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Modification of interpretation biases in worry: an examination of cognitive and physiological responses

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Volume I
Systematic Literature Review
Empirical Project

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Thesis submitted in partial fulfilment of the degree
of Doctorate in Clinical Psychology
Institute of Psychiatry, Psychology & Neuroscience
King's College London
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PART 1
SYSTEMATIC LITERATURE REVIEW

**What evidence is there for the causal role of
cognitive constructs in pathological worry?**

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Supervised by:

Dr Colette Hirsch

Dr Charlotte Krahe

Table of Contents

1. ABSTRACT	6
2. INTRODUCTION.....	7
2.1 Cognitive characteristics of pathological worry.....	10
2.1.1. Cognitive constructs highlighted in the development of a worry bout	10
2.1.2 Maladaptive beliefs about worry	13
2.2. Aims	16
3. METHOD	17
3.1 Search strategy.....	17
3.2 Coding	17
3.3 Inclusion and exclusion criteria.....	18
3.3.1 Inclusion criteria	18
3.3.2 Exclusion criteria	18
3.4 Quality assessment.....	19
4. RESULTS.....	20
4.1 Number of articles	20
4.2 Participant characteristics.....	22
4.3 Paradigms used to manipulate cognitive constructs.....	29
4.3.1 Interpretation bias	29
4.3.2 Attention bias	31
4.3.3 Attentional control	32
4.3.4 Mentation style: Verbal vs. Imagery	33
4.3.5 Intolerance of uncertainty (IU)	34
4.3.6 Goal directed worry stop rules	35
4.4 How is worry assessed in the laboratory?	35
4.5 What evidence is there for the causal relationship between the cognitive constructs and worry?	37
4.5.1 Interpretation bias	37
4.5.2 Attentional bias.....	37
4.5.3 Attentional control	39
4.5.4 Mentation style: Verbal vs. imagery.....	40
4.5.5 Intolerance of uncertainty (IU)	40
4.5.6 Metacognitions in pathological worry.....	41
4.5.7 Goal directed worry stop rules	41
4.5.8 Quality of studies.....	42
5. CONCLUSION.....	43
5.1 Overview of findings.....	43
5.1.2 Cognitive constructs involved in the initiation of worry	43
5.1.3 Beliefs about worry.....	44
5.2 Impact of the review findings on our understanding of the role of cognitive constructs in the initiation and perseveration of worry	46
5.3 Areas for future research development	49
5.4 Limitations	50
6. REFERENCES.....	52
7. APPENDICES	64
7.1 Appendix 1	65
7.2 Appendix 2	69
7.3 Appendix 3	72

List of figures

Figure 121

List of Tables

Table 122
Table 225

1. ABSTRACT

Excessive and debilitating worry is a core feature of generalised anxiety disorder. A number of cognitive constructs have been highlighted as being relevant to the initiation and maintenance of worry, but the extent and quality of the evidence to support these links has never been systematically reviewed. The present review systematically examines the evidence for a causal relationship between the following cognitive constructs and worry: interpretation and attention biases, attentional control, mentation style (verbal vs. imagery), intolerance of uncertainty, positive and negative beliefs about worry, and goal directed worry stop rules. PsycINFO and Web of Science databases were searched and after removal of duplicates and extraction of studies that did not meet inclusion criteria, 13 studies remained. Evidence was found to support a causal relationship between all examined constructs and worry, except positive and negative beliefs about worry. The experimental psychopathology techniques employed to manipulate cognitive constructs are discussed, as are methods of measuring worry and the quality of the studies in the review. Suggestions for future research in this area are made.

2. INTRODUCTION

Worry is an activity that most people experience fairly regularly and it is usually in response to uncertainty about future events. Worry has been defined as “a chain of thoughts and images, negatively affect-laden and relatively uncontrollable” (Borkovec, Robinson, Pruzinsky & DePree, 1983, p. 10). For some people, worry can become excessive and uncontrollable and can have a negative impact on social and occupational functioning. This type of excessive, pathological worry is cited as the defining feature of generalized anxiety disorder (GAD) in the Diagnostic and Statistical Manual of Psychiatric Disorders (DSM-5, American Psychiatric Association, 2013).

When worry becomes pathological, it causes significant distress and impairment in functioning (DSM-5, American Psychiatric Association, 2013), which begs the question of why people worry, what function does it serve? Some theories have examined the role of worry as being a strategy to avoid negative physiological responses (e.g. the cognitive avoidance model; Borkovec, Alcaine, & Behar, 2004; Borkovec & Roemer, 1995), or a maladaptive attempt to cope with negative emotions (e.g. the emotion dysregulation model; Turk, Heimberg, Luterek, Mennin, & Fresco, 2005). Given that worry is primarily a cognitive process, cognitive models of worry (e.g. Davey & Meeten, 2016; Hirsch & Mathews, 2012) have examined cognitive mechanisms thought to drive and maintain pathological worry.

Hirsch & Mathews (2012) focused on cognitive constructs thought to be causally related to worry. They proposed that bottom-up information processing biases in attention and interpretation and top-down processing such as attentional control, influence threat representations at a preconscious level and serve to maintain focus on threat. Attentional and interpretation biases that favour threat also increase the chance of threat representations coming into awareness and being experienced as an intrusive negative thought. Once intrusive negative thoughts occur, Hirsch and Mathews (2012) propose that bottom up processes continue to operate. In addition, worry in verbal

form develops and other conscious processes occur such as allocation of attentional control resources to the negative intrusive thoughts, in an attempt to problem solve leading to excessive, pathological worry.

The Davey and Meeten (2016) model of perseverative worry shares some features of the Hirsch and Mathews (2012) model. Both models highlight the role of information processing biases in the involuntary allocation of attention and information processing resources to threat. Davey and Meeten (2016) examine some of the behavioural and cognitive processes that occur as a result of threat perception and are proposed to influence worry both causally and indirectly through other processes. Once threat perception occurs, they suggest that maladaptive beliefs about worry influence worry perseveration. These include positive beliefs about worry (e.g. the belief that worry is a useful and important processes), which Davey & Meteen (2016) propose influence goal directed worry rules (e.g. the rules that people implicitly or explicitly follow when deciding whether to continue or stop worrying), which then causally influence worry perseveration. Davey and Meeten (2016) also consider the role of negative mood in worry perseveration and how mood facilitates goal directed worry rules and systematic (careful and thorough) processing styles.

Proximal models of worry (Davey & Meteen, 2016; Hirsch & Mathews, 2012) are helpful in defining and refining our understanding of the cognitive processes that contribute to pathological worry. While these models focus on cognitive processes that drive and maintain a worry bout, they also overlap with other commonly cited theories of worry that address cognitive constructs in worry such as the intolerance of uncertainty model (Dugas, Freeston, & Ladouceur, 1997; Dugas, Gagnon, Ladouceur, & Freeston, 1998) and the metacognitive model of GAD (Wells, 1995, 1999, 2006). However, as highlighted by Hirsch and Mathews (2012), evidence that some of these factors have a causal relationship with worry is inconclusive.

Pathological worry is a defining feature of GAD and approximately only 50% of individuals with GAD achieve full remission after treatment (Loerinc et al., 2015). As noted by Hofmann (2014), an integral part of developing effective cognitive-behavioural treatment models is to understand the maladaptive cognitive processes that cause distressing symptomatology, such as worry in GAD. It is thus important to remain curious and continue to update and refine cognitive models of worry based on scientific evidence. The present review focuses on experimental psychopathology literature and seeks to clarify what evidence there is to demonstrate that cognitive constructs thought to be relevant in pathological worry, have a causal relationship with worry, as opposed to a correlational relationship or being a consequence of worry. If evidence suggests that constructs causally relate to worry, then those constructs can be usefully targeted in treatment. The cognitive constructs included in this review were selected by examining proximal models of worry and looking at factors that contribute to the development of and perseveration of a worry episode (e.g. Davey & Meeten, 2016; Hirsch & Mathews, 2012). A second strategy was to consider theories of worry that have promoted key cognitive constructs as causal mechanism in the perseveration of worry (e.g. the construct of intolerance of uncertainty (Dugas, Freeston, & Ladouceur, 1997) and the roles of positive and negative metacognitive beliefs (Wells, 1995, 2006) in a perseverative worry bout. It should be noted that this review is not intended to be an exhaustive account of all cognitive constructs that have been related to pathological worry, rather an evaluation and discussion of cognitive constructs which have been proposed as core elements in theories of pathological worry over the past 30 years or so.

