although there was a significant interaction between cognitive loading and condition.

5.4 Study Seven

5.4.1 Introduction

Study six was the first study to transfer the CBM-I training on to a completely online platform. Whilst study six measured amount of physical activity and physical aerobic exercise participants were participating in during each week of the study, study seven aims to investigate the effect of moderate exercise on interpretation bias and self-report anxiety using the same paradigm as studies three and four, whilst advancing the research methodology so that the experiment could be conducted completely online.

5.4.2 Methodology

Participants

Eighty-two participants were recruited from a general population sample from the University of Essex. Participants were recruited using an online participation and accreditation system 'SONA" and the study was advertised through an email subscription list for small advertisements. Participants age, gender and baseline anxiety scores is detailed in Table 5.5 by condition. Participants were deemed eligible for the study if they scored six or over on the GAD-7 scale, suggesting they had a moderate anxiety, as ascertained by self-report.

Table 5.5 Participant Demographic Information By Condition, Study 7.

Condition	N	Age	Gender Ratio M:F	Anxiety Baseline
CBM-I Positive	21	Mean: 27.08 Range:18-58 SD: 11.05	9:12	Mean:11.95 Range:6-21 SD: 4.31
Exercise	21	Mean:33.82 Range: 19-58 SD: 13.82	6:15	Mean:11.52 Range:6-21 SD: 4.46
CBM-I + Exercise	22	Mean: 28.25 Range: 18-59 SD: 11.80	11:11	Mean:12.25 Range:6-20 SD:3.35
CBM-I Neutral Condition	18	Mean:26.95 Range: 18-58 SD: 10.74	10:8	Mean:12.18 Range:8-20 SD:2.98

Ethics

Ethical considerations were followed the same as within study six (please see chapter five, section 5.3.1).

Materials

The Generalized Anxiety Disorder Questionnaire (GAD-7; Spitzer et al., 2006) was used to initially screen anxiety level of participants, which was an eligibility criteria and was the same as used in study four (please see chapter three, section 3.4.2). The State-Trait Anxiety Inventory (STAI; Spielberger, 1983) was the same as used for study one (please see chapter two, section 2.3.1).

The revised Beck Depression Inventory (BDI-II; Beck et al., 1996) was the same as used in study two (please see chapter two, section 2.4.2). The BDI-II was used to measure self-report depression in participants before session one of training, then after session three of training.

The scrambled sentences test (SST; Rude et al., 2002) was the same as used for study one, however it was adapted slightly to be exercise valanced to echo the exercise valanced CBM-I training technique. The format of the SST was the same, there were four versions with twenty sentences to unscramble in four minutes, each participant completed all four versions of the SST but order and cognitive loading was counterbalanced between conditions, cognitive loading and versions of SST. In each version of the exercise adjusted SST there were ten sentences taken from the previous version that focused on social anxiety characteristics (please see chapter two, section 2.3.1 for full description of original SST) and ten sentences formulated on characteristics of exercise such as 'fatigued' 'weights' 'makes' 'stronger' 'me' 'lifting', positive unscrambling of these words word make the sentence; 'lifting weights makes me stronger', whilst the negative would be 'lifting weights makes me fatigued' (please see appendix G for version one of four exercise adjusted SST for use in study seven).

The equation used to calculate the score was the same as previously used (please see chapter two, section 2.3.1). The SST was used to measure interpretation bias before the first session and after the third session.

Positive Cognitive Bias Modification Training

The positive CBM-I training program was developed from previous versions used in chapters three and four. There were three sessions of the CBM-I positive training program. Each session is made up of six blocks of ten ambiguous scenarios (sixty per session in total), which are trained to be interpreted positively for each session. The training program gives immediate feedback to participants to ensure the ambiguous scenarios are interpreted positively. In each block of ten training scenarios; six focused on exercise anxiety, two on social anxiety and two on physical anxiety. Three CBM-I training programs were developed for use in this research; one for each training session.

Neutral Cognitive Bias Modification Training

The neutral CBM training program was developed from chapter four. There were three sessions of the CBM-I neutral training program. Six blocks of ten ambiguous scenarios (sixty per session in total), in the neutral training participants are not provided feedback, therefore this a pseudo-training condition.

Physical Exercise Protocol

The exercise protocol was compliant to current health and safety regulations as set out by the approved ethics. The duration and intensity used was similar to previous research in order to assume that the predicted effects will occur from the moderate amount of exercise (Brosan, Hoppitt, Shelfer, et al., 2011; Hansen et al., 2001), whilst still aiming to minimize the amount of inconvenience or fatigue to the participants as much as possible. Previous research (R. T. Barnes et al., 2010) advocates that 85% of the cardiovascular aerobic heart rate reserve of each individual should be maintained for 20 to 30 minutes to achieve the desired benefits of aerobic activity, which was relevant for the aims of this research. Therefore, this project asked participants to exercise moderately twice per week for each week of the experiment and they were asked to measure heart rate so that the desired aerobic heart rate that is necessary for the experiment could be monitored and adhered to respectively. The exercise protocol consisted of a light warm-up of low-intensity (20% of heart rate reserve for 5 minutes) and then increased to 80% heart rate reserve for 20 minutes, it then concluded with a ‘cool down’ which was low-intensity for 5 minutes using 20%

heart rate reserve. Aerobic heart rate reserve was calculated using the formula in Figure 2.2 (Uth et al., 2004). Each participant was informed of their goal heart rate reserve figure for the exercise protocol and advised to aim to complete 20 minutes of exercise with their heart rate elevated to the heart rate reserve figure they were given, they were sent reminder emails to complete the exercise and asked to confirm at the end of each week that they had fulfilled this request.

Design

This was an independent measures design. The Dependent variables were STAI-state score, STAI-trait score, SST scores, BDI-II score. The independent variables were: Positive CBM-I, Exercise, CBM-I & Exercise and Neutral CBM-I. session one (baseline) and session three for STAI-State, STAI-Trait and BDI-II, sessions one and three for SST cognitively Loaded, and SST Non-Loaded.

Procedure

Eligible participants were those who scored above six on the GAD-7 pre-screen survey. Once deemed eligible each participant was emailed a summary of the experiment and an information sheet and consent form to sign and return. There were three individual online sessions for each participant to complete once per week for three consecutive weeks. Participants were given three days to complete their weekly session and if they failed to complete the session on time they did not continue the study. This was to ensure consistency in when participants completed the sessions whilst remaining flexible for participant to be able to complete each session around their other commitments. After each session participants were emailed to thank them for taking part in the session and to give further instructions for the next session.

STAI and BDI-II measures were conducted before the CBM-I training in session one, and then after CBM-I training in session three. SST measures were conducted before CBM-I training in session one and after CBM-I training in session three.

Participant's in the exercise and exercise & CBM condition underwent the physical exercise protocol and CBM-I training program detailed in this methodology section. Participants in the positive CBM-I training condition fulfilled one session of positive CBM-I training per week, for three consecutive weeks, as detailed in this methodology section. Participants in the neutral CBM-I training condition completed one session of the neutral training per week, for three consecutive weeks as detailed in this methodology section. Participants that were in the positive CBM-I and neutral CBM-I conditions were asked to refrain from aerobic exercise during the study and also asked each week how much physical activity and how much exercise they were doing, to ensure this would not confound the results of these conditions which were distinctly not expected to exercise.

After the end of session three, participants were invited to a debrief meeting with the researcher, in which they collected participant payment to compensate them for their time. Participants were also given a debrief form which outlined the questionnaires they had completed, the aims of the study and the researchers contact details, in case they had any further questions or would like to withdraw. Participants had an allocated five minutes to discuss with the researcher any questions or concerns they had about the study. Therefore, the process of informed consent was adhered to and the participant was given the right to withdraw, fulfilling the requirements of informed consent.

Data Analytic Approach

A 4x2 factorial ANOVA was used to investigate the effects of condition and session on measures of STAI-State, STAI-Trait and BDI-II. The within-subjects variable was condition and the between-subjects variable are baseline and after the third session for STAI and BDI-II. Pairwise comparisons using Sidak's correction were performed in terms of post-hoc tests. A 2x2x2 mixed ANOVA was also used to analyse the effect on SST measures; the within-subjects variables were cognitive load (load/non-load), and session (one, three) whilst the between-subjects factor was condition. Post Hoc analyses in the form of paired samples T-Tests were performed on significant effects and the effect size *r* calculated (Rosnow & Rosenthal, 2009). Observed power was calculated for significant Post-Hoc analyses in the form of Apriori power analyses using 'G*Power' Software.

5.4.3 Results

Preliminary analysis

Before analysis was conducted, preliminary analysis of the data was conducted to investigate whether assumption of parametric tests had been violated. Assumptions were not violated; therefore, parametric analyses were conducted. One-way ANOVA analyses were conducted to investigate if the conditions differed in STAI, BDI-II, SST, gender and age at baseline. Correlational analysis investigated the level of physical activity and physical activity each week for participants in all conditions, to confirm individuals in the CBM-I positive and CBM-I neutral conditions (that were asked to refrain from exercise) were not significantly similar to the conditions that were asked not to exercise, means and standard deviations of these can be found in Table 5.5.

Main Effects

There was significant interaction between time x condition for state anxiety measures *F*(3, 84) = 5.07, *p*>.05, μ^2 =.15 (please see Table 5.6, Figure 5.4). However, a Sidak pairwise comparison revealed that there was no significant difference between the conditions (MD=1.01, SE=1.30) *p*=.43. Paired samples T-Tests showed that the decrease was not statistically significant in STAI-state in the positive CBM-I condition *t*(21) = 1.32, *p*= .20, CBM-I & Exercise condition *t*(25) = 1.39, *p*= .17 and the exercise condition *t*(20) = -1.84, *p*= .07. However there was a significant increase in STAI-state scores in the neutral CBM-I condition *t*(18) = -4.41, *p*< .005. The results suggest that there was a significant increase in STAI state anxiety measures when individuals underwent the neutral CBM-I training (please see Table 5.6, Figure 5.4).

There was a significant main effect of time, showing a decrease in trait anxiety scores from baseline to post intervention *F*(1, 84) = 8.70, *p*>.005, μ^2 =.09, however, there was no significant interaction between time x condition *F*(3, 84) = 2.12, *p*=.10 (please see Table 5.6). This suggests there was significant reduction in trait anxiety measures over the three sessions although the condition was not a significant factor.

There was a significant interaction between time x condition for BDI-II measures (please see Table 5.6, Figure 5.5) *F*(3, 80) = 6.14, *p*>.001, μ^2 =.18. A Sidak pairwise comparison revealed that there was a significant difference between the conditions (MD=3.91, SE=.75) *p*<.005. Paired samples T-Tests revealed that there was a significant reduction in BDI-II scores for the positive CBM-I condition *t*(21) = 6.38, *p*<.005 and the positive CBM-I & Exercise condition *t*(22) = 3.22, *p*< .005. Whilst there was no significant reduction for the neutral CBM-I condition *t*(18) = .17, *p*=.86, nor the exercise condition *t*(19)=.95, *p*=.35. This suggests that individuals who underwent the positive

CBM-I training or the CBM-I & exercise training decreased in self-report depression (BDI-II scores) significantly, whilst the neutral CBM-I and exercise condition did not.

Table 5.6 Mean & Standard Deviation For STAI- State, Trait Anxiety & BDI-II By Condition, Study 7.

Condition	*N*	*STAI State Anxiety*		*STAI Trait Anxiety*		*BDI-II Depression*	
Session		*Baseline*	*Post Training 3*	*Baseline*	*Post Training 3*	*Baseline*	*Post Training 3*
CBM-I Positive	*22*	**38.36 (11.73)**	**34.72 (9.29)**	**44.72 (9.75)**	**39.86 (9.40)**	**17.5 (6.69)**	**8.86 (6.04)**
CBM-I & Exercise	*26*	**43.61 (13.78)**	**39.42 (13.89)**	**48.96 (12.85)**	**47.07 (14.48)**	**21.39 (10.39)**	**16.26 (12.69)**
CBM-I Neutral	*19*	**32.68 (9.51)**	**40.63 (12.93)**	**43.21 (10.42)**	**44.0 (11.81)**	**15.36 (5.80)**	**15.15 (6.51)**
Exercise	*21*	**45.52 (13.67)**	**49.57 (12.43)**	**51.09 (11.59)**	**47.47 (10.81)**	**19.05 (9.73)**	**17.35 (13.65)**

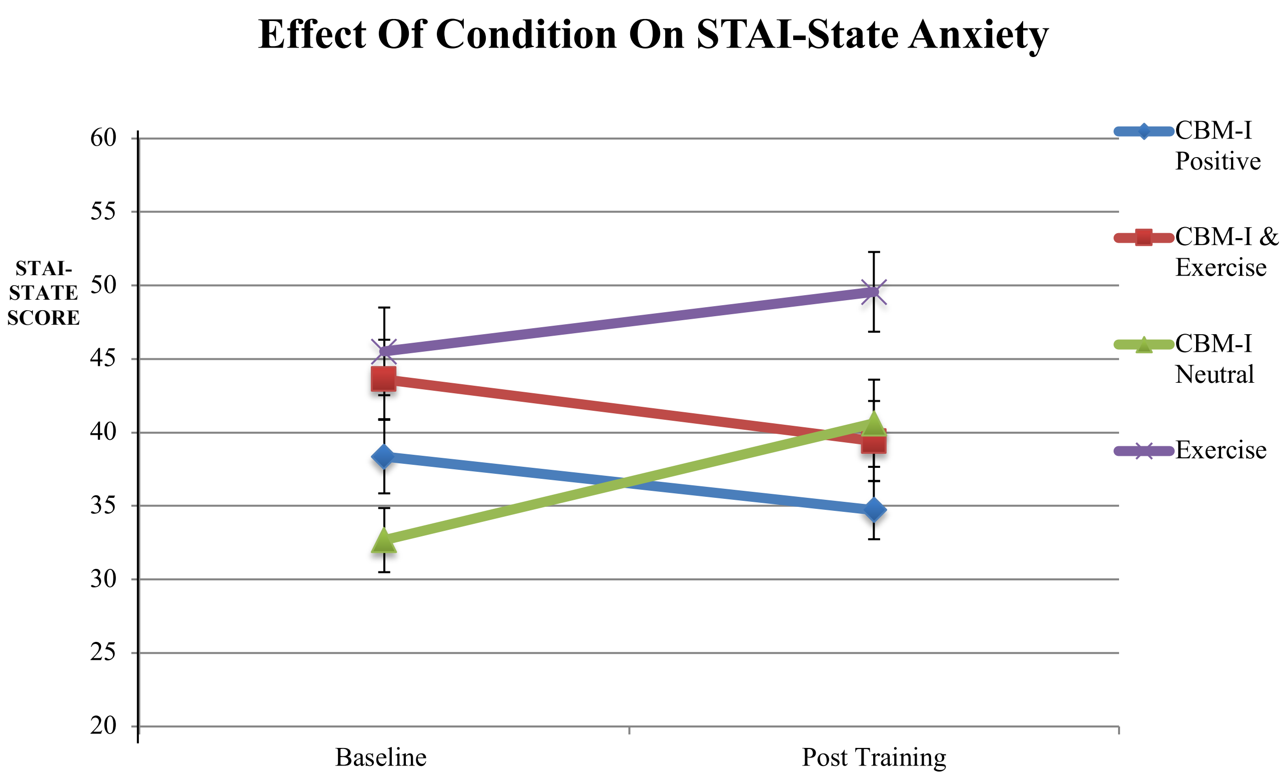


Figure 5.4 Effect of Condition On State Anxiety (STAI), Study 7.

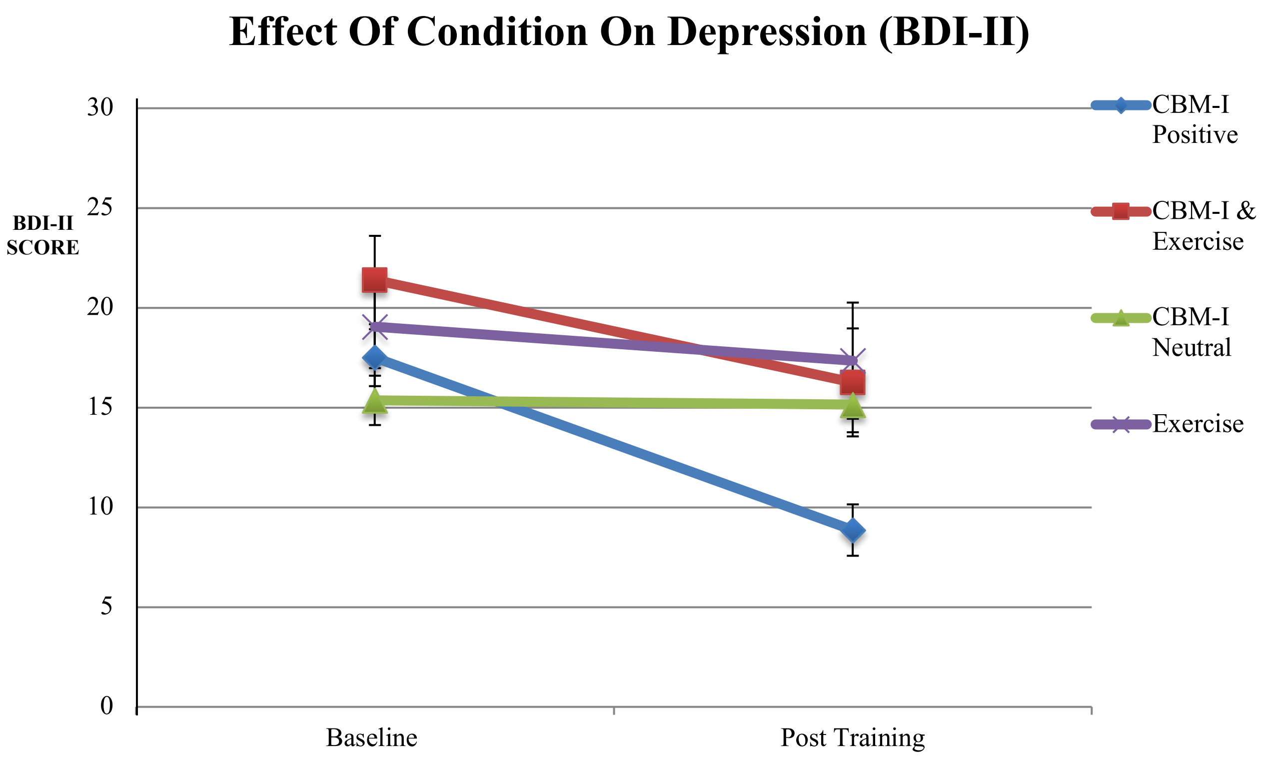


Figure 5.5 Effect of Condition On Depression (BDI-II), Study 7.