2.1 Cognitive characteristics of pathological worry

2.1.1. *Cognitive constructs highlighted in the development of a worry bout*

The first section will focus on cognitive constructs highlighted as being important in the onset of a worry bout and are considered important features of pathological worry (e.g. Davey & Meeten, 2016; Hirsch & Mathews, 2012). Constructs considered are: information processing biases (interpretation and attention biases), attentional control and verbal processing of threat relevant information.

2.1.1.1 *Interpretation bias*

The negative interpretation (as opposed to a benign or neutral interpretation) of ambiguous information is given a role in both the initiation and maintenance of pathological worry (Hirsch & Mathews, 2012; Hirsch, Meeten, Krahé, & Reeder, 2016). Both interpretation and attention biases (see below for a discussion of the role of attention biases in worry) are thought to be relatively automatic, bottom-up processes that occur outside of awareness (Hirsch & Mathews, 2012) and lead to an over-representation of threat in the cognitive system (Hirsch & Mathews, 2012; MacLeod & Rutherford, 2004; Mathews & Mackintosh, 1998). Non-anxious individuals have been found to make benign interpretations of ambiguous information (Hirsch & Mathews, 1997; Hirsch & Mathews, 2000). However, a number of studies have demonstrated that high anxious individuals tend to interpret ambiguous information in a threatening manner (Eysenck, MacLeod, & Mathews, 1987; MacLeod & Cohen, 1993; Mathews, Richards, & Eysenck, 1989; Ogniewicz, Dugas, Langlois, Gosselin, & Koerner, 2014). An increase in the frequency in which high trait anxious individuals generate threat interpretations from ambiguous material are likely to contribute to both triggering and maintaining a worry bout (Hirsch & Mathews, 2012; Mathews, 1990). More recently, research has demonstrated that manipulation of interpretation bias causally affects negative intrusions after a worry period in both high trait worry

participants (Hirsch, Hayes, & Mathews, 2009) and those with a diagnosis of GAD (Hayes, Hirsch, Krebs, & Mathews, 2010).

2.1.1.2 Attention bias

A second information processing bias that is thought to initiate and maintain worry is a threat interpretation bias. High anxious individuals have been found to preferentially attend to threat at the expense of positive or benign stimulus (Mathews, 1990; Mathews & MacLeod, 2002; Mogg, Mathews, & Eysenck, 1992). Individuals with GAD show an attentional bias towards threat. For example, Mathews, Mogg, Kentish, and Eysenck (1995) showed that individuals with GAD were slower to name colours on a Stroop task when the word was threat-related as compared to non-anxious controls. There is mixed evidence to support the theory that individuals who experience high levels of worry may also find it difficult to disengage their attention from threat stimuli (e.g. Fox, Russo, Bowles, & Dutton, 2001; Koster, Crombez, Verschuere, & De Houwer, 2006; Mogg, Holmes, Garner, & Bradley, 2008). Attentional engagement with meaning or content of negative intrusions may facilitate worry (Hirsch et al., 2011). Experimental evidence suggests that attentional biases can be manipulated and that this manipulation has a transfer effect whereby those who were trained to attend to benign stimuli at the expense of threat stimuli reported less negative thought intrusions during a worry task (Hayes, Hirsch, & Mathews, 2010; Krebs, Hirsch, & Mathews, 2010).

2.1.1.3 Attentional control

An important aspect of working memory (Baddeley & Hitch, 1974) is attentional control. Attentional control can be thought of as the ability to resist or suppress distracting information, or shift focus of attention between tasks (Miyake et al., 2000). Attentional control capacity is limited and worry is thought to take up attentional control (Hirsch & Mathews, 2012) and reduces processing efficiency (e.g. Eysenck, Derakshan, Santos, & Calvo, 2007). Hayes, Hirsch, and

Mathews (2008) found that high worriers (as compared to a low worry group) had reduced ability to exert attentional control when thinking about a worry topic. This finding was replicated with individuals with GAD (Stefanopoulou, Hirsch, Hayes, Adlam, & Coker, 2014). Leigh & Hirsch (2011) found that high worriers (but not low worriers) had poor state attentional control as measured by a questionnaire. High worriers also demonstrated reduced working memory capacity (as measured by ability to generate a random sequence by pressing the space bar on the keyboard) when worry was in its normal verbal form (Hirsch, Hayes, Mathews, Perman, & Borkovec, 2012) as opposed to thinking about worries in imagery. The authors proposed that this demonstrates that the verbal nature of worry has a deleterious effect on working memory resources. Fox and colleagues (Fox, Dutton, Yates, Georgiou, & Mouchlianitis, 2015) have also reported a link between improvements in attentional control and improvements in ability to suppress worry related thought intrusions. What is less clear and will be explored in this review is whether there is evidence to suggest that manipulating attentional control causally affects worry.

2.1.1.4 Mentation style during worry

Worry is described as predominantly verbal and non-specific in content (Hirsch & Mathews, 2012). In his reduced concreteness theory of worry, Stöber (1998) proposed that worry was abstract in nature and that this reduced concreteness in worry suppresses imagery. Stöber and Borkovec (2002) examined the concreteness of worry topics described by individuals with GAD and a non-anxious control group. They found that participants with GAD reported less concrete worries than the control group. Yet after therapy, the two groups demonstrated comparable concreteness in their worry descriptions. There have been no assessments of the causal relationship between concreteness/abstractness of thought and worry. However, mentation style (e.g. whether a threat representation is processed in an

abstract/verbal manner or in a concrete manner using imagery) is now considered a transdiagnostic construct associated with perseverative thought in both pathological worry and depression (e.g. Goldwin & Behar, 2012; McGowan et al., 2017; Stöber, 1998; Stokes & Hirsch, 2010; Watkins, 2008). The cognitive avoidance theory of worry (Borkovec et al., 2004) proposes that worry is predominantly verbal as this provides a way of avoiding distressing images. Hirsch and colleagues have examined how worrying in verbal form as compared to imagery is related to worry perseveration. One study demonstrated that participants with GAD as compared to a non-anxious control group experienced less imagery during worry (Hirsch et al., 2012).

Research examining the causal role of verbal processing in worry has manipulated mentation style with individuals who report high levels of worry. Stokes and Hirsch (2010) found that verbal mentation style (as opposed to imagery) was associated with a higher number of negative intrusions in a worry task. Interestingly, verbal worry has also been shown to facilitate attention to threat (Williams, Mathews, & Hirsch, 2014). One possibility is that this highlights a bi-directional relationship whereby attentional biases may bring threat stimuli into awareness, which may promote a worry bout (usually in verbal form), that in turn may facilitate attention to threat, which serves to maintain worry.

2.1.2 Maladaptive beliefs about worry

A key component of pathological worry is its perseverative nature. Once started, people who experience sub-clinical or clinical levels of worry often find it hard to disengage from the worry bout. A number of cognitive constructs focus on beliefs that are thought to drive the perseverative nature of worry, namely intolerance of uncertainty (Dugas, Gagnon, Ladouceur, & Freeston, 1998; Dugas, Gosselin, & Ladouceur, 2001; Ladouceur, Gosselin, & Dugas, 2000), positive and negative beliefs about the utility of worry (Davey, Tallis, & Capuzzo, 1996; Wells, 1995, 2006) and goal directed worry stop rules

(Davey, 2006a; Meeten & Davey, 2011). These constructs focus on beliefs that people who experience pathological worry hold about uncertainty, or about the utility of worry, or about when it is appropriate to stop worrying.

2.1.2.1 Intolerance of uncertainty (IU)

Worry is characterised by concerns about the future where the outcome is unknown. A cognitive construct that has been linked to worry perseveration is intolerance of uncertainty (IU). IU can be defined as “a dispositional characteristic that results from a set of negative beliefs about uncertainty and its implications” (Dugas & Robichaud, 2007, p.24). People high in IU have been found to overestimate the probability of negative outcomes occurring and to seek more information (than those with low IU) before making a decision (Ladouceur, Talbot, & Dugas, 1997; Carleton, Sharpe, & Asmundson, 2007). Inability to tolerate uncertainty has been associated with pathological worry, where individuals who have low tolerance to uncertainty continue to worry in an attempt to resolve the uncertainty (Dugas, Freeston, & Ladouceur, 1997; Koerner & Dugas, 2006). Where IU has been experimentally manipulated, increasing IU has been found to causally affect worry (Ladouceur, Gosselin, & Dugas, 2000; Meeten, Dash, Scarlet, & Davey, 2012).

2.1.2.2. Positive and negative beliefs about worry

The metacognitive model of GAD (Wells, 1995, 2006) examines the role of both positive and negative beliefs about worry. Positive beliefs focus on the utility of worry e.g. “worrying will help me be prepared for whatever happens” and negative beliefs are a negative appraisal of worry e.g. “worrying is harmful/dangerous”. There is evidence to suggest that people who experience chronic worry hold both positive and negative beliefs about worry (e.g. Borkovec & Roemer, 1995; Davey, Tallis, & Capuzzo, 1996; Tallis, Davey, & Capuzzo, 1994).

Cartwright-Hatton and Wells (1997) used the Meta-Cognitions Questionnaire (MCQ) to demonstrate that pathological worry was

associated with positive and negative beliefs about worry. One study has experimentally manipulated positive and negative beliefs about worry and examined their causal effect on worry (Prados, 2011). Prados (2011) reported that inducing positive and negative beliefs about worry did not trigger worry, contrary to predictions by the meta-cognitive model. However, the worry measure in this study was a single-item visual analogue scale and is thus unlikely to be a valid measure of worry.

2.1.2.3 Goal directed worry stop rules

For many people, worrying can serve a purpose, whether it is an attempt to manage distress associated with uncertainty, to feel prepared when negative outcomes are feared, or as a means to avoid distressing images or further decreases in negative affect (all discussed above). Goal directed worry stop rules (Davey & Meeten, 2016; Meeten & Davey, 2011) are rules used implicitly or explicitly, formed by an individual to help them decide whether to continue to worry. Examples of goal directed worry rules are: 'I must focus on every conceivable solution' or 'I must sort out what is worrying me' (Davey, Startup, MacDonald, Jenkins, & Patterson, 2005). Research suggests that high trait worriers possess a number of characteristics that makes them likely to believe they must continue to worry e.g. positive beliefs about the utility of worry (Borkovec & Roemer, 1995; Davey, Tallis, & Capuzzo, 1996; Tallis, Davey, & Capuzzo, 1994) and elevated evidence requirements for decision making (Tallis, Eysenck, & Mathews, 1991). The use of goal directed worry rules are positively associated with trait worry (PSWQ) and a behavioural measure of worry (Davey, Startup, MacDonald, Jenkins, & Patterson, 2005). Individuals with GAD also show significantly higher endorsement of goal directed worry rules than a non-anxious control group (Meeten et al., 2016).

Pathological worriers tend to experience high levels of endemic negative mood (Davey, Hampton, Farrell, & Davidson, 1992; Meyer et al., 1990) and goal directed worry rules (also known as 'as many as

can' stop rules) are assumed to interact with negative mood to result in worry perseveration (e.g. Davey, 2006; Meeten & Davey, 2011; Startup & Davey, 2001). For example, if a pathological worrier holds a rule such as 'I must think about this concern until I feel prepared for every possible outcome' and they are in a negative mood, they may use their current mood state as a source of information about whether they have met their goal. The negative mood provides information which suggests that they are not feeling satisfied or that the tasks goals have not been met (Martin, Ward, Achee, & Wyer, 1993). In this way the worry rule adopted and the concurrent negative mood experienced interact to influence worry perseveration. This interaction between goal directed worry rules and negative mood has been shown to have a causal effect on worry (Meeten & Davey, 2012; Startup & Davey, 2001).

2.2. Aims

Over the past 30 years, our understanding of the cognitive constructs thought to be important in worry has flourished. While there is a wealth of evidence linking these constructs to worry processes, the causal contribution of these constructs to worry is less clear. As noted by Behar, DiMarco, Hekler, Mohlman, and Staples (2009) cognitive models of GAD often present causal hypotheses, but there is a lack of experimental evidence to support and test the proposed models. A review of the literature which specifically examines experiments seeking to determine the causal contribution of these constructs to worry would be a helpful contribution to understanding the current knowledge base in this area and provide directions for future research and treatment. To understand the relationship between cognitive constructs and worry, we need reliable and valid assessments for manipulating these constructs and for measuring worry under controlled conditions. Alongside examining experimental evidence for the causal role of cognitive constructs in worry, an examination of the manipulation of these cognitive constructs and the measurement of worry in the laboratory is another

often overlooked factor. For this reason, the present review will also examine assessments of worry employed in the experimental psychopathology research and assessments of cognitive constructs and their relationship with worry.

The aim of the present review is:

1. To systematically examine the evidence base for the causal role of cognitive constructs proposed to be important in the development and maintenance of a pathological worry bout. Constructs to be examined are: information processing biases including interpretation and attentional biases, attentional control, mentation style (verbal vs. imagery), intolerance of uncertainty, positive and negative beliefs about worry, and goal directed worry stop rules.

3. METHOD

3.1 Search strategy

Two search strategies were used. Firstly the databases Web of Science and PsycINFO were searched from February 6th – 10th 2017. The search process is outlined in the PRISMA flow chart, Figure 1. First, separate searches were conducted for the term ‘worry AND’ combined with the following search terms: “attentional bias”, “attention bias”, “attentional control”, “working memory”, “cognitive control”, “interpretation bias”, “inference* bias”, “intolerance of uncertainty”, “positive beliefs”, “negative beliefs”, (verbal AND image*), (abstract AND concrete), “stop rules”, (“stop rules” AND mood). These searches were then repeated using the term ‘worry* AND’ combined with the search terms listed above. Second, reference lists from published review papers were searched for relevant studies.

3.2 Coding

A standardised data coding form was developed to extract the following information from each study: (a) authors and publication year; (b) construct under examination, (c) study design; (d) characteristics of the study sample (age, sex, size, subgroups); (e) method used to manipulate the construct of interest; (f) outcomes of interest; and (g) brief results.

3.3 Inclusion and exclusion criteria

3.3.1 Inclusion criteria

- Written in English
- Experimental study where one or more of the above named cognitive constructs is manipulated with a control condition
- The outcome measure is an established questionnaire examining worry or a behavioural measure of worry
- The study design is a single-session experiment
- The population is a non-clinical sample, or high trait worriers, or individuals with a diagnosis of GAD

3.3.2 Exclusion criteria

- Participants are below 18 years old
- Not an experiment with a control condition.
- The participants in the experiment have a diagnosis of a mental health condition other than GAD, although co-morbidity where GAD is the primary problem is accepted
- The outcome measure is a measure of trait anxiety as opposed to a measure of worry
- A non-validated worry questionnaire or a single-item worry question is used as the outcome measure

The rationale for these inclusion and exclusion criteria will be outlined. Studies were restricted to those written in English for comprehension reasons and to participants over 18 so as to focus on an adult population (as defined by age ranges adhered to in mental health services in the United Kingdom). Cognitive constructs must have been manipulated in order to examine causal relationships and an appropriate control group is necessary in order to examine the effect of the experimental manipulation on the dependent variable. The outcome measure needed to be an established measure of worry so that some information on the validity of the measure could be examined. Studies were restricted to single session experiments. Once

two or more sessions are introduced it creates potential confounders where variables introduced between sessions and outside of the experimental manipulation may influence the relationship between the construct manipulated and the outcome variable. The population chosen as the focus of the review was a non-clinical sample, or high trait worriers, or individuals with a diagnosis of GAD. In order to allow for constructs relevant to pathological worry to be examined, participants with a primary clinical diagnosis other than GAD were not suitable for this review.