For SST scores (please see Table 5.7, Figure 5.6, Figure 5.7), there was a significant interaction between time x condition x cognitive load, $F(3, 82) = 2.79$, $p>.05$, $\mu^2 =.09$. A Sidak pairwise comparison revealed that there was a significant difference between the condition (MD=15.22, SE=2.35) $p<.005$. Paired samples T-Tests were performed to interpret the interaction effect and found that when the SST was cognitively loaded there was a significant reduction in SST scores in the positive CBM-I condition $t(23) = 7.66$, $p< .005$ and the exercise condition $t(17) = 3.83$, $p< .005$. However there was no significant reduction in SST scores for individuals in the neutral CBM-I condition $t(18) = -1.08$, $p= .29$ or the positive CBM-I & Exercise condition $t(25) = 1.30$, $p= .20$. When the SST was non loaded there was significant decrease in SST scores for the positive CBM-I condition $t(23) = 5.87$, $p< .001$ and the exercise condition $t(17) = 3.73$, $p< .005$. Whilst there was no significant decrease for the positive CBM-I & Exercise condition $t(24) = -.32$, $p=.75$ nor the neutral CBM-I condition $t(18) = 1.36$, $p=.18$. This suggests that when the SST is cognitively loaded or non-loaded individuals who undergo the positive CBM-I training or exercise training significantly decrease in negative interpretation bias measures (SST scores).

Table 5.7 Mean & Standard Deviation For SST Cognitively Loaded & Non-Loaded By Condition, Study 7.

Condition	N	*SST Cognitively Loaded*		*SST Cognitively Non-Loaded*	
Session		*Baseline*	*Post Training 3*	*Baseline*	*Post Training 3*
CBM-I Positive	*24*	**60.91 (19.15)**	**25.20 (12.27)**	**56.71 (23.2)**	**23.13 (18.52)**
CBM-I & Exercise	*25*	**56.78 (22.55)**	**48.04 (20.0)**	**53.41 (20.37)**	**54.94 (18.8)**
CBM-I Neutral	*19*	**46.24 (16.66)**	**49.93 (18.92)**	**48.04 (18.31)**	**44.68 (20.04)**
Exercise	*18*	**55.79 (18.62)**	**32.83 (12.46)**	**60.23 (14.79)**	**37.58 (15.61)**

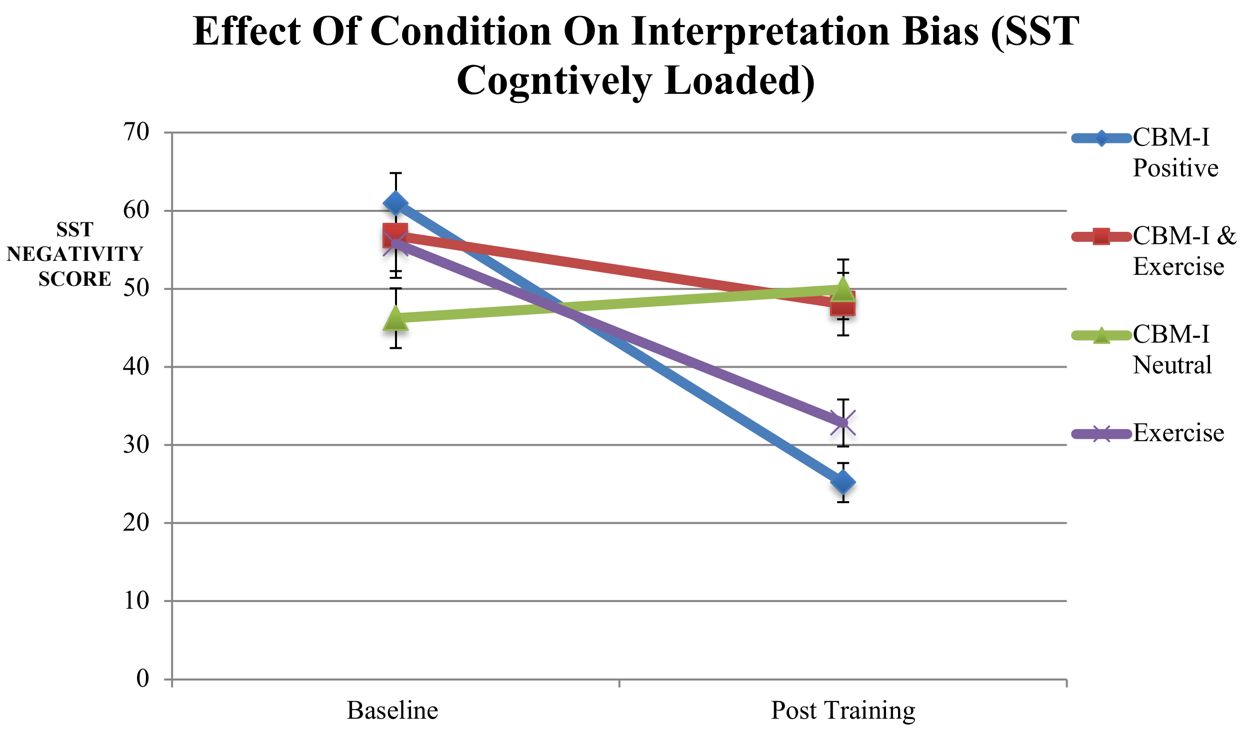


Figure 5.6 Effect Of Condition On Interpretation Bias (SST Cognitively Loaded), Study 7.

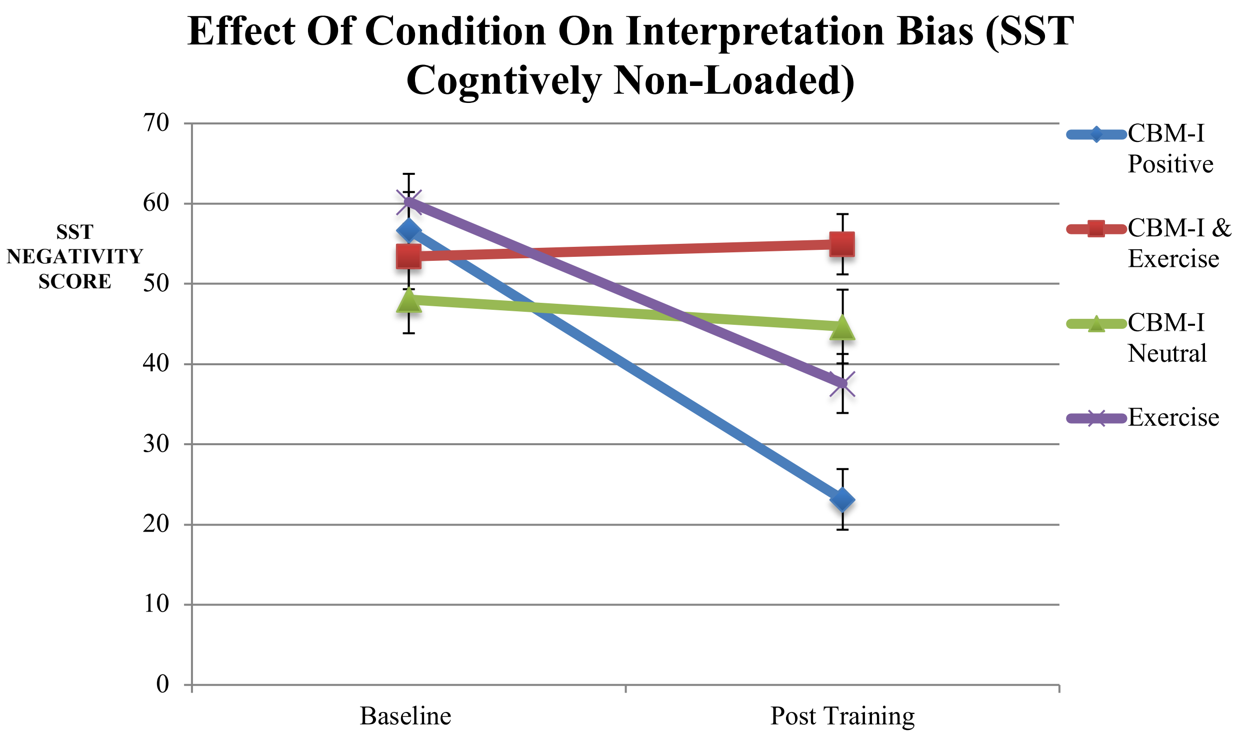


Figure 5.7 Effect Of Condition On Interpretation Bias (SST Cognitively Non-Loaded), Study 7.

5.4.4 Discussion

This study implemented a three session CBM-I and Exercise paradigm, in which participants who has sub-clinical anxiety either underwent positive CBM-I training, a combined protocol of positive CBM-I & Exercise training, neutral CBM-I training or exercise training on its own. The results suggest that participants who underwent the neutral CBM-I training actually increased in STAI-S state anxiety measures over the three sessions of training. Interestingly individuals in the positive CBM-I training and the combined positive CBM-I & exercise training decrease in depression measures (BDI-II) over the three sessions. Interpretation bias measures (SST) also decreased over the three sessions for participants that underwent the positive CBM-I training and the exercise training and this was the same for when the SST was cogntively loaded or non-loaded.

5.5 General Discussion

Study six implemented a six session CBM-I paradigm in which participants with sub-clinical anxiety underwent either a positive or neutral CBM-I training program once per week over six consecutive weeks. These training sessions were fairly brief; thirty scenarios per session in comparison to sixty scenarios per training session in study seven. Study seven implememnted a CBM-I and exercise training similar to that of chapter three. However, the SST was adjusted to be exercise valanced to mimic the exercise orientated CBM-I training and the study ran completely online unlike studies three or four. The results from these two online studies suggest that the longer verison of CBM-I training had a stronger effect on modificaying interpretation biases (measured by SST). Furthermore, there was a significant decrease in depression measures possibly due to the longer training session. Whilst study six presented a significant decrease in trait anxiety measures over the six week period, this could be due to trait anxiety responding to the training over a longer period. Interpretaion bias scores significantly decreased in both study six in repsonse to the positive CBM-I training and study seven in response to the positive training and also the exercise condition. This adds growing support to the premise that positively valenced CBM-I training that is exercise orientated decreases negative bias. In both studies this decrease in negative bias has a knock-on effect for self report trait anixtey in study six and self-report depression in study seven.

This research lends support to previosus findings by Lisk and colleagues, although they investigated both CBM-A and CBM-I training techniques on anxiety and depression, their findings suggest that CBM-I training was the most benefical for anxiety reduction which is supported by the result sof study six in whch there was a significant reduction in trait anciety measures also (Lisk et al., 2018).

The results from these two studies lend support to a growing field of online CBM-I research. The research endorses the CBM-I paradigm alongside moderate physcial exercise protocols for reducing negative cognitive interpretation bias and in turn improving mental well-being.

Chapter 6 Overall Discussion

This doctoral thesis investigates the complex relationship between mental well-being, cognitive bias and physical exercise. The research begins with two studies which measure the effect of mild to moderate physical exercise on typical individual's interpretation biases and measures of mental well-being. Study one investigated the effect of a walking exercise protocol on interpretation biases and anxiety and found a significant reduction in trait anxiety in the walking exercise condition relative to control condition, but no effect on interpretation bias. Study two investigated the effect of single session of moderate exercise on a static bicycle and found a significant reduction in interpretation biases, state and trait anxiety, depression and perceived stress measures in the exercise condition compared to the control condition.

Study three begins to develop an exercise orientated Cognitive Interpretation Bias Modification (CBM-I) training programme that's positively valenced and incorporating a dual method of CBM-I and exercise training against a rest control condition. This is investigated over two sessions of positive CBM-I training, combined CBM-I and exercise, exercise and a rest control condition. Results suggested that there was a significant reduction in perceived stress, which was driven by the combined CBM-I & exercise condition and the rest condition. There was a significant reduction in self-report depression which was drive by the exercise condition and the combined CBM-I & exercise condition, whilst there was no significant effect on cognitive interpretation bias measures.

Study four uses the same methodological paradigm as study three and seven whilst introducing a more robust control condition and recruiting a high anxiety sample. Study four uses a neutral

CBM-I training program instead of a rest control condition, along with a positive CBM-I training condition, a combined CBM-I & exercise condition and physical exercise condition over three sessions and measures the effect of these on interpretation bias and measures of mental well-being. Results suggest a significant reduction in trait anxiety driven by the combined CBM-I & exercise condition and the exercise condition, whilst there were no significant effects on state anxiety, depression, psychological stress, or interpretation bias.

Study five focuses on developing the neutral CBM-I training in direct contrast to the positive CBM-I training over the course of two sessions with a high anxiety sample of participants. The results suggested that trait anxiety reduced in the positive CBM-I condition and there was a significant effect on interpretation biases also. There was a significant correlation between trait anxiety and interpretation biases in the positive CBM-I condition.

Study six recruited a high anxiety sample and was the first study conducted completely online. Study six consisted of six sessions of positive or neutral CBM-I training over six consecutive weeks. The amount of physical activity and exercise was measured throughout the study, but participants were not encouraged nor discouraged from exercising. There was a significant reduction in trait anxiety in the positive CBM-I condition relative to the control condition. There was also a significant reduction in negative interpretation bias in the positive CBM-I condition compared to the control condition.

Whilst study seven consisted of three sessions of positive CBM-I, positive CBM-I & exercise, exercise or neutral CBM-I training over a three-week period. Although the paradigm of this study is similar to that of study three and four, study seven required participants in the exercise and CBM-I & exercise conditions to complete six sessions of moderate exercise (30 minutes at their required heart rate, as calculated) twice per week of the study. Furthermore, study seven introduced an amended Scrambled Sentences Test (SST; measured both cognitively loaded and non-loaded) which had been used in each study previous, to measure cognitive interpretation bias. The amended SST was an exercise adjusted version, which implemented exercise orientated sentences to unscramble alongside the original sentences, which echoes the exercise orientated CBM-I training programs. The results from study seven suggested that there was a significant effect on state anxiety however this seemed to be due to an increase in the neutral CBM-I condition. There was a significant reduction in self-report depression, which was driven by the positive CBM-I condition and the combined CBM-I & exercise condition. Also, there was first reported a significant effect relative of session, condition and cognitive loading and this was a significant reduction in the negative interpretation biases in the positive CBM-I condition and the exercise training condition.

This body of research collectively supports CBM-I training for reducing trait anxiety especially in studies four, five and six where there was a significant reduction in trait anxiety as driven primarily by the positive CBM-I training. Whilst not disregarding that in study four the reduction in trait anxiety was driven by the exercise condition and then combined CBM-I and exercise condition. This lends support for the benefits of exercise which was presented in studies one and two specifically, which showed a significant decrease in trait anxiety in study one after a simple walking exercise protocol. Additionally, in study two a moderate exercise protocol produced a significant reduction in both state and trait anxiety measures, and perceived levels of stress and depression. Furthermore, study three also presented a significant interaction of effect on trait anxiety measures, which was driven again by the combined CBM-I and exercise condition, suggesting exercise plays an important role in anxiety symptomology and this was investigating a sub-clinical sample of participants. Whilst study four presented a much clearer effect, as the combined CBM-I & exercise condition had a stronger effect on trait anxiety measures when compared to the exercise condition or neutral condition. This suggests that when exercise training and positive CBM-I training are combined they have a unique effect on reducing trait anxiety in particular.

This collection of studies often presented an unclear picture of whether cognitive bias modification program had a significant effect on individuals interpretation biases. Studies one, three and four all provided no substantial evidence of interpretation biases significantly being modified. Study six presented a significant interaction between time x condition, so negative biases did decrease over time and dependent of condition. This presented an issue as cognitive loading is paramount to the integrity of measuring cognitive biases. This is because interpretation biases are inherently automatic and so a cognitive load must be used to divert attention for the individual so the cognitive biases they are making are automatic. In study seven the SST used was tailored to the CBM-I training we were using to investigate whether this could possibly be the reason why there was no significant interaction between loading, condition and time in previous studies.

Studies five and seven indeed found a significant interaction between time x loading x condition, the results from study seven in particular lend support to tailoring the SST measure of interpretation bias to be exercise orientated alike the CBM-I training programs used (which were adapted study three onwards to be exercise orientated) a significant interaction effect could be observed and in turn the inference could be made that these CBM-I training techniques reduce negative interpretation bias. This research contradicts the findings of research conducted by Morina & colleagues, because much of the present research supports the notion that cognitive interpretation biases are paramount in the function of anxiety (Morina et al., 2011). Morina et al., (2011) argued that there is a lack of evidence for the relationship between anxiety and cognitive interpretation biases; as lack of positive imagery is usually associated with anxiety. The research in this thesis provides a stronger support for the role of interpretation bias in anxiety, specifically study five which found a strong relationship between interpretation biases and trait anxiety scores both of which were significantly reduced in the positive CBM-I condition. Conversely a similar representation of this relationship is presented in study seven but with depression measures.

A limitation of these inferences that are presented is that self-report depression was only measured in studies two, three and four as the primary focus of this research was anxiety reduction. This suggests that it is indeed negative cognitive biases which influences anxiety as well as depression. Conversely, one could speculate that a positive relationship was not found between negative bias and depression, because depression could be characterised by cognitive attentional biases, although previously thought to be attributed to anxiety (Bar-Haim et al, 2007), as depression is primarily associated with the cognitive biases in the later interpretation stages (Gotlib et al, 2004; Joorman & Avanzato, 2004). Another explanation of this could also be explained by the attentional avoidance to positive stimuli, this decreases positive mood and increases depressive symptoms (Bradley, Mogg & Lee, 1997; Mathews & MacLeod, 2005). Therefore, this suggests that attentional cognitive biases could be at the root of ameliorating depressive symptoms rather than interpretational cognitive biases.

Research by Smith (2012) argues that the current literature is still undecided on whether cognitive interpretation biases stem from the functions of depression. However, cognitive theories of depression are all rooted in the fundamental role of negative cognitive biases in the development and maintenance of clinical depression (Beck, 1976). In turn, a study using a sample of diagnosed clinically depressed individuals, Mogg et al. (2006) investigated encoding of threatening interpretation of ambiguous sentences and homophones. They found that individuals with clinical levels of depression preferentially encoded the ambiguous stimuli as threatening more than those with no diagnosis of depression. This provides some explanation for why in some of the studies there was no significant relationship between negative interpretation bias and depression measures. In a study by Mogg et al. (2006) they used a clinically depressed sample which makes it clearer to make these inferences of relationships between different cognitive biases and disorders. Unfortunately, a limitation of the research in this thesis is that studies one, two and three did not prescreen participants for baseline measures of anxiety or depression. However, considering the main focus of the present research was anxiety, studies four, five, six, and seven all pre-screened participants for anxiety, only accepting individuals who scored in moderate to severe ranges of anxiety on a self-report measure. Additionally, from these baseline anxiety scores participants were then assigned to a condition whilst keeping baseline anxiety, age and gender equal between conditions. This was introduced after study three produced results that were inconclusive in providing any support for the effect of CBM-I training and exercise positively influencing measures of interpretation bias, anxiety, stress or depression.

These results lend support to Mathews and MacLeod (2005), MacLeod and Mathews, (2012), Hertel and Mathews, (2011), findings, which found a strong relationship between anxiety, depression and negative cognitive biases (Hertel & Mathews, 2011; MacLeod & Mathews, 2012; Mathews & MacLeod, 2005).

However, in studies one, three and four negative bias did not significantly decrease respective of condition or loading. This has meant that one of the primary hypotheses of this thesis is not fully supported, as studies one, three and four fail to show a direct link between modifying individuals cognitive biases and a change in their cognitive interpretation biases. This could be due to methodological differences between these studies and that of Mathews and MacLeod (2005) and above others. Research by (Cisler & Koster, 2010) is also now supported by the present research, as they also found that individuals with clinical and subclinical levels of anxiety are determined by preferential attention, furthermore, preferential interpretation of threatening information, which leads to negative interpretation biases.

There is body of research attributing attentional avoidance to positive stimuli to onset and maintenance of depression. With consideration to the findings of these seven studies, which lend considerable support to the link of interpretation bias with anxiety and less support for the link of interpretation bias to depression, future research should investigate the roles of attentional biases with depression. This construct has also been supported by Lisk and colleagues, who found a strong correlation between interpretation bias and anxiety, in direct comparison to attentional bias (Lisk et al., 2018). Lisk employed an eight-week training program in which the first four weeks consisted of attention bias training and the later weeks involved interpretational bias training. Lisk found strong support for benefit of interpretation bias training for anxiety. Considerate of Lisk's findings, future research should employ a similar paradigm of attentional and interpretational bias training program (attention bias modification; ABM & CBM-I), however as different experimental conditions, so that more concrete inferences can be made of whether ABM or CBM-I techniques are most beneficial for either anxiety and/or depression. Also, the influence of physical exercise on interpretation bias, anxiety and depression should not be disregarded. Future research should investigate separate ABM, CBM-I & exercise training conditions over a period of three to four weeks. As study seven yielded a clear effect of reducing anxiety over three weeks of longer training sessions, whilst study six was shorter training sessions over a six-week period which arguably did not produce as strong effects. This arguably contradicts the general assumption that distributed practice is more beneficial than quantity of practice.

Future CBM-I research should also investigate the effect of a gradual increase of intensity of positive scenarios, duration of training sessions (how many scenarios per session of training) and the effect this has on high anxiety individual's commitment and engagement to the CBM-I training programs and in turn the effect on interpretation bias, anxiety and depression. This would be beneficial because individuals high in anxiety often can find the positive training to be sometimes difficult to engage with because they do not hold the positive interpretations that they are required to form in the training, it can be difficult for these individuals to commit and engage in the training. Therefore, by starting the CBM-I training with more neutral scenarios and increasing them in the intensity of positivity in the interpretations of the scenarios, this could allow anxious participants who are more averse to the positive training to become gradually more used to the positive CBM-I training. The basis of this is in a few of the studies presented when a positive and neutral training are used we see almost a similar pattern of the neutral training to the positive when investigating a high anxiety sample. This is present in study five, in which the interpretation biases were significantly affected, yet this could not be attributed to either the positive or neutral training condition. Research should investigate this using a sample of individuals who present as high anxiety and high depression in separate conditions in comparison to a control condition of individuals who present as low in anxiety and depression measures. Tailoring of materials for the research question is also of worthy investigation in future research also, as results of study seven strongly support this. The SST was particularly unpredictable as a measure and only once it was adjusted to echo the scenarios and interpretations the participants were undertaking in the CBM-I training, was a significant interaction found between the cognitive loading technique, time and condition. Therefore, future research should investigate use of appropriate materials tailored for the interventions and participant sample.

In conclusion, this collection of studies has aimed to reduce negative interpretation bias and improve mental well-being, specifically anxiety. The research has evolved from merely measuring and investigating interpretation biases, to modifying biases using CBM-I techniques. The findings lend further support to the use of neutral training and placebo mechanisms used by Krahé & colleagues (Krahé et al., 2016) and Becker & colleagues (Becker et al., 2016) and it was the introduction of a neutral placebo training from study four onwards that one could more clearly see whether the CBM-I training was a genuine effect, rather than any confounding extraneous variables. Furthermore, the introduction of multiple session CBM-I programs in an online format in this research strengthened findings of research by Lisk & colleagues (Lisk et al., 2018). The potential benefits of modifying cognitive interpretation biases in particular are copious, from decreasing depression (Hirsch et al., 2016), anxiety (Richards & French, 1992), stress reactivity (Richards, 2004; Becker et al., 2016), reducing general maladaptive mood (Brosan, Hoppitt, Selfer, et al., 2011) and even increasing resilience to threatening situations (de Voogd et al., 2017; de Voogd, Wiers, de Jong, Zwitser, & Salemink, 2018; de Vries et al., 2016). Lastly, this research further strengthens the findings of Tian & Smith (2011) and Smith & O'Connor (2003) and validates the benefits of physical exercise in the CBM field.

References

Almeida, O. P., MacLeod, C., Ford, A., Grafton, B., Hirni, V., Glance, D., & Holmes, E. (2014). Cognitive bias modification to prevent depression (COPE): study protocol for a randomised controlled trial. *Journal of Trials, 282*(15), 2-9.

American Psychiatric Association. (2013). *Diagnostic And Statistical Manual Of Mental Disorders Fifth Edition DSM-5* (5th ed.). Washington, DC: American Psychiatric Association.

Asmundson, G. J., Fetzner, M. G., Deboer, L. B., Powers, M. B., Otto, M. W., & Smits, J. A. (2013). Let's get physical: a contemporary review of the anxiolytic effects of exercise for anxiety and its disorders. *Depress Anxiety, 30*(4), 362-373. doi:10.1002/da.22043

Babyak, M. A., Blumenthal, J. A., Herman, S., Khatri, P., Doraiswamy, M., Moore, K., . . . Krishnan, R. K. (2000). Exercise Treatment for Major Depression: Maintenance of Therapeutic Benefit at 10 Months. *Psychosomatic Medicine, 62*, 633-638.

Bar-Haim, Y., Lamy, D., Pergamin, L., Bakermans-Kranenburg, M. J., & van IJzendoorn, M. H. (2007). Threat-related attentional bias in anxious and nonanxious individuals: a meta-analytic study. *Psychol Bull, 133*(1), 1-24. doi:10.1037/0033-2909.133.1.1

Barbour, K. A., & Blumenthal, J. A. (2005). Exercise training and depression in older adults. *Neurobiol Aging, 26 Suppl 1*(1), 119-123. doi:10.1016/j.neurobiolaging.2005.09.007

Barlow, D. H., Allen, L. B., & Choate, M. L. (2016). Toward a Unified Treatment for Emotional Disorders - Republished Article. *Behav Ther, 47*(6), 838-853. doi:10.1016/j.beth.2016.11.005

Barnes, D. E., Yaffe, K., Satariano, W. A., & Tager, I. B. (2003). A longitudinal study of cardiorespiratory fitness and cognitive function in healthy older adults. *J Am Geriatr Soc, 51*(4), 459-465.

Barnes, R. T., Coombes, S. A., Armstrong, N. B., Higgins, T. J., & Janelle, C. M. (2010). Evaluating attentional and affective changes following an acute exercise bout using a modified dot-probe protocol. *J Sports Sci, 28*(10), 1065-1076. doi:10.1080/02640414.2010.489196

Bartley, C. A., Hay, M., & Bloch, M. H. (2013). Meta-analysis: aerobic exercise for the treatment of anxiety disorders. *Prog Neuropsychopharmacol Biol Psychiatry, 45*, 34-39. doi:10.1016/j.pnpbp.2013.04.016

Batelaan, N. M., Seldenrijk, A., Bot, M., van Balkom, A. J., & Penninx, B. W. (2016). Anxiety and new onset of cardiovascular disease: critical review and meta-analysis. *Br J Psychiatry, 208*(3), 223-231. doi:10.1192/bjp.bp.114.156554

Baxter, A. J., Scott, K. M., Ferrari, A. J., Norman, R. E., Vos, T., & Whiteford, H. A. (2014). Challenging the myth of an "epidemic" of common mental disorders: trends in the global prevalence of anxiety and depression between 1990 and 2010. *Depress Anxiety, 31*(6), 506-516. doi:10.1002/da.22230

Baxter, A. J., Vos, T., Scott, K. M., Ferrari, A. J., & Whiteford, H. A. (2014). The global burden of anxiety disorders in 2010. *Psychol Med, 44*(11), 2363-2374. doi:10.1017/S0033291713003243

Beard, C. (2011). Cognitive bias modification for anxiety: current evidence and future directions. *Expert Rev Neurother, 11*(2), 299-311. doi:10.1586/ern.10.194

Beck, A., T. (2008). The evolution of the cognitive model of depression and its neurobiological correlates. *Am J Psychiatry, 165*(8), 969-977. doi:10.1176/appi.ajp.2008.08050721

Beck, A., T., & Clark, D. A. (1997). An information processing model of anxiety: automatic and strategic processes. *Behav Res Ther, 35*(1), 49-58.

Beck, A., T., & Haigh, E., A. (2014). Advances in cognitive theory and therapy: the generic cognitive model. *Annu Rev Clin Psychol, 10*, 1-24. doi:10.1146/annurev-clinpsy-032813-153734

Beck, A., T., Steer, R., A., & Brown, G., K. (1996). Beck depression inventory.

Becker, E. S., Ferentzi, H., Ferrari, G., Mobius, M., Brugman, S., Custers, J., . . . Rinck, M. (2016). Always Approach the Bright Side of Life: A General Positivity Training Reduces Stress Reactions in Vulnerable Individuals. *Cognit Ther Res, 40*, 57-71. doi:10.1007/s10608-015-9716-2

Bisson, M. A. S., & Sears, C. R. (2007). The effect of depressed mood on the interpretation of ambiguity, with and without negative mood induction. *Cognition & Emotion, 21*(3), 614-645. doi:10.1080/02699930600750715

Blumenthal, J. A., Babyak, M. A., Doraiswamy, P. M., Watkins, L., Hoffman, B. M., Barbour, K. A., . . . Sherwood, A. (2007). Exercise and pharmacotherapy in the treatment of major depressive disorder. *Psychosom Med, 69*(7), 587-596. doi:10.1097/PSY.0b013e318148c19a

Bowler, J. O., Mackintosh, B., Dunn, B. D., Mathews, A., Dangleish, T., Hoppitt, L., & Avanzato, C. (2012). A Comparison of Cognitive Bias Modification for Interpretation and Computerized Cognitive Behavior Therapy: Effects on Anxiety, Depression, Attentional Control, and Interpretive Bias. *Journal of Consulting and Clinical Psychology, 80*(6), 1021-1033.

Brosan, L., Hoppitt, L., Selfer, L., Sillence, A., & Mackintosh, B. (2011). Cognitive bias modification for attention and interpretation reduces trait and state anxiety in anxious patients referred to an out-patient service: Results from a pilot study. *Journal of Behavior Therapy and Experimental Psychiatry, 42*. doi:10.1016/j.jbtep.2010.12.0 06

Butler, E., Mobini, S., Rapee, R. M., Mackintosh, B., Reynolds, S. A., & Walla, P. (2015). Enhanced effects of combined cognitive bias modification and computerised cognitive behaviour therapy on social anxiety. *Cogent Psychology, 2*(1), 905-1001. doi:10.1080/23311908.2015.1011905

Chalder, M., Wiles, N. J., Campbell, J., Hollinghurst, S. P., Haase, A. M., Taylor, A. H., . . . Lewis, G. (2012). Facilitated physical activity as a treatment for depressed adults: randomised controlled trial. *BMJ, 344*, e2758. doi:10.1136/bmj.e2758

Chisholm, D., Sweeny, K., Sheehan, P., Rasmussen, B., Smit, F., Cuijpers, P., & Saxena, S. (2016). Scaling-up treatment of depression and anxiety: a global return on investment analysis. *Lancet Psychiatry, 3*(5), 415-424. doi:10.1016/S2215-0366(16)30024-4

Cisler, J. M., & Koster, E. H. (2010). Mechanisms of attentional biases towards threat in anxiety disorders: An integrative review. *Clin Psychol Rev, 30*(2), 203-216. doi:10.1016/j.cpr.2009.11.003

Clark, D., A., & Beck, A., T. (2010). Cognitive theory and therapy of anxiety and depression: convergence with neurobiological findings. *Trends Cogn Sci, 14*(9), 418-424. doi:10.1016/j.tics.2010.06.007

Clark, D., A., & Steer, R., A. (1996). Empirical status of the cognitive model of anxiety and depression.

Clark, D. A., & Beck, A., T. (2011). *Cognitive therapy of anxiety disorders: Science and practice.*: Guilford Press.

Cohen, S., Kamarck, T., & Mermelstein, R. (1983). A global measure of perceived stress. *J Health Soc Behav, 24*(4), 385-396.

Colcombe, S. J., Erickson, K. I., Scalf, P. E., Kim, J. S., Prakash, R., McAuley, E., . . . Kramer, A. F. (2006). Aerobic exercise training increases brain volume in aging humans. *J Gerontol A Biol Sci Med Sci, 61*(11), 1166-1170.

Conn, V. S. (2010). Depressive symptom outcomes of physical activity interventions: meta-analysis findings. *Ann Behav Med, 39*(2), 128-138. doi:10.1007/s12160-010-9172-x

Cooper, S. L., & Tomporowski, P. D. (2017). Acute effects of exercise on attentional bias in low and high anxious young adults. *Mental Health and Physical Activity, 12*, 62-72. doi:10.1016/j.mhpa.2017.02.002

Cristea, I. A., Kok, R. N., & Cuijpers, P. (2015). Efficacy of cognitive bias modification interventions in anxiety and depression: meta-analysis. *Br J Psychiatry, 206*(1), 7-16. doi:10.1192/bjp.bp.114.146761

Daley, A. J. (2018). Exercise therapy and mental health in clinical populations: is exercise therapy a worthwhile intervention? *Advances in Psychiatric Treatment, 8*(04), 262-270. doi:10.1192/apt.8.4.262

Dauwan, M., Begemann, M. J., Heringa, S. M., & Sommer, I. E. (2016). Exercise Improves Clinical Symptoms, Quality of Life, Global Functioning, and Depression in Schizophrenia: A Systematic Review and Meta-analysis. *Schizophr Bull, 42*(3), 588-599. doi:10.1093/schbul/sbv164

De Moor, M. H., Beem, A. L., Stubbe, J. H., Boomsma, D. I., & De Geus, E. J. (2006). Regular exercise, anxiety, depression and personality: a population-based study. *Prev Med, 42*(4), 273-279. doi:10.1016/j.ypmed.2005.12.002

de Voogd, E. L., de Hullu, E., Burnett Heyes, S., Blackwell, S. E., Wiers, R. W., & Salemink, E. (2017). Imagine the bright side of life: A randomized controlled trial of two types of interpretation bias modification procedure targeting adolescent anxiety and depression. *PLoS One, 12*(7), e0181147. doi:10.1371/journal.pone.0181147

de Voogd, L., Wiers, R. W., de Jong, P. J., Zwitser, R. J., & Salemink, E. (2018). A randomized controlled trial of multi-session online interpretation bias modification training: Short- and long-term effects on anxiety and depression in unselected adolescents. *PLoS One, 13*(3), e0194274. doi:10.1371/journal.pone.0194274

de Vries, Y. A., de Jonge, P., van den Heuvel, E., Turner, E. H., & Roest, A. M. (2016). Influence of baseline severity on antidepressant efficacy for anxiety disorders: meta-analysis and meta-regression. *Br J Psychiatry, 208*(6), 515-521. doi:10.1192/bjp.bp.115.173450

Deslandes, A., Moraes, H., Ferreira, C., Veiga, H., Silveira, H., Mouta, R., . . . Laks, J. (2009). Exercise and mental health: many reasons to move. *Neuropsychobiology, 59*(4), 191-198. doi:10.1159/000223730

Dietrich, A., & Audiffren, M. (2011). The reticular-activating hypofrontality (RAH) model of acute exercise. *Neurosci Biobehav Rev, 35*(6), 1305-1325. doi:10.1016/j.neubiorev.2011.02.001

Dowd, S. M., Vickers, K. S., & Krahn, D. (2004). Exercise for depression: It really does help-here's how to get patients moving. *Current Psychiatry, 3*, 10-24.