3.4 Quality assessment

The quality of the studies was assessed using selected items from the Specialist Unit for Review Evidence (SURE; 2013). The SURE measure provides questions to assist with the critical appraisal of randomised controlled trials and other experimental studies. For the purpose of this review, aspects of the SURE assessment that were relevant to experimental psychopathology were chosen (see Appendix 1 for a copy of the quality assessment checklist). There were 11 questions scored either 0 or 1 and three questions were scored 0, 1, or 2 to allow for differentiation between the presence of a measured component and its quality. The questions examined key domains of experimental psychopathology study design such as identification of the cognitive construct to be examined and importantly its manipulation method, the appropriateness of the comparator/control condition, study confounders (e.g. are relevant variables such as age, gender, or baseline levels of trait worry, measured and assessed to be similar between groups at baseline), appropriateness of statistical analysis, appropriateness of the type of worry task used as the dependent variable, and whether the study conclusions are supported by the results, and finally, where limitations of the experiment were discussed. This review is examining research with a time span of 24 years and best practice recommendations for research publication have changed in that time. An obvious example is the reporting of effect sizes in a published manuscript. This quality tool does not

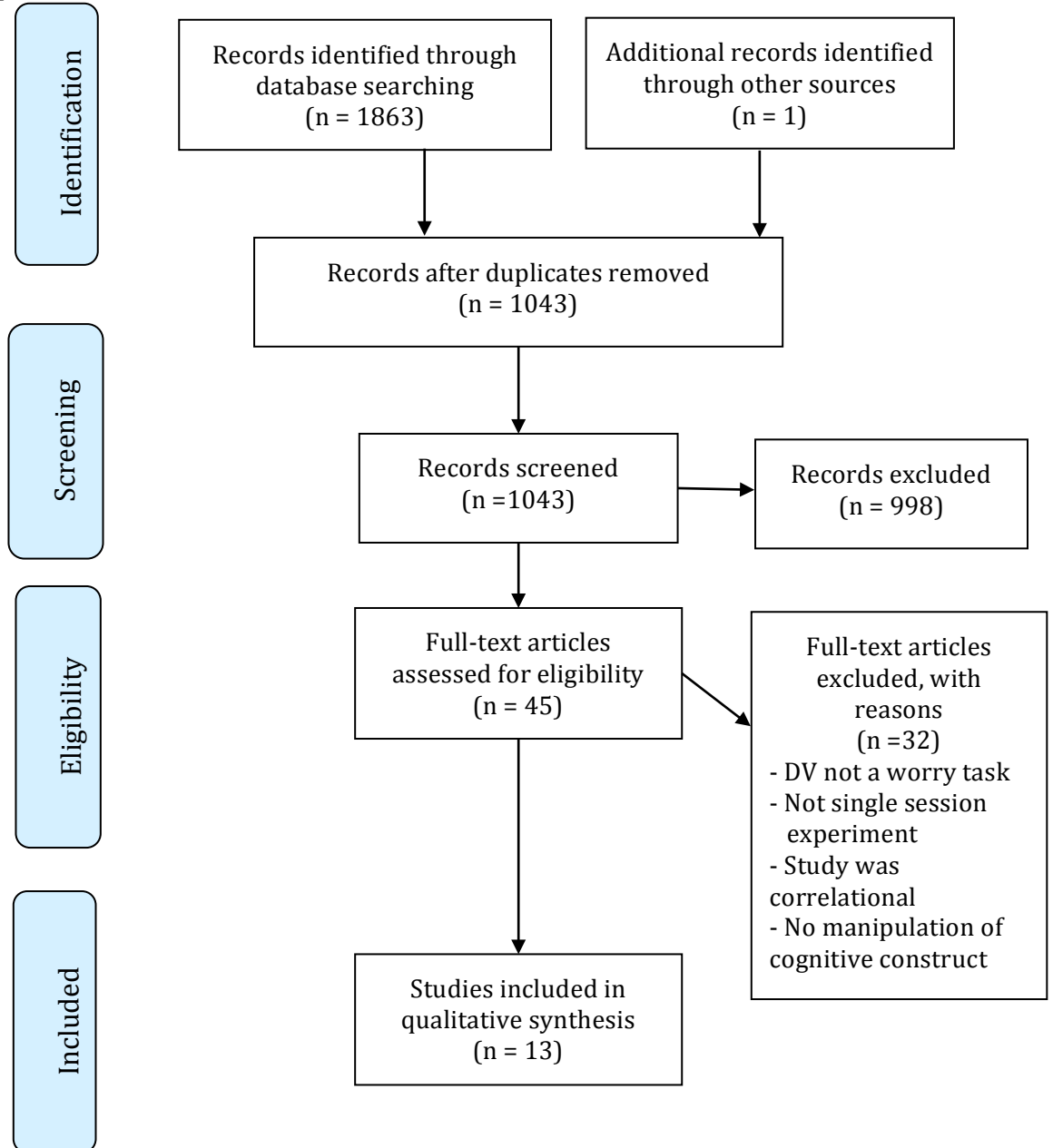
withhold marks for non-publication of effect sizes, but this will be discussed in considering best practice for experimental psychopathology research.

4. RESULTS

4.1 Number of articles

The initial search returned 991 records from the Web of Science database and 872 from the PsychINFO database, giving a total of 1863 records. Examination of reference sections of other published papers provided one extra reference. After duplicates were removed, 1043 records were retained. Papers were screened for relevance by examining the title and abstracts. Common reasons for exclusion at this stage were a child or adolescent sample, a review paper, a correlational design, or no worry outcome measure. The full text of the remaining articles ($n = 45$) was then examined. Articles were excluded for the following reasons: i) worry was not an outcome measure in the study ($n = 22$) e.g. participants were asked to worry, but the outcome measure was amount/frequency of imagery during a worry period or a measure of working memory capacity during a worry period, ii) the study was not a single session experiment such as a treatment intervention ($n = 3$), iii) data was correlational ($n = 3$), iv) construct of interest was measured but not manipulated ($n = 1$), v) worry outcome measure was a single visual analogue scale and thus not a validated questionnaire or established behavioural measure of worry ($n = 2$), vi) there was no control condition ($n = 1$). Thirteen studies were retained for inclusion in the review.

Figure 1
PRISMA flowchart of the screening and eligibility assessment process



4.2 Participant characteristics

See Table 1 for an overview of participant characteristics. The total number of participants in the 13 studies was 783. Eight studies ($n = 413$) had a participant population comprised of students, three studies ($n = 250$) recruited staff and student participants, one study recruited a community high-trait worry sample ($n = 80$), and one study ($n = 40$) recruited participants who had a diagnosis of GAD. All studies were interested in examining how the manipulation of a cognitive construct thought to be relevant to pathological worry, affected a measure of worry in the laboratory. Studies varied in whether they employed a clinical population (e.g. participants with a diagnosis of GAD, ($n = 1$), a high trait worry population ($n = 6$), a non-high trait worry population ($n = 1$), both high worriers and non-worriers ($n = 1$), or no worry level screening ($n = 4$).

Table 1

Study characteristics

Study	Sample	% female	Age range Mean (SD)	Ethnicity
<i>Interpretation bias papers</i>				
Hirsch, Hayes, & Mathews (2009)	N = 40 High worriers (≥ 56 on PSWQ), university staff and students	80	Mean age benign grp = 34.9 (13.3) vs. control grp = 36.4 (13.8)	NR
Hayes, Hirsch, Krebs, & Mathews (2010)	N = 40 GAD patients	77.5	Mean age benign grp = 43 (13.6) vs. 41 (9.3) in the control grp	NR
<i>Attentional bias papers</i>				
Krebs, Hirsch, & Mathews (2010)	N = 64 Students scoring ≤ 55	69	Whole sample = 23.78 (4.95)	NR

		on PSWQ		Tht grp explicit = 24.50 (4.32) Neu grp = explicit = 24.17 (5.19) Tht grp standard = 22.57 (2.71) Neu grp standard = 23.87 (7.56)	
Hayes, Hirsch, & Mathews (2010)	N = 48 Students high worriers (\geq 56 on PSWQ)	81	Benign grp = 27 (8.6) Control grp = 26.2 (6.3)	NR	
Hirsch, MacLeod, Mathews, Sandher, & Siyani, & Hayes (2011)	N = 64 Students, non high trait worriers (\leq 55 on PSWQ)	66	19.5 (2.7)	NR	
Sass, Evans, Xiong, Mirghassemi, & Tran (2017)	N = 41 Students: High worry sample (PSWQ = 54.7)	70.73	Training condition = 19.3 (1.1) Control condition = 19.85 (2.1)	70% = Caucasian 7% = African American 7% = Asian or Pacific Islander 13% = other	
<i>Attentional control paper</i>					
Rapee (1993)	N = 68 Students: self- reported high and low worriers	High worry grp = 80 Low worry grp = 50	High worry grp = 19 (SD 2.4) Non-worry grp = 21.4 SD (5.4)	NR	
<i>Verbal/Imagery papers</i>					
Stokes & Hirsch	N = 60 Staff &	88.33	Verbal grp = 26.83	NR	

(2010)	students at university, high worriers (≥ 56 on PSWQ)		(13.44) Imagery grp = 25.34 (8.69)	
Hirsch, Perman, Hayes, Eagleson, & Mathews (2015)	N = 80 Community sample, high worriers (≥ 56 on PSWQ)	70% female	Negative verbal = 33.30 (9.76) Negative imagery = 31.75 (8.85) Positive verbal = 32.80 (12.61) Positive imagery = 33.10 (9.85)	NR
<i>Intolerance of uncertainty papers</i>				
Ladouceur, Gosselin, & Dugas (2000)	N = 42 Students	71.43	22.75 (4.50)	NR
Meeten, Dash, Scarlett, & Davey (2012)	N = 46 Students	71.74	Range = 19-47 Mean = 26.8 (5.52).	NR
<i>Goal directed worry stop rule and negative mood papers</i>				
Startup & Davey (2001) Exp 3	N = 40 Students	NR	NR	NR
Meeten & Davey (2011)	N = 150 University students and staff	74	Range = 18-42 Mean = 21.91 (4.25)	NR

Note: IB = Interpretation bias; AB = Attention bias; AC = Attentional control; V/I = Verbal/Imagery; IU = Intolerance of uncertainty; WSR = Worry stop rules; PSWQ = Penn State Worry Questionnaire; Tht = Threat; Neu - Neutral; Grp = Group; NR = Not reported

The study that required a GAD population (Hayes et al., 2010) used the structured clinical interview for the DSM (SCID; First, Spitzer, Gibbon, & Williams, 1997) to confirm a diagnosis of GAD. The PSWQ

(Meyer et al. 1990) was used in all studies that screened participants as high or non-high trait worriers. Studies varied on how they used the PSWQ to define high worriers. Three studies (Hayes, Hirsch, & Mathews, 2010; Hirsch et al. 2009; Hirsch, et al. 2015) employed a cut-off score of ≥ 56 on the PSWQ. Sass et al. (2017) used ≥ 62 as a cut-off for their high worry group at the screening phase, but reported that the mean PSWQ score of those who agreed to take part after screening was 54.7, thus lower than their intended cut-off. Rapee (1993) recruited participants who considered themselves to be worriers or non-worriers. The lowest mean PSWQ score of the worriers group was 63.7. Where studies specified a non-high trait worry population (Hirsch et al., 2011; Krebs et al., 2010) the PSWQ cut-off score was ≤ 55 .

The mean age of the GAD group was 42 (11.45) years, the average of the mean ages of the high trait worry participants across all studies was 26.56 (7.64) and the average mean age of the non-high worry groups across all studies was 21.64 (3.83) and mean age in the non-screened groups (one study in this category did not report participant ages) was 23.82 (4.85). The gender distribution in the GAD group was 80% female. The average gender distribution across all the high worry sample was 78.34% female, in the non-high worry groups it was 61.67% female and in the non-screened groups it was 72.39% female, with one study in this category not reporting gender distribution. One of the studies in this review reported participant ethnicity (Sass et al., 2017; see Table 1 for age and gender of participants in each experiment).

Table 2

Systematic review findings

Study	Sample GAD or non- clinical	Experiment cell sizes	Manipulation task/method	Worry task	Effect of IV on DV Y/N?	Quality rating 0-13
<i>Interpretation bias papers</i>						

Hirsch, Hayes, & Mathews (2009)	NC	Benign training: $n = 20$ vs. control training: $n = 20$	i) task ii) scenarios	Homograph Ambiguous task	Worry breathing focus	Y	17
Hayes, Hirsch, Krebs, & Mathews (2010)	GAD	Benign training: $n = 20$ vs. control training: $n = 20$	i) task ii) scenarios	Homograph Ambiguous task	Worry breathing focus	Y	17
<i>Attentional bias papers</i>							
Krebs, Hirsch, & Mathews (2010)	NC	$n = 16$ in each condition i) Tht training/explicit instruction ii) Tht training/standard instruction iii) Neu training/explicit instruction iv) Neu training/standard instruction	Dot probe task		Worry breathing focus	Y	17
Hayes, Hirsch, & Mathews (2010)	NC	Benign grp $n = 42$ vs. Control grp $n = 42$	i) Dot probe task ii) Dichotic listening task		Worry breathing focus	Y	17
Hirsch, MacLeod, Mathews, Sandher, Siyani, & Hayes (2011)	NC	$n = 16$ in each condition i) encourage selective engagement [with threat meanings] ii) discourage	Novel training Participants switched attention between structure and semantic content of words	attention task:	Worry breathing focus	Y	16

		selective disengage- ent iii) discourage selective engagement iv) encourage selective disengage- ent					
Sass, Evans, Xiong, Mirghass emi, Tran (2017)	NC	Attention training condition n = 20 Control condition n = 21	Modified probe task	dot	PSWQ scores	Y	15
<i>Attentional control paper</i>							
Rapee (1993)		$n = 50$ high worriers Task 1 $n =$ 13 Task 1 $n =$ 11 Task 1 $n =$ 13 Task 1 $n =$ 13 $n = 18$ low worriers Task 1 $n = 4$ Task 1 $n = 5$ Task 1 $n = 5$ Task 1 $n = 4$	4 tasks that used different aspects of AC i) Phonological loop ($n = 17$) ii) Phonological loop & central executive ($n =$ 16) iii) Visuospatial sketchpad ($n =$ 18) iv) Visuospatial sketchpad & central executive ($n = 17$)		Worry about current worry topic Frequenc -y of worry related thoughts in worry alone vs. worry with AC	Y	16
<i>Verbal/Imagery papers</i>							
Stokes & Hirsch (2010)	NC	Imagery training grp $n = 30$ Verbal training grp $n = 30$	Training worry or using imagery	to verbally focus task	Worry breathing focus task	Y	17
Hirsch,	NC	Negative	Training to think		Worry	Y	17