Ekkekakis, P. (Ed.) (2013). *Routledge Handbook Of Physical Activity And Mental Health*. London & New York.

Ensari, I., Greenlee, T. A., Motl, R. W., & Petruzzello, S. J. (2015). Meta-Analysis of Acute Exercise Effects on State Anxiety: An Update of Randomized Controlled Trials over the Past 25 Years. *Depress Anxiety, 32*(8), 624-634. doi:10.1002/da.22370

Erickson, K. I., Leckie, R. L., & Weinstein, A. M. (2014). Physical activity, fitness, and gray matter volume. *Neurobiol Aging, 35 Suppl 2*, S20-28. doi:10.1016/j.neurobiolaging.2014.03.034

Everaert, J., Mogoase, C., David, D., & Koster, E. H. (2015). Attention bias modification via single-session dot-probe training: Failures to replicate. *J Behav Ther Exp Psychiatry, 49*(Pt A), 5-12. doi:10.1016/j.jbtep.2014.10.011

Fava, G. A., Gatti, A., Belaise, C., Guidi, J., & Offidani, E. (2015). Withdrawal Symptoms after Selective Serotonin Reuptake Inhibitor Discontinuation: A Systematic Review. *Psychother Psychosom, 84*(2), 72-81. doi:10.1159/000370338

Fitzgerald, A., Rawdon, C., & Dooley, B. (2016). A randomized controlled trial of attention bias modification training for socially anxious adolescents. *Behav Res Ther, 84*, 1-8. doi:10.1016/j.brat.2016.06.003

Fox, K. R. (1999). The influence of physical activity on mental well-being. *Public Health Nutr, 2*(3A), 411-418.

Geneen, L. J., Moore, R. A., Clarke, C., Martin, D., Colvin, L. A., & Smith, B. H. (2017). Physical activity and exercise for chronic pain in adults: an overview of Cochrane Reviews. *Cochrane Database Syst Rev, 4*, CD011279. doi:10.1002/14651858.CD011279.pub3

Ghahramanlou-Holloway, M., Wenzel, A., Lou, K., & Beck, A. T. (2007). Differentiating cognitive content between depressed and anxious outpatients. *Cogn Behav Ther, 36*(3), 170-178. doi:10.1080/16506070701374256

Gortner, E.-M., Rude, S. S., & Pennebaker, J. W. (2006). Benefits of expressive writing in lowering rumination and depressive symptoms. *Behavior Therapy, 37*(3), 292-303.

Gotlib, I. H., Kasch, K. L., Traill, S., Joormann, J., Arnow, B. A., & Johnson, S. L. (2004). Coherence and specificity of information-processing biases in depression and social phobia. *J Abnorm Psychol, 113*(3), 386-398. doi:10.1037/0021-843X.113.3.386

Hall, C. (2016). The Neuropsychological Effects of Exercise: A New Prescription for Healing. *UC Merced Undergraduate Research Journal, 9*(1), 2-11.

Haller, H., Cramer, H., Lauche, R., Gass, F., & Dobos, G. J. (2014). The prevalence and burden of subthreshold generalized anxiety disorder: a systematic review. *BMC Psychiatry, 14*(28), 128. doi:10.1186/1471-244X-14-128

Hallion, L., S., & Ruscio, A., M. (2011). A meta-analysis of the effect of cognitive bias modification on anxiety and depression. *Psychol Bull, 137*(6), 940-958. doi:10.1037/a0024355

Hansen, C. J., Stevens, L. C., & Coast, J. R. (2001). Exercise duration and mood state: How much is enough to feel better? *Health Psychology, 20*(4), 267-275.

Herring, M. P., Lindheimer, J. B., & O'Connor, P. J. (2014). The effects of exercise training on anxiety. *American Journal of Lifestyle Medicine, 8*(6), 388-403.

Hertel, P. T., & Mathews, A. (2011). Cognitive Bias Modification: Past Perspectives, Current Findings, and Future Applications. *Perspect Psychol Sci, 6*(6), 521-536. doi:10.1177/1745691611421205

Hillman, C., H., Erickson, K., I., & Framer, A., F. (2008). Be smart, exercise your heart: exercise effects on brain and cognition. *Nature Reviews: Neuroscience, 9*, 58-65.

Hirsch, C. R., Meeten, F., Krahé, C., & Reeder, C. (2016). Resolving ambiguity in emotional disorders: the nature and role of interpretation biases. *Annual review of clinical psychology, 12*, 281-305.

Hoffman, D. L., Dukes, E. M., & Wittchen, H. U. (2008). Human and economic burden of generalized anxiety disorder. *Depress Anxiety, 25*(1), 72-90. doi:10.1002/da.20257

Holmes, E. A., Lang, T. J., & Shah, D. M. (2009). Developing interpretation bias modification as a "cognitive vaccine" for depressed mood: imagining positive events makes you feel better than thinking about them verbally. *J Abnorm Psychol, 118*(1), 76-88. doi:10.1037/a0012590

Holmes, E. A., Mathews, A., Dalgleish, T., & Mackintosh, B. (2006). Positive interpretation training: effects of mental imagery versus verbal training on positive mood. *Behav Ther, 37*(3), 237-247. doi:10.1016/j.beth.2006.02.002

Holmes, M. K., Erickson, K., Luckenbaugh, D. A., Drevets, W. C., Bain, E. E., Cannon, D. M., . . . Zarate, C. A., Jr. (2008). A comparison of cognitive functioning in medicated and unmedicated subjects with bipolar depression. *Bipolar Disord, 10*(7), 806-815. doi:10.1111/j.1399-5618.2008.00628.x

Hoppitt, L., Illingworth, J. L., MacLeod, C., Hampshire, A., Dunn, B. D., & Mackintosh, B. (2014). Modifying social anxiety related to a real-life stressor using online Cognitive Bias Modification for interpretation. *Behav Res Ther, 52*, 45-52. doi:10.1016/j.brat.2013.10.008

Jakupcak, M., Wagner, A., Paulson, A., Varra, A., & McFall, M. (2010). Behavioral activation as a primary care-based treatment for PTSD and depression among returning veterans. *J Trauma Stress, 23*(4), 491-495. doi:10.1002/jts.20543

Janz, K. F. (2002). Use of heart rate monitors to assess physical activity. *Physical activity assessments for health-related research*, 143-161.

Joormann, J., & D'Avanzato, C. (2010). Emotion regulation in depression: Examining the role of cognitive processes. *Cognition & Emotion, 24*(6), 913-939. doi:10.1080/02699931003784939

Joormann, J., & Quinn, M. E. (2014). Cognitive processes and emotion regulation in depression. *Depress Anxiety, 31*(4), 308-315. doi:10.1002/da.22264

Joormann, J., Waugh, C. E., & Gotlib, I. H. (2015). Cognitive Bias Modification for Interpretation in Major Depression: Effects on Memory and Stress Reactivity. *Clin Psychol Sci, 3*(1), 126-139. doi:10.1177/2167702614560748

Keshavan, M., S., Vinogradov, S., Rumsey, J., Sherrill, J., & Wagner, A. (2014). Cognitive Training in Mental Disorders: Update and Future Directions. *m J Psychiatry, 171*, 510-522.

Kessler, R., C., & Greenberg, P., E. (2002). The Economic Burden Of Anxiety And Stress Disorders. *Neuropsychopharmcology, 67*, 981-992.

Khalili-Torghabeh, S., Salehi Fadardi, J., Mackintosh, B., Reynolds, S., & Mobini, S. (2014). Effects of a Multi-session Cognitive Bias Modification Program on Interpretative Biases and Social Anxiety Symptoms in a Sample of Iranian Socially-Anxious Students. *Journal of Experimental Psychopathology, 5*(4), 514-527. doi:10.5127/jep.037713

Krahé, C., Mathews, A., Whyte, J., & Hirsch, C., R. (2016). Cognitive bias modification for interpretation with and without prior repetitive negative thinking to reduce worry and rumination in generalised anxiety disorder and depression: protocol for a multisession experimental study with an active control condition. *BMJ Open, 6*(12). doi:10.1136/bmjopen-2016-013404

Krebs, G., Pile, V., Grant, S., Degli Esposti, M., Montgomery, P., & Lau, J. Y. (2018). Research Review: Cognitive bias modification of interpretations in youth and its effect on anxiety: a meta-analysis. *Journal of Child Psychology and Psychiatry, 59*(8), 831-844.

Krogh, J., Nordentoft, M., Sterne, J. A., & Lawlor, D. A. (2011). The effect of exercise in clinically depressed adults: systematic review and meta-analysis of randomized controlled trials. *J Clin Psychiatry, 72*(4), 529-538. doi:10.4088/JCP.08r04913blu

Lang, T. J., Blackwell, S. E., Harmer, C. J., Davison, P., & Holmes, E. A. (2012). Cognitive Bias Modification Using Mental Imagery for Depression: Developing a Novel Computerized Intervention to Change Negative Thinking Styles. *Eur J Pers, 26*(2), 145-157. doi:10.1002/per.855

Lawlor, D. A., & Hopker, S. W. (2001). The effectiveness of exercise as an intervention in the management of depression: systematic review and meta-regression analysis of randomised controlled trials. *British Medical journal, 322*, 1-8.

Lisk, S. C., Pile, V., Haller, S. P. W., Kumari, V., & Lau, J. Y. F. (2018). Multisession Cognitive Bias Modification Targeting Multiple Biases in Adolescents with Elevated Social Anxiety. *Cognitive Therapy and Research*. doi:10.1007/s10608-018-9912-y

Mackintosh, B., Mathews, A., Eckien, D., & Hoppitt, L. (2013). Specificity effects in the modification of interpretation bias and stress reactivity. *Journal of Experimental Psychopathology, 4*(2), 133-147.

Mackintosh, B., Mathews, A., Yiend, J., Ridgeway, V., & Cook, E. (2006). Induced biases in emotional interpretation influence stress vulnerability and endure despite changes in context. *Behav Ther, 37*(3), 209-222. doi:10.1016/j.beth.2006.03.001

MacLeod, C., & Mathews, A. (2012). Cognitive bias modification approaches to anxiety. *Annu Rev Clin Psychol, 8*, 189-217. doi:10.1146/annurev-clinpsy-032511-143052

Mathews, A., & Mackintosh, B. (2000). Induced emotional interpretation bias and anxiety. *Journal of Abnormal Psychology, 109*(4), 602.

Mathews, A., & MacLeod, C. (2005). Cognitive vulnerability to emotional disorders. *Annu Rev Clin Psychol, 1*, 167-195. doi:10.1146/annurev.clinpsy.1.102803.143916

McCrone, P. R., Dhanasiri, S., Patel, A., Knapp, M., & Lawton-Smith, S. (2008). *Paying the price: the cost of mental health care in England to 2026*: King's Fund.

McEntree, D. J., & Halgin, R. P. (1996). Therapists attitudes about addressing the role of exercise in Psychotherapy. *Journal of Clinical Psychology, 52*(1), 48-60.

Mendlowicz, M. V., & Stein, M. B. (2000). Quality of life in individuals with anxiety disorders. *Am J Psychiatry, 157*(5), 669-682. doi:10.1176/appi.ajp.157.5.669

Mennin, D. S., Fresco, D. M., Ritter, M., & Heimberg, R. G. (2015). An Open Trial of Emotion Regulation Therapy for Generalized Anxiety Disorder and Cooccurring Depression. *Depress Anxiety, 32*(8), 614-623. doi:10.1002/da.22377

Mogg, K., & Bradley, B. P. (2006). Time course of attentional bias for fear-relevant pictures in spider-fearful individuals. *Behav Res Ther, 44*(9), 1241-1250. doi:10.1016/j.brat.2006.05.003

Morina, N., Deeprose, C., Pusowski, C., Schmid, M., & Holmes, E. A. (2011). Prospective mental imagery in patients with major depressive disorder or anxiety disorders. *J Anxiety Disord, 25*(8), 1032-1037. doi:10.1016/j.janxdis.2011.06.012

Mutrie, N., & Faulkner, G. (2003). Physical activity and mental health. *In Interventions for mental health*, 82-97.

Notebaert, L., Clarke, P. J., Grafton, B., & MacLeod, C. (2015). Validation of a novel attentional bias modification task: the future may be in the cards. *Behav Res Ther, 65*, 93-100. doi:10.1016/j.brat.2014.12.007

O'Connor, D. B., & Shimizu, M. (2002). Sense of personal control, stress and coping style: a cross-cultural study. *Stress and Health, 18*(4), 173-183. doi:10.1002/smi.939

Otto, M. W., Church, T. S., Craft, L. L., Greer, T. L., Smits, J. A., & Trivedi, M. H. (2007). Exercise for mood and anxiety disorders. *Primary care companion to the Journal of clinical psychiatry, 9*(4), 287.

Paillard, T. (2015). Preventive effects of regular physical exercise against cognitive decline and the risk of dementia with age advancement. *Sports Med Open, 1*(1), 20. doi:10.1186/s40798-015-0016-x

Paluska, S. A., & Schwenk, T. L. (2000). Physical activity and mental health: current concepts. *Sports Med, 29*(3), 167-180.

Penedo, F. J., & Dahn, J. R. (2005). Exercise and well-being: a review of mental and physical health benefits associated with physical activity. *Curr Opin Psychiatry, 18*(2), 189-193.

Ploughman, M. (2008). Exercise is brain food: the effects of physical activity on cognitive function. *Dev Neurorehabil, 11*(3), 236-240. doi:10.1080/17518420801997007

Rapee, R. M., & Heimberg, R. G. (1997). A cognitive-behavioral model of anxiety in social phobia. *Behaviour Research and Therapy, 35*(8), 741-756.

Rebar, A. L., Stanton, R., & Rosenbaum, S. (2017). Comorbidity of depression and anxiety in exercise research. *Lancet Psychiatry, 4*(7), 519. doi:10.1016/S2215-0366(17)30164-5

Richards, A. (2004). Anxiety and the resolution of ambiguity. *Cognition, emotion and psychopathology: Theoretical, empirical and clinical directions*, 130-148.

Richards, A., & French, C. C. (1992). An anxiety-related bias in semantic activation when processing threat/neutral homographs. *The Quarterly Journal of Experimental Psychology Section A, 45*(3), 503-525.

Rose, E. A., & Parfitt, G. (2007). A quantitative analysis and qualitative explanation of the individual differences in affective responses to prescribed and self-selected exercise intensities. *J Sport Exerc Psychol, 29*(3), 281-309.

Rosnow, R. L., & Rosenthal, R. (2009). Effect sizes: Why, when, and how to use them. *Zeitschrift für Psychologie/Journal of Psychology, 217*(1), 6-14.

Roy, A., K., Vasa, R., A. , Bruck, M., Mogg, K., Bradley, B., P., Sweeney, M., . . . Pine, D., S. (2008). Attention Bias Toward Threat in Pediatric Anxiety Disorders. *J Am Acad Child Adolesc Psychiatry, 47*(10), 1189-1196. doi:10.1097/CHI

Rude, S. S., Wenzlaff, R. M., Gibbs, B., Vane, J., & Whitney, T. (2002). Negative processing biases predict subsequent depressive symptoms. *Cognition & Emotion, 16*(3), 423-440. doi:10.1080/02699930143000554

Salemink, E., Kindt, M., Rienties, H., & van den Hout, M. (2014). Internet-based cognitive bias modification of interpretations in patients with anxiety disorders: a randomised controlled trial. *J Behav Ther Exp Psychiatry, 45*(1), 186-195. doi:10.1016/j.jbtep.2013.10.005

Salemink, E., van den Hout, M., & Kindt, M. (2009). Effects of positive interpretive bias modification in highly anxious individuals. *J Anxiety Disord, 23*(5), 676-683. doi:10.1016/j.janxdis.2009.02.006

Salmon, P. (2001). Effects of physical exercise on anxiety, depression, and sensitivity to stress: a unifying theory. *Clin Psychol Rev, 21*(1), 33-61.

Saxena, S., Van Ommeren, M., Tang, K. C., & Armstrong, T. P. (2009). Mental health benefits of physical activity. *Journal of Mental Health, 14*(5), 445-451. doi:10.1080/09638230500270776

Scott, K. M., Bruffaerts, R., Tsang, A., Ormel, J., Alonso, J., Angermeyer, M. C., . . . Von Korff, M. (2007). Depression-anxiety relationships with chronic physical conditions: results from the World Mental Health Surveys. *J Affect Disord, 103*(1-3), 113-120. doi:10.1016/j.jad.2007.01.015

Smith, Summers, B., J., Dillon, K., H., Macatee, R., J., & Cougle, J., R. (2016). Hostile interpretation bias in depression. *Journal of Affective Disorders, 203*, 9-13.

Smith, E. (Ed.) (2000). *The body in psychotherapy.* NC: McFarland & Co.

Smith, J. C. (2013). Effects of emotional exposure on state anxiety after acute exercise. *Med Sci Sports Exerc, 45*(2), 372-378. doi:10.1249/MSS.0b013e31826d5ce5

Smith, J. C., & O'Connor, P. J. (2003). Physical activity does not disturb the measurement of startle and corrugator responses during affective picture viewing. *Biological Psychology, 63*(3), 293-310. doi:10.1016/s0301-0511(03)00072-3

Sowislo, J. F., & Orth, U. (2013). Does low self-esteem predict depression and anxiety? A meta-analysis of longitudinal studies. *Psychol Bull, 139*(1), 213-240. doi:10.1037/a0028931

Spielberger, C. D. (1983). Manual for the State-Trait Anxiety Inventory STAI (form Y)(" self-evaluation questionnaire").

Spitzer, R., L., Koroenke, K., Williams, J., B., W., & Lowe, B. (2006). A Brief Measure for Assessing Generalized Anxiety Disorder. *ARCH INTERN MED, 166*, 1092-1097.

Standage, H., Ashwin, C., & Fox, E. (2010). Is manipulation of mood a critical component of cognitive bias modification procedures? *Behav Res Ther, 48*(1), 4-10. doi:10.1016/j.brat.2009.08.005

Stathopoulou, G., & Powers, M. B. (2006). Exercise Interventions for Mental Health: A Quantitative and Qualitative Review. *CLINICAL PSYCHOLOGY: SCIENCE AND PRACTICE, 13*(2), 179-193.

Stonerock, G. L., Hoffman, B. M., Smith, P. J., & Blumenthal, J. A. (2015). Exercise as Treatment for Anxiety: Systematic Review and Analysis. *Ann Behav Med, 49*(4), 542-556. doi:10.1007/s12160-014-9685-9

Strohle, A. (2009). Physical activity, exercise, depression and anxiety disorders. *J Neural Transm (Vienna), 116*(6), 777-784. doi:10.1007/s00702-008-0092-x

Stubbs, B., Koyanagi, A., Hallgren, M., Firth, J., Richards, J., Schuch, F., . . . Vancampfort, D. (2017). Physical activity and anxiety: A perspective from the World Health Survey. *J Affect Disord, 208*, 545-552. doi:10.1016/j.jad.2016.10.028

Stubbs, B., Vancampfort, D., Rosenbaum, S., Firth, J., Cosco, T., Veronese, N., . . . Schuch, F. B. (2017). An examination of the anxiolytic effects of exercise for people with anxiety and stress-related disorders: A meta-analysis. *Psychiatry Res, 249*, 102-108. doi:10.1016/j.psychres.2016.12.020

Talukdar, T., Nikolaidis, A., Zwilling, C. E., Paul, E. J., Hillman, C. H., Cohen, N. J., . . . Barbey, A. K. (2017). Aerobic Fitness Explains Individual Differences in the Functional Brain Connectome of Healthy Young Adults. *Cereb Cortex*, 1-10. doi:10.1093/cercor/bhx232

Tian, Q., & Smith, J. C. (2011). Attentional bias to emotional stimuli is altered during moderate-but not high-intensity exercise. *Emotion, 11*(6), 1415-1424. doi:10.1037/a0023568

Tolmunen, T., Lehto, S. M., Julkunen, J., Hintikka, J., & Kauhanen, J. (2014). Trait anxiety and somatic concerns associate with increased mortality risk: a 23-year follow-up in aging men. *Ann Epidemiol, 24*(6), 463-468. doi:10.1016/j.annepidem.2014.03.001

Uth, N., Sorensen, H., Overgaard, K., & Pedersen, P. K. (2004). Estimation of VO2max from the ratio between HRmax and HRrest--the Heart Rate Ratio Method. *Eur J Appl Physiol, 91*(1), 111-115. doi:10.1007/s00421-003-0988-y

Vogelzangs, N., Seldenrijk, A., Beekman, A. T., van Hout, H. P., de Jonge, P., & Penninx, B. W. (2010). Cardiovascular disease in persons with depressive and anxiety disorders. *J Affect Disord, 125*(1-3), 241-248. doi:10.1016/j.jad.2010.02.112

Way, K., Kannis-Dymand, L., Lastella, M., & Lovell, G. P. (2018). Mental health practitioners' reported barriers to prescription of exercise for mental health consumers. *Mental Health and Physical Activity, 14*, 52-60. doi:10.1016/j.mhpa.2018.01.001

Weinstein, A., Maayan, G., & Weinstein, Y. (2015). A study on the relationship between compulsive exercise, depression and anxiety. *J Behav Addict, 4*(4), 315-318. doi:10.1556/2006.4.2015.034

White, L. K., Suway, J. G., Pine, D. S., Field, A. P., Lester, K. J., Muris, P., . . . Fox, N. A. (2018). The Cognitive and Emotional Effects of Cognitive Bias Modification in Interpretations in Behaviorally Inhibited Youth. *Journal of Experimental Psychopathology, 7*(3). doi:10.5127/jep.053615

Wiers, R. W., Bartholow, B. D., van den Wildenberg, E., Thush, C., Engels, R. C., Sher, K. J., . . . Stacy, A. W. (2007). Automatic and controlled processes and the development of addictive behaviors in adolescents: a review and a model. *Pharmacol Biochem Behav, 86*(2), 263-283. doi:10.1016/j.pbb.2006.09.021

Williams, D. M., Dunsiger, S., Ciccolo, J. T., Lewis, B. A., Albrecht, A. E., & Marcus, B. H. (2008). Acute Affective Response to a Moderate-intensity Exercise Stimulus Predicts Physical Activity Participation 6 and 12 Months Later. *Psychol Sport Exerc, 9*(3), 231-245. doi:10.1016/j.psychsport.2007.04.002

Appendix A Chapters in the Thesis that are Published or Under Review

◊ The research conducted in this doctoral thesis was funded by the department of Psychology at the University of Essex & the Economic Social Research Council under grant code; 1651378.

◊ Chapter 1 was submitted to the Journal of Cognitive Therapy & Research for the Anxiety and Health Special Issue on the 13th July 2018. This article at the time of thesis submission is under review.

◊ Chapter 2 was submitted to the Journal Frontiers in Psychology; Movement Science & Sport Psychology section on the 18th May 2018 as an original research article. This article is now published, please see published article on next page (citation is below).

Clarke, S., C., Cooper, N., R., Rana, M. & Mackintosh, B. (2018). Cognitive Interpretation Bias: The Effect of a Single Session Moderate Exercise Protocol on Anxiety and Depression. *Frontiers in Psychology*, *9*, 1363. doi:10.3389/fpsyg.2018.01363.

---

frontiers in Psychology

ORIGINAL RESEARCH
published: 08 August 2018
doi: 10.3389/fpsyg.2018.01363

Cognitive Interpretation Bias: The Effect of a Single Session Moderate Exercise Protocol on Anxiety and Depression

Séraphine C. Clarke*, Nicholas R. Cooper, Mirinalee Rana and Bundy Mackintosh

Department of Psychology, Centre for Brain Sciences, University of Essex, Colchester, United Kingdom

Research conducted within the cognitive bias modification (CBM) paradigm has revealed that cognitive biases such as negative cognitive interpretation biases contribute to mental health disorders such as anxiety (Beard, 2011). It has been shown that exercise reduces anxiety (Ensari et al., 2015). Exercise has also been found to reduce negative cognitive attention biases (Tian and Smith, 2011), however, no research to date has investigated the effect of exercise on cognitive interpretation bias. The key aims of the current project is to investigate whether moderate exercise reduces self-reported symptoms of depression and stress. Additionally, to establish which intensity of exercise is required to achieve anxiety reduction and reduce an individual's negative cognitive interpretation biases. Study 1 recruited a healthy sample of adult participants who were randomly assigned to one of two conditions: a walking exercise protocol or a control condition ($n = 2 \times 12$). Participants completed anxiety and cognitive interpretation bias measures before and after the walking exercise or control condition. Those in the walking exercise condition presented less symptoms of trait anxiety on a measure of state and trait anxiety inventory (STAI), compared to controls relative to baseline measures following the intervention. Study 2 recruited frequent exercisers who were assigned to an exercise or control group ($n = 2 \times 24$). Participants completed anxiety, depression, psychological stress, and cognitive interpretation bias measures before and after the exercise or control condition. Following the intervention, negative interpretation biases decreased in the exercise group and stayed stable in the control group. The exercise group also had significantly decreased anxiety, depression, and stress measures after the exercise condition, while controls did not. The research concludes that CBM holds promise for the management of mood disorders and exercise is an effective accompaniment to psychotherapy.

Keywords: anxiety, depression, ameliorating affect, mood enhancement, cognitive interpretation bias, physical exercise

OPEN ACCESS

Edited by:
Sergio Machado,
Salgado de Oliveira University, Brazil

Reviewed by:
Federica Sancassiani,
Università degli Studi di Cagliari, Italy
Debora Cutuli,
Sapienza Università di Roma, Italy

****Correspondence:***
Séraphine C. Clarke
clarkepsy@outlook.com

Specialty section:
This article was submitted to Movement Science and Sport Psychology, a section of the journal Frontiers in Psychology

Received: *18 May 2018*
Accepted: *16 July 2018*
Published: *08 August 2018*

Citation:
Clarke SC, Cooper NR, Rana M and Mackintosh B (2018) Cognitive Interpretation Bias: The Effect of a Single Session Moderate Exercise Protocol on Anxiety and Depression. Front. Psychol. 9:1363. doi: 10.3389/fpsyg.2018.01363

INTRODUCTION

The beneficial effects of acute and chronic exercise on healthy individuals and those with sub-clinical or clinical anxiety and depression have been well established (Herring et al., 2014; Stubbs et al., 2017) and exercise has been advocated as a treatment for maladaptive mood and emotional problems (Paluska and Schwenk, 2000; Barbour and Blumenthal, 2005;

Penedo and Dahn, 2005; Otto et al., 2007). Health care providers such as the National Health Service (NHS) in the United Kingdom have advocated exercise interventions independent or in conjunction with psychological and/or pharmacological therapies for affective emotional problems (Fox, 1999; Saxena et al., 2009; Daley, 2018). Benefits of physical exercise in a variety of different physical disorders including diabetes, renal disease, and osteoporosis, has been shown to be effective (Fentem, 1994). There is also a strong body of evidence regarding the physiological benefits of regular physical exercise on the human body (Salmon, 2001; Asmundson et al., 2013), as well as improved psychological wellbeing (Fox, 1999). Exercise is arguably not a panacea for mental health problems, however, it can reduce the symptoms of the less severe cases of anxiety, chronic stress and depression, and in turn could reduce rising health costs nationally and internationally (McCrone et al., 2008).

Although anxiety disorders are characterized particularly by symptoms of worry, the basis of vulnerability and fundamental mechanisms are common in all anxiety disorders (Mineka et al., 1998). The study of the cognitive dimensions of anxiety focuses on this notion of vulnerability (Clark and Beck, 2011). Vulnerability is defined as an individual's perception of the 'self' that is exposed to internal and external threat over which the individual has little or no control to provide a reassurance of security or safety (Beck et al., 2005). Also, in the previous 30 years or so, cognitive models of anxiety and depression disorders have greatly highlighted the fundamentally crucial part selective information processing (so-called 'cognitive bias') plays in the development and maintenance of emotional psychopathology (Beck and Clark, 1997). However, the effects of physical exercise on the processing of these threat-related negative cognitive biases in individuals who experience frequent and severe episodes of anxiety and anxiety disorders is much less understood (Cooper and Tomporowski, 2017).

Physical activity and physical exercise are definitions that are usually used interchangeably, however, these concepts are not the same. Physical activity is defined as any bodily movement producing the expending of energy. While physical exercise is a subset of physical activity that is routine and structured with the aim to improve cardiovascular fitness level and overall health and wellbeing (Caspersen et al., 1985). Research has primarily focused on structured physical exercise programs relative to its psychological benefits, although there has been an emergence of cross-sectional studies which have consistently shown high self-reported levels of habitual physical activity to be associated with better mental health (Salmon, 2001). Research into the effects of exercise on emotion is predominantly focused on self-reported measures of anxiety, stress and depression symptoms or on clinical psychological assessment measures, to investigate the effects of exercise after a single protocol of exercise, a training program or affective responses during physical exercise (Williams et al., 2008; Ekkekakis, 2013). These experiments have undoubtedly given insights on benefits of exercise on alleviating moods and there is substantial evidence for this relationship to be considered as a therapeutic approach in the treatment of anxiety disorders (Fox, 1999). Previous research by Hansen et al. (2001) and Salmon (2001) suggest that exercise is emotion enhancing when it is performed at a 'manageable level' for the individual that is engaged in the activity.

Clinical and subclinical levels of anxiety are associated with biases in the predominant and automatic strategic stages of attention (Bar-Haim et al., 2007), while depression is associated with cognitive biases in the later stages (Gotlib et al., 2004; Joormann and D'Avanzato, 2010; Hallion and Ruscio, 2011). However, depression and anxiety are highly comorbid (Brown et al., 2001) and anxiety has also been associated with negative cognitive interpretation bias as well as attentional biases (Mathews and MacLeod, 2005; Hallion and Ruscio, 2011). This proposes another understanding of anxiety, perhaps it is characterized by attentional bias, the tendency to search for high risk, threatening or danger to the self, and also interpretation biases which is a tendency to evaluate present and past situations in negative, rather than benign or positive, manner. While depression may only be characterized by interpretation biases, which would explain why individuals with depression commonly ruminate about situations from the past (Krahé et al., 2016). Furthermore, the psychotherapy interventions in place for anxiety and depression disorders are grounded in cognitive theory that rest heavily on the assumption that cognitive biases are causally related to symptoms. These assumptions have been demonstrated and a strong relationship between anxiety, depression and a variety of negative cognitive biases (attentional, interpretational, and memory) is becoming established in the literature (Mathews and MacLeod, 2005; Vrijsen et al., 2014). Individuals who suffer with anxiety or depression are therefore likely to have negative cognitive interpretation biases (Richards and French, 1992; Richards, 2004).

Cognitive models of the functioning of anxiety suggest that there are biased routes of our fundamental information processing, operating within our cognitive system that possibly are not consciously accessible and these are important in experiencing an unexpected manifestation of anxiety (Mathews and MacLeod, 2005). It is suggested that individuals who present with anxiety and depression tend toward the negative aspect of ambiguous situations and therefore inclined to interpret such ambiguous and neutral conditions negatively instead of positively. Negative mood states are frequently related to negative cognitive biases of attention and interpretation (Rose and Parfitt, 2007). Individuals who suffer with clinical disorders such as anxiety, stress and depression, frequently exhibit a preferential response toward negative relative to positive or benign/neutral information and have a tendency to interpret ambiguous situations and environments negatively rather than positively. There is evidence to suggest that cognitive biases are rooted in psychological processes in clinical populations; suggesting that anxiety and stress-related symptoms could be considerably reduced in vulnerable populations if we could reduce their tendency to make negative cognitive biases and thereby improve mood state (Mackintosh et al., 2006; Brosnan et al., 2011). In terms of cognitive bias, depression and anxiety are associated with difficulty in disengaging one's attention from mood-congruent (negative) self-relevant stimuli. This may be coupled with attentional avoidance to positive stimuli. Together, these lead to a decrease in positive mood and increase in negative depressive symptoms (Gotlib et al., 2004; Mathews and MacLeod, 2005).

Research conducted by Salmon (2001), suggests attention to aerobic exercise has been unproportionate to the focus given to non-aerobic exercises in which muscle activity is brief, high intensity and is not maintained. Aerobic physical exercise can be defined as an activity involving large muscle groups, increased heart rate and respiration, such as swimming, running, and aerobic dancing. According to a meta-analysis by Petruzzello et al. (1991), there were no significant disparities between the types of aerobic exercise an individual engaged in, the only significant differences were aerobic physical exercise having an increased positive effect on mood than non-aerobic exercises. These studies consistently show an improvement in mood after engaging in an aerobic exercise protocol. However, a study by Gupta et al. (2006) investigated the effect of a non-aerobic short-term yoga program on individuals with various mental and physical health issues, specifically anxiety. Their findings suggest the yoga program significantly reduced participants self-reported state and trait anxiety levels from by the end of the program. This suggests that some non-aerobic exercise can have a positive effect on reducing self-report anxiety, in this case specifically for a clinical sample.

Smith (2013) investigated the role of moderate exercise on emotional affect, using an exercise protocol and the perceived rated level of exertion scale (PRE) to achieve a moderate amount of exercise enough to be deemed beneficial. Smith (2013) found that moderate exercise reduced levels of state anxiety and concluded that moderate exercise has anxiolytic effects and, furthermore, could be resistant to emotionally arousing negative/threatening stimuli. This has implications for how positive mood could be potentially protected by moderate exercise even when individuals are presented with negative imagery. This effect of emotional resilience has also been reported by O'Connor and Shimizu (2002).

Research into the effects of exercise training on cognitive interpretation biases in anxiety, depression, and stress-related disorders is sparse and the insight it could lend to our understanding of the cognitive mechanisms could be valuable. The key aims of the present study is to establish which intensity of exercise is required to achieve anxiety reduction and whether this is related to changes in an individual's negative cognitive interpretation biases. Furthermore, it will investigate whether there will be a reduction in anxiety when exercise is performed and reduces self-reported symptoms of depression and stress. These research aims will be addressed with two experimental studies. The hypothesis of Study 1 is that there will be significant decrease in negative interpretation bias while under a cognitive load (remembering a six-digit number during the task) compared to when not under a cognitive load and a reduction in anxiety measures in the walking exercise condition relative to the control condition.