Perman, Hayes, Eagleson & Mathews (2015)		verbal training $n = 20$ Negative imagery training $n = 20$ Positive verbal training $n = 20$ Positive imagery training $n = 20$		about scenarios using images or verbally	breathing focus task		
<i>Intolerance of uncertainty papers</i>							
Ladouceur, Gosselin, & Dugas (2000)	NC	Raised induction $n = 21$ Lowered induction $n = 21$	IU n IU n	Computerised Roulette game with incentive to win money for a charity. Certainty about whether charity would get its money was manipulated	Modified PSWQ questions	Y	14
Meeten, Dash, Scarlett, & Davey (2012)	NC	Raised induction $n = 25$ Lowered induction $n = 21$	IU n IU n	Participants provided with a script describing a person in an uncertain situation. They were asked to imagine themselves as that person and write a diary entry as that person	Worry catastrophising task	Y	16
<i>Goal directed worry stop rule and negative mood papers</i>							
Startup & Davey (2001) Exp 3	NC	AMA SR $n = 20$ FL SR $n = 20$ After tertile split on PSWQ:		Worry stop rule manipulation instructions	Worry catastrophising task	Y	16

		HW/AMA	<i>n</i>				
		= 7					
		HW/FL	<i>n</i>				
		= 7					
		LW /AMA	<i>n</i>				
		= 6					
		LW/FL	<i>n</i>				
		= 8					
Meeten & Davey (2011)	NC	<i>n</i> = 15 each	grp	Worry stop rule manipulation instructions + Mood induction using film	Worry catastroph-hising task	Y	17
		AMA Neg					
		AMA Anx					
		AMA Ang					
		AMA Pos					
		AMA Neu					
		FL Neg					
		FL Anx					
		FL Ang					
		FL Pos					
		FL Neu					

Note: IB = Interpretation bias; AB = Attention bias; AC = Attentional control; V/I = Verbal/Imagery; IU = Intolerance of uncertainty; WSR = Worry stop rules; PSWQ = Penn State Worry Questionnaire; Tht = Threat; Neu - Neutral; Grp = Group; NR = Not reported; GAD = Generalised anxiety disorder; NC = Non clinical; Y = Yes; N = No; AMA = 'As many as can' stop rule; FL = 'Feel like' stop rule; HW = High worry; LW = Low worry

4.3 Paradigms used to manipulate cognitive constructs

The experiments discussed in this review used a number of experimental paradigms to manipulate the cognitive construct of interest (see Table 2 for an overview of manipulation methods). These will be discussed here along with an examination of whether the experiments included a check on whether the manipulation of the construct was successful.

4.3.1 Interpretation bias

Interpretation bias was manipulated in two studies (Hayes, Hirsch, Krebs, et al., 2010; Hirsch et al., 2009) by using a homograph task and an ambiguous scenarios task. The homograph task presents word pairs (devised by Grey and Mathews, 2000) where the cue word is a homograph with a threat or benign meaning e.g. 'beat' which is then paired with a disambiguating word fragment e.g. beat - mu_ic or

beat – fi_ht. Depending on the training condition a participant is assigned to, they will either see all threat or all benign associated word fragments and participants are instructed to press a key as soon as they know what the word in the word fragment is and then they are prompted to fill in the corresponding missing letter. In order to assess training effects, (Hayes, Hirsch, Krebs, et al., 2010) also presented 20 test trials after training where the disambiguating word fragment was 50% threat and 50% benign and the time taken to indicate that they knew what the word was, was a measure of interpretation and thus a manipulation check. The ambiguous scenarios task presents the participant with up to 90 audio recorded scenarios that cover a range of worry topics and the scenario is emotionally ambiguous until the final word, which disambiguates the scenario. The participant then sees a comprehension question on the computer screen. An example scenario from Hirsch et al. (2009, p. 46) where the final disambiguating word is in parentheses is “You are given the task of arranging the annual office party. Despite having very little time, you do your best to prepare food, drink and entertainment. As the night approaches, you think that the event will be a (success/disaster).” A comprehension question then checks that the participant has understood the scenario in the appropriate context e.g. “Did people enjoy the party you planned?” yes/no. Assessment of change in interpretation bias in the ambiguous scenarios task is measured in the (Hayes, Hirsch, Krebs, et al., 2010) paper by a small number (20/90) of test trials where the scenario presented remains ambiguous and the yes/no response to the comprehension question indicates the interpretation valence. Hayes, Hirsch, Krebs, et al. (2010) reported that there was no expected effect of training group on the homograph test trial latencies, raising the question as to whether the manipulation was successful using this task. There was a significant effect of training group on the test trials for the ambiguous scenarios task where the benign group made significantly more benign interpretations than the control group. This was further qualified by finding that the training

effect transferred onto a sentence completion task where participants were provided with a sentence that remained ambiguous until the final word. Participants were asked to generate as many one word completions as possible to each sentence, in the order that they came to mind. The benign training group generated proportionally fewer negative completions than the control group (Hayes, Hirsch, Krebs, et al., 2010). These finding suggests that the ambiguous scenarios training task was successful at manipulating interpretation bias in the required direction.

4.3.2 Attention bias

Attentional bias was manipulated by using a modified dot-probe task in two experiments (Krebs et al., 2010; Sass et al. 2017) and one experiment also employed both the dot probe task and a dichotic listening task (Hayes, Hirsch, & Mathews, 2010). The dichotic listening task (Hayes, Hirsch, & Mathews, 2010) used 10 worry related scenarios and 10 benign scenarios that were presented at the same time with one benign and one worry scenarios presented simultaneously over 2 minutes. Participants were informed of the title of the text to follow and which ear it would begin in. The texts switched ears during each scenario to encourage tracking and participants completed comprehension questions relating to the story they were asked to track at the end of each presentation. The benign training group were asked to track benign texts and the control training group tracked benign texts and worry-related texts 50% of the time for each type in counterbalanced order. Hayes, Hirsch, and Mathews (2010) found that accuracy for the comprehension questions in the dichotic listening task was significantly higher in the control as compared to the benign group. One possibility is that high worriers naturally attend to worry-related material as opposed to benign topics (Hayes, Hirsch, & Mathews, 2010).

As described in Hayes, Hirsch, and Mathews (2010), a typical dot-probe task to train individuals to benign stimuli will show the

participant a threat – non-threat word pair and after a 750ms one word is replaced by a target (a dot) and the participant has to press a button when the target appears. In order to train attention to benign information, the target is consistently in the location of the non-threat word. To assess the effectiveness of the manipulation Hayes, Hirsch and Mathews (2010) and Krebs et al. (2010) included eight test trials within the training trials where four targets appeared in the threat word location and four in the neutral word location regardless of the training group. The response latency to locate the target was the measure of attentional bias. In both studies there was an effect of training on response latencies in the expected direction based on type of training received. Sass et al. (2017) also employed a manipulation assessment measure by using a dot probe task to assess attentional bias before and after a manipulation phase. They were able to report that the manipulation was successful. Hirsch et al. (2011) used a novel attention training task to train participants to selectively engage with benign information or disengage from threat meanings. The manipulation was designed to either focus on attentional engagement with the meaning of threat or non-threat words (depending on allocation to condition of increase or decrease threat processing) or with the attentional disengagement from threat or non threat words. A manipulation check suggested that the training was successful in inducing a group difference in attentional bias through selective engagement with and selective disengagement from threat meanings (Hirsch et al., 2011).

4.3.3 Attentional control

Rapee (1993) used four different tasks to examine the effect of attentional control on worry. The tasks were employed to examine different aspects of working memory and were described by Rapee (1993) as follows. To employ the phonological loop, the first task required participants to say the word 'one' at approximately 1 second intervals. The second task employed both the phonological loop and

the component of the central executive concerned with the phonological loop required participants to generate random letters of the alphabet at approximately one second intervals. The third task utilised the visuo-spatial sketchpad required participants to touch keys on a 9-button key pad in the shape of an S. Finally, the fourth task examined use of the visuo-spatial sketchpad and the component of the central executive relating to the visuo-spatial sketchpad and required participants to randomly touch keys on a keypad. To assess whether participants were able to complete each task adequately, Rapee (1993) compared the mean time between responses on a participant's designated task and the evenness of responses when they were doing the task alone (baseline phase) and while doing the task when worrying, for each task. Using a repeated measures ANOVA with all tasks assessed in the ANOVA, Rapee (1993) reported a significant effect of task as one would expect, but no interaction effect between task and worry phase. This suggests that participants were able to adequately complete the task while not worrying and while worrying.

4.3.4 Mentation style: Verbal vs. Imagery

Stokes and Hirsch (2010) manipulated processing style by training participants to worry while using a verbal or an imagery processing style. Participants in the imagery condition were trained by asking them to imagine completing familiar scenarios and engaging in all their senses (e.g. see, smell, taste, hear) to heighten the image. Participants in the verbal condition were asked to think about every day scenarios, but as though they were talking to themselves. Participants then used these different information processing styles while worrying about a personal worry topic for 5 minutes, where the dependent variable was number of negative thought intrusions recorded in a breathing focus task before and after the word period (see Appendix 2 for further details on the worry breathing focus task). As a manipulation check, Stokes and Hirsch (2010) asked participants to complete two visual analogue scales assessing what percentage of

the time the participants thought they had engaged in verbal processing and imagery during the worry phase. Only those who scored above 55% in their designated mentation condition and that this was also at least 10% greater than their score on the other mentation style were included in the analysis. Hirsch et al. (2015) trained participants to think about positive or negative outcomes to scenarios in either words or images. Participants were first asked to think about a common concept 'friendship' in either words or images and were then provided with scenarios which were potentially worrying and were asked to think about positive or negative outcomes (depending on condition allocation). The amount of time spent thinking about each scenario was progressively increased. As a manipulation check, participants rated their thinking style after each scenario.

4.3.5 Intolerance of uncertainty (IU)

Two experiments manipulated IU (Ladouceur et al., 2000; Meeten et al., 2012). Ladouceur et al. (2000) used a Roulette game to manipulate IU. Participants were informed that money would be donated to a fictitious charity if the participant finished the Roulette game with money over a certain limit. Participants in the increase IU group were informed that their chances of winning were low, the implication being that the charity would get no money. Those in the decrease IU group were informed that the chance of winning was high and whatever the outcome, the charity would receive their money, thus reducing uncertainty about whether the charity would gain any money. In order to evaluate the manipulation, participants responded to six questions to evaluate IU about the experimental task. These questions were based on the Intolerance of Uncertainty Scale (Freeston, Rheaume, Letarte, Dugas, & Ladouceur, 1994). Meeten et al. (2012) used an IU manipulation technique based on work by Kelly, (2009) whereby participants were asked to read a story where the central character is in a situation with low or high IU. Participants

were asked to imagine themselves in the story, and stories were gender congruent in order to facilitate assimilation with the character. Participants were then asked to think of a situation in their own life where they were unsure whether the outcome would be good or bad and then they were required to write a diary entry as the character with high or low IU about the personal uncertain event that they had just described. To assess efficacy of the manipulation, a manipulation check was employed which was in the form of three visual analogue questions, which assessed beliefs about uncertainty and its implications. These questions were significantly correlated with the Intolerance of Uncertainty scale Short form (Carleton, Norton, & Asmundson, 2007).

4.3.6 Goal directed worry stop rules

Two experiments manipulated goal directed worry stop rules (Meeten & Davey, 2012; Startup & Davey, 2001) by providing verbal and written instructions asking participants to complete a worry catastrophising task by using one of two rules. Those in the ‘as many as can’ stop rule condition were asked to “take part in the interview until they had reached their goal of sufficiently exploring their worry”. Those in the ‘feel like continuing’ condition were asked to take part in the interview as long as they felt like continuing with the interview” (Startup & Davey, 2001, p. 91). In the Meeten and Davey (2012) study, participants were asked to confirm that they had understood the instructions. Neither study performed a manipulation check.

4.4 How is worry assessed in the laboratory?

Employing valid and reliable ways to measure worry in the laboratory is crucial to better understanding the cognitive antecedents of worry. In seven experiments (Hayes, Hirsch, Krebs et al. 2010; Hayes, Hirsch, & Mathews, 2010; Hirsch et al., 2011, 2009; Hirsch et al., 2015; Krebs et al., 2010; Stokes & Hirsch, 2010) the worry breathing focus task is used as an outcome measure. This task is adapted from a behavioural measure of worry developed by Borkovec, Robinson,

Pruzinsky, and DePree (1983) and refined by Ruscio and Borkovec (2004). The dependent variable is number of negative thought intrusions that occur in a breathing focus period before and after a worry period (see Appendix 2 for a full description of the worry breathing focus task).

Three experiments employed the catastrophising interview procedure as a behavioural measure of worry. This worry task was modelled on an interview designed by Vasey & Borkovec (1992) and modified by (Davey & Levy, 1998). Here, the dependent variable is the number of responses generated in a catastrophising interview on a personal worry topic (see Appendix 3 for a full description of the catastrophising interview). Rapee (1993) assessed worry by asking participants to think about a topic of current concern, which they could worry about. This was then discussed with the experimenter to remind the participant of the salient aspects of the worry and participants engaged in worry using this topic during the experiment. Rapee (1993) does not refer to the validity of this technique as a measure of worry. However, it is a technique now commonly employed as a measure of worry (e.g. Behar, Zuellig, & Borkovec, 2005; Llera & Newman, 2010). One experiment (Sass et al., 2017) used a trait measure of worry, the Penn State Worry Questionnaire (PSWQ; Meyer et al., 1990) as a means of measuring worry before and after manipulation of a clinical construct. This is a trait measure of worry and one would not expect a relatively brief experimental manipulation to affect a trait worry measure. However, it should be highlighted that baseline PSWQ scores in the Sass et al. (2017) study were from the screening stage of the study, approximately 30 days prior to the experiment. The PSWQ has good test-retest reliability (Molina & Borkovec, 1994), internal consistency (Brown, Antony, & Barlow, 1992) and discriminant validity (Meyer et al., 1990). One experiment (Ladouceur et al., 2000) used three questions based on items from the PSWQ (Meyer et al. 1990), but modified to ask about participants worry relevant to the IU manipulation. It is not clear whether this

assessment of worry had been piloted and whether the 3-item measure had good validity and reliability.

4.5 What evidence is there for the causal relationship between the cognitive constructs and worry?

4.5.1 Interpretation bias

Two studies (Hayes, Hirsch, Krebs et al., 2010; Hirsch et al., 2009) have examined the effect of manipulating interpretation bias on worry. Both experiments used the worry breathing focus task as the measure of worry. Homograph and ambiguous scenarios tasks were used to provide either benign training (non-threat interpretations) or sham training (50/50 benign- threat interpretations) with a high trait worry sample (Hirsch et al., 2009). There was a significant effect (large effect, $f^2 = 0.63$) of training on the number of negative thought intrusions during the worry breathing focus task with the benign training condition having significantly fewer intrusions than the control group both before and after the worry period (Hirsch et al., 2009). This was also the case when these interpretation bias training methods were employed with participants with GAD, (Hayes, Hirsch, Krebs et al., 2010) where there was also a large effect size ($f^2 = 0.43$).

4.5.2 Attentional bias

Four experiments examined the effect of attentional bias on worry and all reported a significant effect of bias training on worry task with a medium – large effect size. Hayes, Hirsch and Mathews (2010) used a dot probe task and a dichotic listening task to train high trait worriers ($56 \geq$ PSWQ) to attend to non-threatening words and text and worry related stimuli. A control condition received attention training to benign and threat stimuli equally. Using the worry breathing focus task as a laboratory proxy measure of worry, they reported that negative intrusions increased significantly from before to after the worry period in the control training group ($r = .57$, large effect), but that there was no significant difference in the benign

training group ($t = <1$), suggesting that benign training was a protective factor during the worry task.