STUDY 1

Methodology

Participants

Twenty-four participants were recruited to take part in this study from a student population at the University of Essex, Colchester, United Kingdom (see **Table 1** for mean age, gender ratio, and mean HR rest). To be eligible, individuals had to be able to engage in physical activity. Study requirements were that individuals did not exercise for 12 h prior to participating and must be fluent in spoken and written English. Participants were told they would be required to complete a series of questionnaires, and they may or may not be required to undertake a walking exercise protocol. Ethical approval was granted from the University of Essex Ethics Committee.

Materials

State and trait anxiety

The state and trait components of the State Trait Anxiety Inventory (STAI; Spielberger, 1983) questionnaire were used to assess global and transient levels of anxiety. The STAI assesses apprehension, tensions, nervousness, and worry in 20 questions on a 4-point Likert scale. The first part measures state anxiety; which is an immediate measure of the participant's current state of anxiety. The second part is the trait anxiety scale, which measures an individual's predisposition for personal anxiety. This scale has been identified as a reliable tool for assessing anxiety and an individual's aggregate. Reliability scores of this scale range from 0.65 to 0.86 for the trait version and 0.16 to 0.62 for the state version (Barnes et al., 2010).

Cognitive interpretation bias

The Scrambled Sentences Test (SST; Rude et al., 2002; Standage et al., 2010) was used to measure negative cognitive interpretation bias. The SST involves unscrambling a list of 20 sentences, this is done in cognitively non-loaded and cognitively loaded conditions, where the participant is subject to a simultaneous cognitive load task or not (e.g., remembering a six-digit number). Participants firstly, had the task explained to them by the researcher and then were asked to complete three practice questions, which were scored before the participant completed the SST to ensure they understood the task correctly, the practice question scores were not recorded for further analysis. For the loaded and non-loaded trials, only those during which the participant correctly recalled the six-digit number were included for analysis. Participants had 4 min to complete as many of scrambled sentences as possible. The score of negative or positive responses to the cognitive interpretation bias tasks were then collected and recorded. This method aims to investigate the tendency of each individual to interpret ambiguous information either positively or negatively and was measured before and after the intervention. From the data gathered, a negative interpretation bias score was calculated using Eq. (1). The SST has been suggested to be reliable at establishing a cause and effect between negative interpretation biases and predicting there after depressive symptoms for up to 8 weeks post SST (Rude et al., 2002).

$$SST = 100 \times \frac{Negative}{Correct} \qquad (1)$$

Design

Anxiety measures are assessed using a 2 × 2 mixed factorial design in which the within-subjects factor is Time (Session 1 and Session 2) and the between-subjects factor is Intervention group. The SST data is analyzed with a mixed measures 2 × 2 × 2 factorial design: SST-type (Load/NoLoad) × Session (Session 1 and Session 2) × Intervention (walking exercise/Control Group). The within-subjects variables are SST-type, and Session, while the between-subjects factor is the intervention (walking exercise) or control group.

Procedure

Once participants were recruited and deemed eligible for the study, they were invited to a study appointment with the primary researcher. The researcher summarized the process of the experiment and what would be required of them for participation. Participants then read through an information sheet, signed a consent form and were informed of their right to withdraw without penalty.

Participants were randomly assigned to one of the two Intervention groups: walking exercise group (n = 12), and the control group (n = 12). Randomization was achieved by assigning each individual a participant identification number between 1 and 24, each ID number was randomly assigned the digit one or two for respective groups in equal proportions (1: walking exercise group, 2: control group). The experiment was split into session 1 and session 2, in-between the sessions the participants either completed the moderate walking exercise or had 30 min to relax (control group). The order in which the SST's were administered were counterbalanced (load or non-load).

Session 1

All participants completed the state and trait versions of the STAI to measure self-reported anxiety before the experimental and control condition to establish an accurate baseline. All participants then did the practice SST and completed the first and second measures of interpretation bias (SST) both cognitively loaded and non-loaded which they had 4 min to do each set of 20 sentences.

Intervention

The exercise group spent 30 min walking at a brisk pace around the University grounds, and then were invited back into the experiment lab. The control group spent the 30-min period in the experiment lab, the only stipulation was to refrain from internet use, social media, and not use their mobile phones.

Session 2

All participants then completed different versions of the SST (loaded and non-loaded) followed by the STAI. Once completed each participant was thanked for their participation and debriefed. Participants were provided with a copy of the debrief information, which outlined the aims of the study and how all participant data is anonymized and kept securely. They were provided contact details of the primary researcher in the instance they would like more information about the study or would like to withdraw from the study post-participation.

Data Analytic Approach

A mixed measures 2 × 2 × 2 mixed factorial ANOVA was used to analyze the data collected to investigate; Load/No Load × Walking Exercise/No Exercise × Session 1/Session 2. The within-subjects variable is whether the SST was cognitively loaded/non-loaded, and session 1/session 2, while the between-subjects factor is the moderate exercise/control group. A 2 × 2 ANOVA was used to measure the effect of moderate intensity exercise on state and trait anxiety. The within-subjects factor is session 1/session 2, while the between-

TABLE 1 | Study 1: Mean and standard deviation for walking and control condition for STAI and SST measures.

	Baseline: Session 1 Post condition: Session 2	*N*	Mean, range, and *SD* age	Gender ratio M:F	Walking exercise condition Mean (*SD*)	Control condition Mean (*SD*)
STAI-S	Session 1	12	Walking Exercise Group Mean: 29.50 Range: 21–40 *SD*: 7.03	Walking Exercise Group: 1:5	37.58 (9.22)	33.25 (9.88)
	Session 2				30.50 (8.74)	31.08 (941)
STAI-T	Session 1	12			44.0 (13.78)	38.5 (9.51)
	Session 2				40.41 (15.69)	38.16 (11.18)
SST Cognitively loaded	Session 1	12	Control Group:	Control Group: 2:4	30.87 (27.67)	19.64 (19.74)
	Session 2				31.18 (28.08)	14.96 (13.81)
			Mean: 28.58 Range: 22–38 *SD*: 5.45			
SST Cognitively non-loaded	Session 1	12			26.58 (23.19)	19.50 (15.37)
	Session 2				31.16 (29.08)	22.56 (21.91)

subjects factor is the exercise/control group. Any significant effects found will be further investigated with Tukey HSD *post hoc* tests.

Results

Preliminary Analysis

Before the full analysis was conducted, preliminary analysis of the data was conducted to investigate the assumptions of parametric tests; the data was assessed for outliers using box plot graphs, no outliers were identified. The histogram of standardized residuals indicated that the data contained approximately normally distributed errors, as did the normal P–P plot of standardized residuals, which showed points that were close to the line of fit. Levene's test of homogeneity of variance was also used and found for all measures to be non-significant and therefore did not violate the assumption of homogeneity of variance. The scatterplot of standardized residuals showed that the data met the assumptions of homogeneity of variance and linearity. The Box's test was insignificant for the analysis of experimental group, loading, and time on the SST's, and was also insignificant for the STAI measures. The assumptions of parametric data were not violated, therefore parametric analyses could be performed.

Main Effects

There was a significant effect of pre and post measures of state anxiety measures $F(1, 23) = 10.17$, $p < 0.005$, $\eta_p^2 = 0.316$, but no significant main effect of intervention group $F(1, 23) = 2.87$, $p = 0.10$ (**Table 1**). The interaction between session and intervention group was statistically significant for trait anxiety, $F(1, 23) = 5.02$, $p < 0.05$, $\eta_p^2 = 0.186$ (**Table 1**). A Tukey HSD *post hoc* test confirmed that participants in the walking exercise condition significantly decreased in trait anxiety measures ($SE = 0.72$), $p < 0.01$. There was no significant effect of the intervention on interpretation bias scores (SST) $F(1, 23) = 0.37$, $p = 0.54$.

Discussion

The findings from Study 1 suggests a significant decrease in self-reported trait anxiety measures when participants underwent a single session walking exercise protocol. However, the hypothesis is only partially supported, because there was no significant effect of walking exercise on state anxiety measures relative to the control condition. Furthermore, walking exercise had no significant effect on negative interpretation bias measures, both cognitively loaded and non-loaded, relative to the control group. The reduction in self-reported state anxiety supports the hypothesis, however, the effect was not relevant to group, therefore this rests on a reduction in state anxiety over time and one cannot assume this was due to the walking exercise intervention. There was a significant reduction in trait anxiety relative to the intervention group, from this we can suggest that the walking exercise had a positive effect on mood and in turn reduced individuals self-reported trait anxiety. This was in comparison to the control group which as hypothesized did not decrease in self-report trait anxiety measures, suggesting that a rest control condition does not improve mood state. This holds promise for the foundations of this research, which was the anxiolytic affect that physical activity has for anxiety and mood enhancement in general.

These findings suggest that as little as 30 min of low intensity exercise such as walking can have a positive effect on mental wellbeing, by reducing self-reported trait anxiety. However, it would seem that more moderate cardiovascular exercise is required to affect an individual's cognitive interpretation biases.

STUDY 2

Introduction

Research has previously investigated the role of cognitive interpretation biases in stress reactivity (Mackintosh et al., 2013; Joormann et al., 2015). However, research to date has not investigated the effect of cognitive interpretation bias on perceived psychological stress as an independent factor, despite their being support for a link between clinical depression and perceived stress (Joormann and Quinn, 2014; Joormann et al., 2015). Indeed, our understanding of which psychological mechanisms mediate stress and how they affect mental health has been unclear (Creswell et al., 2005). Stress is a physiological disruption caused by tangible or subjective threats, which disrupt an individual's physical or psychological state and may be caused by a single or combined physical, physiological, and psychosocial conditions (Sapolsky, 2004; Iwasaki, 2006). The stress response through the hypothalamic–pituitary–adrenal axis is thought to be a major physiological mechanism in which stress influences one's health and cognition (Cohen et al., 2007; Norman et al., 2011). Previous research has also found that increased perceived psychological stress correlates with depression (Mazure, 1998; Hammen, 2005). Perceived levels of stress are suggested to be an important factor when studying the effects of exercise on cognitive biases (Salmon, 2001). Kajtna et al. (2011) investigated the effect of mood states on experienced levels of stress, they found no significant correlation between high experienced levels of stress and negative mood-states. This suggests that the physiological effect of stress has no effect on negative emotions and perhaps no effect on cognitive biases. This suggests support for the concept that mood enhancement of which elicited form exercise will not affect an individual's cognitive bias, while there is also support to the contrary (Hallion and Ruscio, 2011). Furthermore, various studies have found support for the notion that those who suffer with clinical depression preferentially encode threatening interpretations (Mogg and Bradley, 2006; Mogg and Bradley, 2016). However, the evidence is not clear-cut and others have found no such evidence of negative interpretation bias in depressed individuals (Bisson and Sears, 2007).

Research into the effects of exercise training on cognitive interpretation biases in anxiety, depression and stress-related disorders is sparse and the insight it could lend to our understanding of the cognitive mechanisms could be valuable. The key aims of the present study is to establish at which intensity of exercise is required to achieve anxiety reduction and whether this is related to changes in an individual's negative cognitive interpretation biases. Furthermore, it will investigate whether moderate exercise reduces self-reported symptoms of depression and stress. These research aims will be addressed with two experimental studies. The second study hypothesizes is that there will be significant decrease in negative interpretation bias while cognitively loaded, and a reduction in depression, stress, and anxiety measures in the moderate exercise condition relative to the control condition.

The key aims of the present study is to establish at which intensity of exercise is required to achieve anxiety reduction and whether this is related to changes in an individual's negative cognitive interpretation biases. Furthermore, it will investigate whether moderate exercise reduces self-reported symptoms of anxiety, depression and stress. The hypothesizes for this second experimental study is that there will be significant decrease in negative interpretation bias while cognitively loaded, and a reduction in depression, stress, and anxiety measures in the moderate exercise condition relative to the control condition.

Methodology

Participants

Forty-eight participants were recruited to participate in the study from a general population sample at a private gym in which they were members and randomly assigned to either an exercise or non-exercise (control) group (see **Table 2** for mean age, gender ratio, and mean HR rest). Randomization was achieved by assigning each individual a participant identification number between 1 and 48, each ID number was randomly assigned the digit one or two for respective groups in equal proportions (1: exercise group, 2: control group). Participants were recruited from and the experiment was conducted in, a private members gym in Colchester, United Kingdom. Eligibility requirements were that individuals must refrain from cardiovascular exercise 12 h prior to the experiment (regardless of the intensity) and they must be fluent in spoken and written English. Participants had to be over 18 years old and be regular gym users (twice a week or more) in order to be eligible. Participants were made told that the research had no affiliation with the gym, nor was there any obligation for them to participate. Ethical approval was granted from the University of Essex Ethics Committee.

Materials

State and Trait Anxiety and Cognitive interpretation bias (SST) were measured as in Study 1.

Depressive symptoms

The revised Beck Depression Inventory (BDI-II; Beck et al., 1996) was used in this research because it measures attitudes, characteristics, and symptoms associated with depression. It is a 21 item inventory measured with a 4-point Likert scale. The BDI-11 score is calculated by totaling the answers from each questionnaire and scores of above 30 are indicative of severe depression.

Perceived psychological stress

The Perceived Stress Scale (PSS; Cohen et al., 1983) was used to measure how stressed the participant perceived themselves as being over the past 2 months. Responses on the 14-point scale are given on a rating of one (never) to four (always). The PSS contains questions such as "How often in the past 2 months have you dealt successfully with irritating life hassles?" and is used to measure an individual's perception of how they are coping with stressors. Furthermore, this suggests that due to current circumstances an individual's perception of their level of coping with stressors can change sporadically.

Design

This experiment used a mixed measures 2 × 2 × 2 factorial design; which will be used to analyze the data collected to investigate hypothesis one; Load/Non-Load × Exercise/ControlGroup × Session1/Session2. The within-subjects variable is the cognitively loaded or non-loaded SST, and session 1/session 2, while the between-subjects factor is the exercise/control group. The data analysis approach will use a 2 × 2 mixed factorial design; in which the within-subjects factor is Session1/Session2 (before and after experimental/control condition), and the between-subjects factor is exercise/control group. The dependent variables are the self-report measures of anxiety (STAI), stress (PSS), depression (BDI-II), and interpretation bias (SST).

Procedure

Once participants were recruited and deemed eligible for the study, they were invited to a study appointment with the primary researcher. The researcher summarized the process of the experiment and what would be required of them for participation. Participants then read through an information sheet, signed a consent form and were informed of their right to withdraw without penalty.

Participants were randomly assigned to the intervention group (n = 24) or the control group (n = 24) the experiment was split into session 1 and session 2, in-between the sessions the participants either completed the moderate intensity exercise protocol or had 40 min to relax.

Session 1

Participants completed the STAI, BDI-II, and PSS. They then had 4 min to complete each SST (the order of which were counter balanced between subjects). Although participants were for the majority randomly assigned to groups, a running tally was kept of gender and the state and trait anxiety scores (STAI) from session one, to allow for a homogenized sample in both the experimental and control group.

Intervention

Participants were assigned to either the experimental condition (a moderate exercise protocol) or the control condition, in which the participants had 40 min to relax until the second session of the experiment. The exercise protocol was compliant to current health and safety regulations as set out by the gym being used. The duration and intensity used was similar to previous research (e.g., Hansen et al., 2001; Russell, 2003), and based on findings that advocates that 85% of the cardiovascular aerobic heart rate reserve of each individual should be maintained for 20–30 min to achieve the desired benefits of aerobic activity (Barnes et al., 2010), which was relevant for the aims of this research. This research used a static cycle machine (York-Fitness-Model-110) in the gymnasium, as this reduces impact on joints and is safest for the participant, as they remain seated. The static-cycle machine was used to measure heart rate so that the desired aerobic heart rate that is necessary for the experiment can be monitored and adhered to respectively. This provided participants with continuous feedback of their heart rate reserve and when to increase/decrease their aerobic intensity. Heart rate monitors are recognized to be a reliable and valid measure of measuring exercise intensity and rate of exertion during aerobic exercise (Janz, 2002). Aerobic heart rate reserve was calculated using Eq. (2) (Uth et al., 2004). The exercise protocol consisted of a light warm up of low-intensity; which is 20% of heart rate reserve for 5 min, and then increased to 80% heart rate reserve for 30 min, then concluded with a 'cool down' which was low-intensity pedaling for 5 min using 20% heart rate reserve.

$$\begin{aligned} &HR\,reserve = HR\,resting - HRmaximum \\ &Z = 80\%\ of\ reserve \\ &Z + HR\,resting = Aerobic\,Heart\,Rate \end{aligned} \tag{2}$$

Session 2

Participants were invited back into the private consultation room to complete the third and fourth SSTs (counterbalanced between subjects) followed by the STAI, BDI-II, and PSS questionnaires. Once completed each participant was thanked for their participation and debriefed. Participants were provided with a copy of the debrief information, which outlined the aims of the study and how all participant data is anonymized and kept securely. They were provided contact details of the primary researcher in the instance they would like more information about the study or would like to withdraw from the study post-participation.

Data Analytic Approach

A mixed measures 2 × 2 × 2 mixed factorial ANOVA was used to analyze the data collected to investigate hypothesis one; Load/No Load × Exercise/No Exercise × Session1/Session2. The within-subjects variable is whether the SST was cognitively loaded/non-loaded, and session 1/session 2, while the between-subjects factor is the moderate exercise/control group. A 2 × 2 ANOVA was used to measure the effect of moderate intensity exercise on anxiety, depression, and perceived levels of psychological stress. The within-subjects factor is session 1/session 2, while the between-subjects factor is the exercise/control group. Any significant effects

TABLE 2 | Study 2: Means and standard deviations for STAI, PSS, BDI-II, and SST measures for moderate exercise and control condition.

	Baseline: Session 1 Post condition: Session 2	*N*	Mean, range, and *SD* age	Gender ratio M:F	Moderate exercise condition Mean (*SD*)	Control condition Mean (*SD*)
STAI- S	Session 1	24	Exercise Group: Mean: 27.79 Range: 20–47 SD: 7.30	Exercise Group: 10:14	46.33 (12.49)	38.75 (6.74)
	Session 2	24			31.04 (7.6)	39.58 (5.61)
STAI- T	Session 1	24			44.42 (7.87)	38.42 (7.87)
	Session 2	24			33.33 (10.70)	40.00 (6.20)
PSS	Session 1	24	Control Group: Mean: 25.66 Range: 19–42 SD: 6.22	Control Group: 9:15	31.75 (5.11)	25.21 (6.46)
	Session 2	24			22.29 (4.51)	22.54 (5.70)
BDI-II	Session 1	24			17.63 (7.44)	12.46 (5.70)
	Session 2	24			6.58 (3.85)	11.88 (5.60)
SST Cognitively loaded	Session 1	20	Exercise Group: *N* = 8 Mean: 30.12 Range: 20–47 SD: 10.65	Exercise Group: 1:3	46.66 (16.63)	45.37 (16.97)
	Session 2	20			42.77 (33.13)	52.92 (22.38)
SST Cognitively non-loaded	Session 1	20	Control Group: *N* = 12 Mean: 26.91 Range: 19–38 SD: 5.88	Control Group: 5:7	79.27 (17.39)	52.18 (25.75)
	Session 2	20			14.53 (6.47)	45.29 (20.01)

found will be further investigated with Tukey HSD *post hoc* tests.

Results

Preliminary Analysis

Before the full analysis was conducted, preliminary analysis of the data was conducted to investigate the assumptions of parametric tests; the data was assessed for outliers using box plot graphs, there were outliers for STAI-State, STAI-Trait, and BDI-II. Due to a modest sample size it was deemed appropriate to leave the outliers in.

The histogram of standardized residuals indicated that the data for SST, STAI-State, STAI-Trait, BDI-II, and PSS contained approximately normally distributed errors, as did the normal P–P plot of standardized residuals, which showed points that were close to the line of fit. In respect that Kolmogorov–Smirinov test showed several dependent variables to not be normally distributed, therefore skew and kurtosis *z*-scores were calculated to investigate any positive or negative skew in the data set. The skew and kurtosis *z*-scores calculated showed no obvious positive or negative skew to the data. Levene's test of homogeneity of variance was also used and found for all measures to be non-significant and therefore did not violate the assumption of homogeneity of variance.

The scatterplot of standardized residuals showed that the data met the assumptions of homogeneity of variance and linearity. The Box's test was insignificant for the analysis of experimental group, loading, and time on the SST's, and was also insignificant for the STAI, BDI-II, and PSS measures. The assumptions of parametric data were not violated, therefore parametric analyses could be performed.

Main Effects

Individuals who participated in the exercise group decreased in both state and trait anxiety measures, while the control group remained stable from session 1 to session 2 (**Table 2**). This was exemplified by a significant interaction between session and intervention group reducing state anxiety measures, $F(1, 46) = 43.78$, $p < 0.005$, $\eta_p^2 = 0.488$, and reducing trait anxiety measures, $F(1, 46) = 39.54$, $p < 0.005$, $\eta_p^2 = 0.462$ (**Table 2**). Tukey HSD *post hoc* tests revealed that participants in the exercise group significantly decreased in state anxiety measures ($SE = 1.21$), $p < 0.001$. Tukey HSD *post hoc* tests also confirmed that participants in the moderate exercise condition significantly decreased in trait anxiety measures also ($SE = 1.0$), $p < 0.01$.

Likewise, there was a significant decrease in self-report stress measures in the exercise condition relative to the control condition, and this was a significant interaction between session and intervention group, $F(1, 46) = 11.24$, $p < 0.005$, $\eta_p^2 = 0.196$ (**Table 2**). Tukey HSD *post hoc* tests reveal a significant decrease in stress measures in the exercise condition ($SE = 1.10$), $p < 0.05$. Participants who underwent the moderate exercise protocol also decreased in self-report depression measures, the interaction between session and intervention group was significant $F(1, 46) = 48.81$, $p < 0.005$, $\eta_p^2 = 0.515$ (**Table 2**). Tukey HSD *post hoc* tests support this finding of a significant decrease in depression measures in the exercise condition ($SE = 0.74$), $p < 0.001$.

There was a no significant reduction in interpretation bias scores in either the exercise or control condition, regardless of whether the SST was cognitively loaded or cognitively non-loaded $F(1, 16) = 3.25$, $p = 0.09$ (**Table 2**). Considering the modest sample size and that the main effect is not vastly distant from being statistically significant, the SST was then analyzed combining both cognitively loaded and non-loaded versions of the measure and there was a significant interaction between intervention group and session, $F(1, 43) = 24.11$, $p < 0.005$, $\eta_p^2 = 0.359$. Tukey HSD *post hoc* tests suggest that for individuals who participated in moderate intensity exercise, there was significant decrease in negative interpretation bias from baseline to post exercise ($SE = 3.80$), $p < 0.05$.

Discussion

The findings from Study 2 suggest that individuals who underwent the moderate exercise protocol reported significantly lower on both state and trait anxiety measures, relative to those in the control condition. Furthermore, participants in the moderate exercise condition also reported a significant decrease in depression and stress-related symptoms relative to those in the control condition. Participants who underwent the moderate exercise protocol also reduced in negative interpretation bias scores relative to controls, however, this was not specific to the cognitively loaded condition, which was specified in the hypothesis. When both cognitively loaded and non-loaded conditions were analyzed combined, it suggested that participants in the moderate exercise condition presented less negative cognitive interpretation biases from baseline measures, relative to participants in the control condition.

GENERAL DISCUSSION

The purpose of Study 1 was to further investigate the functions of exercise and mood enhancement, with a focus of anxiety. The aim was to further our understanding of the relationship between exercise regimes and self-report anxiety. The interest primarily was to investigate whether one single session of exercise is sufficient to produce the anxiolytic effects that is well founded. Furthermore, to investigate whether less intense exercise such as walking can produce the same mood enhancing effects as a more intense cardiovascular exercise session. The present research also investigated whether a cognitive load manipulation could have an effect on individual's interpretation biases, and whether this produced a more positive or negative representation of an individual's interpretation biases. Study 2 aimed to investigate, whether moderate intensity physical exercise was necessary to effect cognitive interpretation biases and whether this could in turn reduce reported symptoms of stress and depression, as well as anxiety. Study 2 also employed a cognitive load manipulation to measure whether individual's cognitive biases could in fact be affected by a single bout of moderate physical exercise.

Needless to say, there is an abundance of research focusing on the longer term effects of physical exercise for reducing self-report anxiety, however, the results of this present study do highlight some mood enhancing effects after a single session of physical exercise, these effects seem to be more so with moderate intensity exercise compared to light intensity physical exercise. The investigation of cognitive interpretation biases was made using the SST, which is administered both cognitively loaded and non-loaded. It takes concentration to remember the six-digit number, which decreases the amount of concentration an individual has while performing the task, therefore their attention is distracted from these threat-engaging thoughts which provoke negative interpretation biases. The underlying logic of this cognitive loading manipulation being that individuals would find it difficult to suppress these negative thoughts and interpretations during the cognitive load manipulation, and therefore the cognitive load measure would be a more accurate representation of an individual cognitive interpretation bias in comparison to the non-cognitively loaded measure. However, the cognitive load manipulation did not significantly affect whether the participants presented more positive or negative interpretation biases in either Study 1 or Study 2.

Both studies together lend valuable insights from multiple perspectives. They offer further understanding into the relationship between physical exercise and anxiety reduction on the ground that regardless of the mode of exercise employed (physical activity, physical aerobic exercise), there is arguably growing support for the connection between physical exercise and mood enhancement. However, the nature of the methodological design of these two studies (within-subjects) provided sufficient statistical rigor for the purpose of these two studies. These studies were designed as analog studies, so it becomes important for the betterment of our understanding to replicate these studies with a clinical or subclinical sample, as currently this cannot be generalized to a wider population. There could be a greater improvement in these individuals as the scope for reduction in anxiety and depression could be increased. Whether future research employing similar methodology to that of these two studies are able to replicate these findings or larger sample sizes differ in responses across conditions could become more pronounced, remains to be resolved.

CONCLUSION

The present studies have built upon the current literature and have lent support to claims that moderate intensity walking and aerobic exercise ameliorate the symptoms of anxiety, depression, and psychological stress. In Study 2, there were signs that SST (interpretation) could also be changed. However, the present research investigated a non-clinical sample that have no previously diagnosed mental health conditions, therefore to what extent this research can be applied holds promise, but indeed is limited. Given the exciting potential for the use of exercise and cognitive bias modification in the clinical interventions, more research into this emerging field is clearly warranted.

AUTHOR CONTRIBUTIONS

SC responsible for data collection, analysis, production of original research article. NC responsible for production and editing of original research article. MR responsible for data collection. BM responsible for research design, methodology, and editing of original research article.

FUNDING

This research was funded by the Economic Social Research Council (165137), and the Department of Psychology at the University Essex.

REFERENCES

Asmundson, G. J., Fetzner, M. G., Deboer, L. B., Powers, M. B., Otto, M. W., and Smits, J. A. (2013). Let's get physical: a contemporary review of the anxiolytic effects of exercise for anxiety and its disorders. *Depress. Anxiety* 30, 362–373. doi: 10.1002/da.22043

Barbour, K. A., and Blumenthal, J. A. (2005). Exercise training and depression in older adults. *Neurobiol. Aging* 26(Suppl. 1), 119–123. doi: 10.1016/j.neurobiolaging.2005.09.007

Bar-Haim, Y., Lamy, D., Pergamin, L., Bakermans-Kranenburg, M. J., and van IJzendoorn, M. H. (2007). Threat-related attentional bias in anxious and nonanxious individuals: a meta-analytic study. *Psychol. Bull.* 133, 1–24. doi: 10.1037/0033-2909.133.1.1

Barnes, R. T., Coombes, S. A., Armstrong, N. B., Higgins, T. J., and Janelle, C. M. (2010). Evaluating attentional and affective changes following an acute exercise bout using a modified dot-probe protocol. *J. Sports Sci* 28, 1065–1076. doi: 10.1080/02640414.2010.489196

Beard, C. (2011). Cognitive bias modification for anxiety: current evidence and future directions. *Expert Rev. Neurother* 11, 299–311. doi: 10.1586/ern.10.194

Beck, A. T., and Clark, D. A. (1997). An information processing model of anxiety: automatic and strategic processes. *Behav. Res. Ther* 35, 49–58. doi: 10.1016/S0005-7967(96)00069-1

Beck, A. T., Emery, G., and Greenberg, R. L. (2005). *Anxiety Disorders and Phobias: A Cognitive Perspective*. New York, NY: Basic Books.

Beck, A. T., Steer, R. A., and Brown, G. K. (1996). *Beck Depression Inventory*. San Antonio, TX: Psychological Corporation.

Bisson, M. A. S., and Sears, C. R. (2007). The effect of depressed mood on the interpretation of ambiguity, with and without negative mood induction. *Cogn. Emot.* 21, 614–645. doi: 10.1080/02699930600750715

Brosnan, L., Hoppitt, L., Selfer, L., Sillence, A., and Mackintosh, B. (2011). Cognitive bias modification for attention and interpretation reduces trait and state anxiety in anxious patients referred to an out-patient service: results from a pilot study. *J. Behav. Ther. Exp. Psychiatry* 42, 258–264. doi: 10.1016/j.jbtep.2010.12.006

Brown, T. A., Campbell, L. A., Lehman, C. L., Grisham, J. R., and Mancill, R. B. (2001). Current and lifetime comorbidity of the DSM-IV anxiety and mood disorders in a large clinical sample. *J. Abnorm. Psychol.* 110, 585–599. doi: 10.1037//0021-843x.110.4.585

Caspersen, C. J., Powell, K. E., and Christenson, G. M. (1985). Physical activity, exercise, and physical fitness: definitions and distinctions for health-related research. *Public Health Rep.* 100, 126–131.

Clark, D. A., and Beck, A. T. (2011). *Cognitive Therapy of Anxiety Disorders: Science and Practice*. New York, NY: Guilford Press.

Cohen, S., Janicki-Deverts, D., and Miller, G. E. (2007). Psychological stress and disease. *J. Am. Med. Assoc.* 298, 1685–1687. doi: 10.1001/jama.298.14.1685

Cohen, S., Kamarck, T., and Mermelstein, R. (1983). A global measure of perceived stress. *J. Health Soc. Behav.* 24, 385–396. doi: 10.2307/2136404

Cooper, S. L., and Tomporowski, P. D. (2017). Acute effects of exercise on attentional bias in low and high anxious young adults. *Ment. Health Phys. Act.* 12, 62–72. doi: 10.1016/j.mhpa.2017.02.002

Creswell, D. J., Welch, W. T., Taylor, S. E., Sherman, D. K., Gruenewald, T. L., and Mann, T. (2005). Affirmation of personal values buffers neuroendocrine and psychological stress responses. *J. Psychol. Sci.* 16, 846–851. doi: 10.1111/j.1467-9280.2005.01624.x

Daley, A. J. (2018). Exercise therapy and mental health in clinical populations: is exercise therapy a worthwhile intervention? *Adv. Psychiatr. Treat.* 8, 262–270. doi: 10.1192/apt.8.4.262

Ekkekakis, P. (ed.). (2013). *Handbook of Physical Activity and Mental Health.* London: Routledge.

Ensari, I., Greenlee, T. A., Motl, R. W., and Petruzzello, S. J. (2015). Meta-analysis of acute exercise effects on state anxiety: an update of randomized controlled trials over the past 25 years. *Depress. Anxiety* 32, 624–634. doi: 10.1002/da.22370

Fentem, P. H. (1994). Benefits of exercise in health & disease. *ABC Sports Med.* 308, 1291–1295.

Fox, K. R. (1999). The influence of physical activity on mental well-being. *Public Health Nutr.* 2, 411–418. doi: 10.1017/S1368980099000567

Gotlib, I. H., Kasch, K. L., Traill, S., Joormann, J., Arnow, B. A., and Johnson, S. L. (2004). Coherence and specificity of information-processing biases in depression and social phobia. *J. Abnorm. Psychol.* 113, 386–398. doi: 10.1037/0021-843X.113.3.386

Gupta, N., Khera, S., Vempati, R. P., Sharma, R., and Bijlani, R. L. (2006). Effect of yoga based lifestyle intervention on state and trait anxiety. *Indian J. Physiol. Pharmacol.* 50, 41–47.

Hallion, L. S., and Ruscio, A. M. (2011). A meta-analysis of the effect of cognitive bias modification on anxiety and depression. *Psychol. Bull.* 137, 940–958. doi: 10.1037/a0024355

Hammen, C. (2005). Stress and depression. *Annu. Rev. Clin. Psychol.* 1, 293–319. doi: 10.1146/annurev.clinpsy.1.102803.143938

Hansen, C. J., Stevens, L. C., and Coast, J. R. (2001). Exercise duration and mood state: how much is enough to feel better? *Health Psychol.* 20, 267–275.

Herring, M. P., Lindheimer, J. B., and O'Connor, P. J. (2014). The effects of exercise training on anxiety. *Am. J. Lifestyle Med.* 8, 388–403. doi: 10.1177/1559827613508542

Iwasaki, Y. (2006). Counteracting stress through leisure coping: a prospective health study. *Psychol. Health Med.* 11, 209–220. doi: 10.1080/13548500500155941

Janz, K. P. (2002). "Use of heart rate monitors to assess physical activity," in *Physical Activity Assessments for Health-Related Research*, ed. G. J. Welk (Champaign, IL: Human Kinetics), 143–161.

Joormann, J., and D'Avanzato, C. (2010). Emotion regulation in depression: examining the role of cognitive processes. *Cogn. Emot.* 24, 913–939. doi: 10.1080/02699931003784939

Joormann, J., and Quinn, M. E. (2014). Cognitive processes and emotion regulation in depression. *Depress. Anxiety* 31, 308–315. doi: 10.1002/da.22264

Joormann, J., Waugh, C. E., and Gotlib, I. H. (2015). Cognitive bias modification for interpretation in major depression: effects on memory and stress reactivity. *Clin. Psychol. Sci.* 3, 126–139. doi: 10.1177/2167702614560748

Kajtna, T., Štukovnik, V., and Dolenc Grošelj, L. (2011). Effect of acute sleep deprivation on concentration and mood states with a controlled effect of experienced stress. *Izvirni Članek* 80, 354–361.

Krahé, C., Mathews, A., Whyte, J., and Hirsch, C. R. (2016). Cognitive bias modification for interpretation with and without prior repetitive negative thinking to reduce worry and rumination in generalised anxiety disorder and depression: protocol for a multisession experimental study with an active control condition. *BMJ Open* 6:e013404. doi: 10.1136/bmjopen-2016-013404

Mackintosh, B., Mathews, A., Eckien, D., and Hoppitt, L. (2013). Specificity effects in the modification of interpretation bias and stress reactivity. *J. Exp. Psychopathol.* 4, 133–147. doi: 10.5127/jep.025711

Mackintosh, B., Mathews, A., Yiend, J., Ridgeway, V., and Cook, E. (2006). Induced biases in emotional interpretation influence stress vulnerability and endure despite changes in context. *Behav. Ther.* 37, 209–222. doi: 10.1016/j.beth.2006.03.001

Mathews, A., and MacLeod, C. (2005). Cognitive vulnerability to emotional disorders. *Annu. Rev. Clin. Psychol.* 1, 167–195. doi: 10.1146/annurev.clinpsy.1.102803.143916

Mazure, C. M. (1998). Life stressors as risk factors in depression. *Clin. Psychol. Sci. Pract.* 5, 291–313. doi: 10.1111/j.1468-2850.1998.tb00151.x

McCrone, P. R., Dhanasiri, S., Patel, A., Knapp, M., and Lawton-Smith, S. (2008). *Paying the Price: The Cost of Mental Health Care in England to 2026.* London: King's Fund.

Mineka, S., Watson, D., and Clark, L. A. (1998). Comorbidity of anxiety and unipolar mood disorders. *Annu. Rev. Psychol.* 49, 377–412. doi: 10.1146/annurev.psych.49.1.377

Mogg, K., and Bradley, B. P. (2006). Time course of attentional bias for fear-relevant pictures in spider-fearful individuals. *Behav. Res. Ther.* 44, 1241–1250. doi: 10.1016/j.brat.2006.05.003

Mogg, K., and Bradley, B. P. (2016). Anxiety and attention to threat: cognitive mechanisms and treatment with attention bias modification. *Behav. Res. Ther.* 87, 76–108. doi: 10.1016/j.brat.2016.08.001

Norman, G. J., Cacioppo, J. T., Morris, J. S., Karelina, K., Malarkey, W. B., Devries, A. C., et al. (2011). Selective influences of oxytocin on the evaluative processing of social stimuli. *J. Psychopharmacol.* 25, 1313–1319. doi: 10.1177/0269881110367452

O'Connor, D. B., and Shimizu, M. (2002). Sense of personal control, stress and coping style: a cross-cultural study. *Stress Health* 18, 173–183. doi: 10.1002/smi.939

Otto, M. W., Church, T. S., Craft, L. L., Greer, T. L., Smits, J. A., and Trivedi, M. H. (2007). Exercise for mood and anxiety disorders. *Prim. Care Companion J. Clin. Psychiatry* 9, 287–294. doi: 10.4088/PCC.v09n0406

Paluska, S. A., and Schwenk, T. L. (2000). Physical activity and mental health: current concepts. *Sports Med.* 29, 167–180. doi: 10.2165/00007256-200029030-00003

Penedo, F. J., and Dahn, J. R. (2005). Exercise and well-being: a review of mental and physical health benefits associated with physical activity. *Curr. Opin. Psychiatry* 18, 189–193. doi: 10.1097/00001504-200503000-00013

Petruzzello, S., Landers, D., Hatfield, B., Kubitz, K., and Salazar, W. (1991). A meta-analysis on the anxiety-reducing effects of acute and chronic exercise. *Sports Med.* 11, 143–182. doi: 10.2165/00007256-199111030-00002

Richards, A. (2004). "Anxiety and the resolution of ambiguity," in *Cognition, Emotion and Psychopathology: Theoretical, Empirical and Clinical Directions*, ed. J. Yiend (New York, NY: Cambridge University Press), 130–148. doi: 10.1017/CBO9780511521263.008

Richards, A., and French, C. C. (1992). An anxiety-related bias in semantic activation when processing threat/neutral homographs. *Q. J. Exp. Psychol. A* 45, 503–525. doi: 10.1080/02724989208250625

Rose, E. A., and Parfitt, G. (2007). A quantitative analysis and qualitative explanation of the individual differences in affective responses to prescribed and self-selected exercise intensities. *J. Sport Exerc. Psychol.* 29, 281–309. doi: 10.1123/jsep.29.3.281

Rude, S. S., Wenzlaff, R. M., Gibbs, B., Vane, J., and Whitney, T. (2002). Negative processing biases predict subsequent depressive symptoms. *Cogn. Emot.* 16, 423–440. doi: 10.1080/02699930143000554

Russell, J. A. (2003). Core affect and the psychological construction of emotion. *Psychol. Rev.* 110, 145–172. doi: 10.1037/0033-295X.110.1.145

Salmon, P. (2001). Effects of physical exercise on anxiety, depression, and sensitivity to stress: a unifying theory. *Clin. Psychol. Rev.* 21, 33–61. doi: 10.1016/S0272-7358(99)00032-X

Sapolsky, R. M. (2004). Social status and health in humans and other animals. *Annu. Rev. Anthropol.* 33, 393–418. doi: 10.1146/annurev.anthro.33.070203.144000

Saxena, S., Van Ommeren, M., Tang, K. C., and Armstrong, T. P. (2009). Mental health benefits of physical activity. *J. Ment. Health* 14, 445–451. doi: 10.1080/09638230500270776

Smith, J. C. (2013). Effects of emotional exposure on state anxiety after acute exercise. *Med. Sci. Sports Exerc.* 45, 372–378. doi: 10.1249/MSS.0b013e31826d5ce5

Spielberger, C. D. (1983). *Manual for the State-Trait Anxiety Inventory STAI (form Y)("Self-Evaluation Questionnaire")*. Palo Alto, CA: Consulting Psychologists Press.

Standage, H., Ashwin, C., and Fox, E. (2010). Is manipulation of mood a critical component of cognitive bias modification procedures? *Behav. Res. Ther.* 48, 4–10. doi: 10.1016/j.brat.2009.08.005

Stubbs, B., Koyanagi, A., Hallgren, M., Firth, J., Richards, J., Schuch, F., et al. (2017). Physical activity and anxiety: a perspective from the World Health Survey. *J. Affect. Disord.* 208, 545–552. doi: 10.1016/j.jad.2016.10.028

Tian, Q., and Smith, J. C. (2011). Attentional bias to emotional stimuli is altered during moderate- but not high-intensity exercise. *Emotion* 11, 1415–1424. doi: 10.1037/a0023568

Uth, N., Sorensen, H., Overgaard, K., and Pedersen, P. K. (2004). Estimation of VO2max from the ratio between HRmax and HRrest–the Heart Rate Ratio Method. *Eur. J. Appl. Physiol.* 91, 111–115. doi: 10.1007/s00421-003-0988-y

Vrijsen, J. N., Becker, E. S., Rinck, M., van Oostrom, I., Speckens, A., Whitmer, A., et al. (2014). Can memory bias be modified? the effects of an explicit cued-recall training in two independent samples. *Cogn. Ther. Res.* 38, 217–225. doi: 10.1007/s10608-013-9563-y

Williams, D. M., Dunsiger, S., Ciccolo, J. T., Lewis, B. A., Albrecht, A. E., and Marcus, B. H. (2008). Acute affective response to a moderate-intensity exercise stimulus predicts physical activity participation 6 and 12 months later. *Psychol. Sport Exerc* 9, 231–245. doi: 10.1016/j.psychsport.2007.04.002

Conflict of Interest Statement: The authors declare that the research was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.

Appendix B State Trait Anxiety Inventory

SELF-EVALUATION QUESTIONNAIRE STAI Form Y-1

Please provide the following information:

ID____ Date_______________________S______

Age___________________________ Gender__________________ T______

DIRECTIONS:

A number of statements which people have used to describe themselves are given below. Read each statement and then 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**

SELF-EVALUATION QUESTIONNAIRE

STAI Form Y-2

ID____ Date________________

DIRECTIONS

A number of statements which people have used to describe themselves are given below. Read each statement and then delete the appropriate number to the right of the statement to indicate how you **GENERALLY** feel.

		ALMOST NEVER	SOMETIMES	OFTEN	ALMOST ALWAYS
21.	I feel pleasant ……………………………………………………….	**1**	**2**	**3**	**4**
22.	I feel nervous and restless …………………………………………..	**1**	**2**	**3**	**4**
23.	I feel 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 interest …………………………………………………	**1**	**2**	**3**	**4**

Appendix C Percieved Stress Scale

Perceived Stress Scale

Instructions

The questions in this scale ask you about your feelings and thoughts **during the last 2 months.** In each case, you will be asked to indicate how often you felt or thought a certain way. Although some of the questions are similar, there are differences between them and you should treat each one as a separate question. The best approach is to answer each question fairly quickly. That is don't try and count up the number of times you felt a particular way, but rather indicate the alternative that seems like a reasonable estimate.

For each question circle the most appropriate response.

0 = never 1= almost never 2 =sometimes 3 =fairly often 4 =very often

1) In the last 2 months, how often have you been upset because of something that happened unexpectedly?

0 1 2 3 4

2) In the last 2 months, how often have you felt that you were unable to control the important things in your life?

0 1 2 3 4

3) In the last 2 months, how often have you felt nervous and stressed?

0 1 2 3 4

4) In the last 2 months, have you often dealt with irritating life hassles?

0 1 2 3 4

5) In the last 2 months, how often have you felt you were effectively coping with important changes that were occurring in your life?

0 1 2 3 4

6) In the last 2 months, how often have you felt confident about your ability to handle your personal problems?

0 1 2 3 4

7) In the last 2 months, how often have you felt things were going your way?

0	1	2	3	4

8) In the last 2 months, how often have you found that you could not cope with all the things you had to do

0	1	2	3	4

9) In the last 2 months, how often have you been able to control irritations in your life?

0	1	2	3	4

10) In the last 2 months, how often have you felt you were on top of things?

0	1	2	3	4

11) In the last 2 months, how often have you been angered because of things that happened that were outside of your control?

0	1	2	3	4

12) In the last 2 months, how often have you found yourself thinking about things that you have to accomplish?

0	1	2	3	4

13) In the last 2 months, how often have you been able to control the way that you spend your time?

0	1	2	3	4

14) In the last 2 months, how often have you felt that difficulties were piling up so high that you could not overcome them?

0	1	2	3	4

Appendix D Beck's Revised Depression Inventory

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 discourage 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.

I can't concentrate as well as usual.

3 It's hard to keep my mind on anything for very long.

4 I find I can't concentrate on anything.

20. Tiredness of 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 changes 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.

Appendix E GAD-7 Generalised Anxiety Disorder Questionnaire

When answering the next 7 questions please consider **how you have felt over the last 2 weeks. How often have you been bothered by the following problems?**
Please select the most appropriate response.

>>

(In the last 2 weeks how often have you...)

1. Felt nervous, anxious or on edge

Not at all	Several days	More than half the days	Nearly every day

>>

(In the last 2 weeks how often have you...)

2. Not been able to stop or control worrying

Not at all	Several days	More than half the days	Nearly every day

>>

(In the last 2 weeks how often have you been...)

3. Worrying too much about different things

Not at all	Several days	More than half the days	Nearly every day

>>

(In the last 2 weeks how often have you had...)

4. Trouble relaxing

Not at all	Several days	More than half the days	Nearly every day

>>

(In the last 2 weeks how often have you...)

5. Been so restless that it is hard to sit still

Not at all	Several days	More than half the days	Nearly every day

>>

(In the last 2 weeks how often have you...)

6. Become easily annoyed or irritable

Not at all	Several days	More than half the days	Nearly every day

>>

(In the last 2 weeks how often have you...)

7. Felt afraid, as if something awful might happen

Not at all	Several days	More than half the days	Nearly every day

>>

Appendix F Example of Scambled Sentences Test

Participant ID-

Session-

Group –

Cognitively Loaded Task

1ST SCRAMBLED SENTENCE TEST -1

Unscramble the sentences to form statements. Each of the scrambled sentences contains six words. Unscramble five words in each sentence by placing a number over each of the five words indicating the proper order.

For example:

3 4 2 1 5

has green child the eyes blue

Each sentence can be unscrambled into more than one statement, but you should choose only one statement to unscramble. You have 4 minutes to unscramble as many sentences as possible. Work as quickly and as accurately as possible.

apprehensive people with relaxed new I'm

meetings tense relaxed I at feel

can errors cannot social make I

others foolish I to sensible appear

uneasy other with easy I'm people

won't fool will a I look

think worthwhile others worthless I am

I'm people stressed relaxed other with

approaching fine scary people is new

superiors my I please will displease

occasions avoid I social enjoy usually

opinions do me bother others' don't

people usually from withdraw don't I

gatherings dread love usually I social

attend I social avoid usually functions

Write the 6 digit number in the box below

Appendix G Example of Online Version of Exercise Adjusted SST

This is part of the unscrambling task, you will need your stopwatch!

You have 4 minutes to unscramble the following sentences, you must order the sentence so that it makes sense, but leave out one word each time.

Whilst you unscramble these sentences you will be asked to remember a 6 digit number, which you will be asked to recall at the end of the task.

For example....

In the example below you would reorder the words in the list to make either of two sentences....

i'm relaxed with new people

OR

i'm apprehensive with new people

You do so by entering the order by **numbering each word in each box, one of the boxes must be left blank** for the word you do not choose.

sentence 7

[ ] apprehensive [5] people [3] with [2] relaxed [4] new [1] I'm

[ ] I'm out of time SKIP!

>>

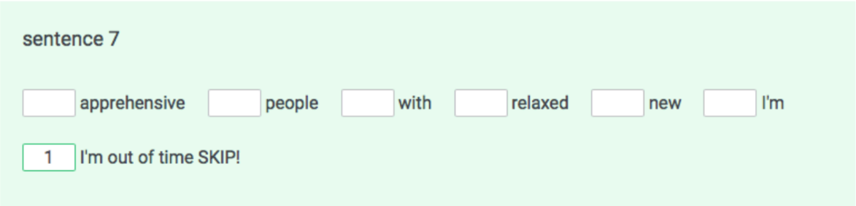
Remember once you start you have only **4 minutes** to complete **20 sentences, so unscramble them as quickly as you can.**

If your stopwatch alerts you that **your 4 minutes is up,** you must SKIP.
To SKIP you must put a **'1' in the box *'I'm out of time SKIP!'***
You must not SKIP, unless you are out of time. See example below.

Stopwatch at the ready!

You will be asked to record the number you have been given to remember at the end of part 1 of this task. You are not allowed to write this number down.

Ready for the number you need to remember?
Stopwatch ready? You must allow 4 minutes.



\>>

During part 1 you must try to remember the number...

597236

Start your 4 minutes now...

\>>

sentence 1

apprehensive people with relaxed new I'm

>>

sentence 2

infrequently try regularly exercise to I

>>

sentence 3

can errors cannot social make I

>>

>>

sentence 4

me over people worthwhile think worthless

>>

sentence 5

☐ fatigued ☐ weights ☐ makes ☐ stronger ☐ me ☐ lifting

>>

sentence 6

☐ are ☐ trails ☐ long ☐ rewarding ☐ cycle ☐ shattering

>>

sentence 7

☐ dislike ☐ I ☐ friends ☐ like ☐ with ☐ running

☐ I'm out of time SKIP!

>>

sentence 8

☐ meetings ☐ tense ☐ relaxed ☐ I ☐ at ☐ feel

☐ I'm out of time SKIP!

>>

sentence 10

sportclub a joining daunting is exciting

I'm out of time SKIP!

>>

sentence 11

sport badminton is boring a relaxing

I'm out of time SKIP!

>>

sentence 12

how considered is I'm important isn't

I'm out of time SKIP!

>>

sentence 13

☐ tennis ☐ I ☐ competent ☐ am ☐ terrible ☐ at

☐ I'm out of time SKIP!

>>

sentence 14

☐ disinterested ☐ rowing ☐ feel ☐ makes ☐ accomplished

☐ me ☐ I'm out of time SKIP!

>>

sentence 15

☐ enjoyable ☐ is ☐ snowboarding ☐ dangerous ☐ sport

☐ a ☐ I'm out of time SKIP!

>>

sentence 16

☐ makes ☐ exhausted ☐ feel ☐ healthy ☐ exercising ☐ me

☐ I'm out of time SKIP!

>>

sentence 17

☐ avoid ☐ people ☐ rarely ☐ I ☐ other ☐ often

☐ I'm out of time SKIP!

>>

sentence 18

☐ scary ☐ new ☐ people ☐ meeting ☐ is ☐ fun

☐ I'm out of time SKIP!

>>

sentence 19

☐ inconvenient ☐ swimming ☐ very ☐ convenient ☐ I

☐ find ☐ I'm out of time SKIP!

>>

sentence 20

☐ car ☐ rather ☐ I ☐ use ☐ my ☐ bicycle

☐ I'm out of time SKIP!

>>

What was the 6 digit number you were asked to remember?

>>

Appendix H Exercise & Activity Questionnaire

Are you a member of a gym or sports club?

Yes	No	I exercise but do not attend a gym

>>

In the last week how many hours have you participated in cardiovascular exercise ? (Also known as aerobic/cardio exercise) examples; running, cycling, playing netball, football.

I haven't done any cardio exercise this week	less than 2 hours	2-3 hours	3-4 hours	4-5 hours	5+ hours

>>

In the last week how many hours have you participated in any other exercise not previously stated? examples; weightlifting, yoga. Please give details.

>>

During the last week how many hours have you been actively walking?

Less than 2 hours	2-4 hours	4-6 hours	Over 7 hours

>>

Over the last week how many hours have you been active in total?

2-4 hours	4-6 hours	6-8 hours	8-10 hours	10-12 hours	12+ hours

>>

Do you most frequently exercise outside or indoors?

Outside	Indoors

>>

Appendix I Example of Cognitive Bias Modification Training Scenarios

PART 3

You are about to begin the cognitive training component of this experiment. In this session you will be presented with scenarios, try to put yourself into the situation so you can imagine the scenario vividly.

- You will be presented with a scenario to read, the last word of the scenario will be an incomplete word, it may one or two missing letters.
- You will be required to figure out the FIRST missing letter from the incomplete word.
- e.g 'h-ppy' first missing letter would be 'a' making the word 'happy' or 'inv-gor-ting' first missing letter would be 'i' making the word 'invigorating'.
- Once you have figured out the first missing letter, you should enter this single letter in lower case. This will be followed with feedback of correct or incorrect depending on your response.
- You will then be asked a 'yes' or 'no' question related to the scenario you have read, this will be followed with feedback of correct or incorrect depending on your response.

It is early in the morning and you are taking a short cut through the park.
There are several exercise points along the path for keep-fit enthusiasts.
On some high pull-up bars ahead, you see a man suspended from a bar by his...

>>

h-nds

>>

>>

Do you think the man planned to keep fit?

Yes	No

>>