Hayes, Hirsch and Mathews (2010) noted that a limitation of their study design was that one could not differentiate the contribution of the dot-probe task and dichotic listening task to attention bias change. Krebs et al. (2010) examined the effects of attention bias modification on negative thought intrusions using only the dot-probe task. Participants were non-high trait worriers (PSWQ ≤ 55) and a key difference between this study and the Hayes, Hirsch and Mathews (2010) study is that participants were trained to attend to either threat or neutral words. The authors also examined the effect of giving explicit vs. standard instructions on the dot probe task. Explicit instructions highlighted the relationship between word valance and target location and usual instructions that did not highlight this link. There was a significant effect of instruction type whereby the explicit instructions led to greater differences in attention to threat words vs. neutral in the threat group ($d = 1.75$, large effect) and greater differences in attention to neutral vs. threat words in the neutral groups ($d = .88$, large effect). Importantly, there was also an effect of training and instruction type on negative intrusions after worry where those in the attention to threat condition had a significantly greater number of negative intrusions after the worry period, but this effect was only when intrusion valence was rated by an independent assessor ($d = 1.20$, large effect), not when self-rated.

A modified dot probe task was also used by Sass, Evans, Xiong, Mirghassemi, and Tran (2017) to examine the effect of training high trait worry (PSWQ ≥ 54.7) participants to attend to pleasant stimuli or neutral stimuli. They found a significant effect of training on trait worry scores where there was a significant reduction in PSWQ scores from pre-post training in the group who were trained to attend to pleasant stimuli ($\eta_p^2 .257$, large effect). There was no change in trait worry scores in the control condition. However, baseline PSWQ scores

were those measured at the screening phase and there was approximately 30 days between initial PSWQ measure and post-task PSWQ measure.

Hirsch et al. (2011) further explored the role of attention bias in worry by examining whether the causal relationship between attention bias and worry is driven by preferential engagement with threat stimuli (at the cost of not attending to neutral or positive stimuli) or difficulty disengaging from threat stimuli. Hirsch et al. (2011) trained non-high trait worry participants (PSWQ ≤ 55) to either increase or decrease threat processing (see above for discussion of task). Hirsch et al. (2011) reported that the procedure designed to encourage selective engagement with threat produced a greater number of negative thought intrusions than the procedure designed to discourage selective engagement with threat ($d = 1.14$, large effect). This would suggest that attentional bias drives worry by facilitating engagement with threat stimuli, rather than preventing disengagement with threat stimuli.

4.5.3 Attentional control

One study (Rapee, 1993) examined attentional control where the dependent variable was a measure of worry. Rapee (1993) reported that a task (discussed in detail above) that employed both the central executive and phonological loop aspects of working memory was more effective in reducing number of worry thoughts (as compared to the worry alone period, $r = .83$, large effect), than tasks which employed only the phonological loop, or a task which uses the visuo-spatial scratch pad and the phonological loop (Rapee, 1993). The implication of this is that worry uses resources in the central executive and phonological loop as tasks using these resources reduced worry. There were no significant differences between high and low worriers on number of worry-related thoughts, although Rapee (1993) highlights the fact that participant numbers in the low worry group were low ($n = 18$).

4.5.4 Mentation style: Verbal vs. imagery

Two studies examined the effect of modifying mentation style on an established worry task. Stokes and Hirsch (2010) manipulated mentation style by training participants to worry using imagery or using a verbal processing style. Using the worry breathing focus task they found that there was a significant difference in the number of negative intrusions from pre to post worry period ($f = .42$, large effect), with the verbal mentation style condition reporting significantly more intrusions than the imagery condition. This finding was replicated by (Hirsch et al., 2015) who found that thinking about a personal worry using negative imagery resulted in significantly fewer negative intrusions in subsequent breathing focus period as compared to negative verbal worry ($d = 0.86$, large effect).

4.5.5 Intolerance of uncertainty (IU)

Two studies examined the effect of experimentally manipulating IU on a worry task. Ladouceur et al. (2000) manipulated IU in a student population using a Roulette game scenario (discussed above). Worry was measured by a 3-item assessment, which was based on questions from the PSWQ (Meyer et al., 1990), but modified to be relevant to the manipulation task. There was a significant effect of IU manipulation on reported worry about the charity ($r = .66$, large effect) where the groups with increased IU reported more worry about the charity than the low IU group. The authors highlight a critique of this study as being that the measures of IU and worry were only relevant to the gambling task. They recommend also including general measures of IU and worry in future research (Ladouceur et al., 2000). Meeten et al. (2012) used an imagined scenario task to manipulate IU. The worry task was a catastrophising interview procedure (Davey, 2006b; Vasey & Borkovec, 1992). This was a general measure of worry unrelated to the IU task, which overcomes the critique from the Ladouceur et al. (2000) paper that the worry task was only relevant to the gambling task. Meeten et al. (2012) reported that those in the high

IU manipulation produced significantly more steps on the worry interview than those in the low IU group ($r = .44$, medium effect size). Meeten et al. (2012) further explored whether negative mood (self-reported anxiety and sadness) mediated the relationship between IU and worry catastrophising steps. However, mediational analyses found that neither anxiety nor sadness ratings were significant mediators.

4.5.6 Metacognitions in pathological worry

The database search returned one experiment that examined the effect of negative or positive beliefs about worry, but as discussed above, it could not be included in the review.

4.5.7 Goal directed worry stop rules

There is evidence to support the causal role of ‘as many as can’ worry stop rules and negative mood in worry. Startup and Davey (2001) manipulated worry stop rules for high and low worriers. High worriers (who had significantly higher levels of negative mood than low worriers) and low worriers were asked to complete the worry catastrophising interview either while using an ‘as many as can’ worry stop rule (e.g. take part in the interview until you have reached the goal of sufficiently exploring your worry) or while using a ‘feel like stop rule (e.g. take part in the interview until you no longer feel like continuing). Interestingly there was a significant interaction between stop rule and group where high worriers (in a low mood) produced significantly more catastrophising steps than low worriers when using an ‘as many as can stop rule ($r = 0.63$, large effect) and this pattern was reversed when participants were using a ‘feel like’ stop rule with low worriers producing more catastrophising steps than high worriers (although the difference did not reach significance, $r = 0.36$, medium effect). Startup and Davey (2001) argued that this is evidence that ‘as many as can’ goal directed worry rules and negative mood have a causal influence on worry perseveration.

Meeten and Davey (2012) examined the effect of manipulating

worry stop rules in the context of different types of negative mood. They used film clips to induce participants into either a sad, angry, or anxious mood and used a positive and neutral mood induction as control conditions. Half the participants were then asked to engage in the worry catastrophising interview while using an ‘as many as can’ stop rule and the other half were asked to use a ‘feel like continuing’ stop rule. Meeten and Davey (2012) found that participants generated significantly more catastrophising steps when using an ‘as many as can’ stop rule and in a sad ($d = 0.80$, large effect), anxious ($d = 0.87$, large effect), and angry ($d = 0.91$, large effect), mood state than when using a ‘feel like continuing’ stop rule. In contrast, those in the positive condition generated significantly more catastrophising steps when using the ‘feel like continuing’ stop rule ($d = 0.94$, large effect). In the neutral mood condition there was no significant difference in the number of steps generated by the two stop-rule conditions ($d = .40$, small effect). These findings suggest that mood and stop rule interact to affect catastrophising steps when thinking about a personally relevant worry topic.

4.5.8 Quality of studies

As can be seen from Table 2, seven of the thirteen studies were scored as 17/17. Four studies received a score of 16. Reasons for losing a point were that potential confounding variables such as age and gender of participants were not detailed (Startup & Davey, 2001), there was no reference as to whether the outcome measure was a validated or established measure of worry (Rapee, 1993), a potential confounding variable was not equivalent at baseline (Meeten et al. 2012), or no study limitations were discussed (Hirsch et al. 2011). One study received a score of 15 (Sass et al. 2017). Two points were lost due to baseline measures for the study being assessed approximately 30 days prior to the study and the conclusions attributing change in PSWQ worry scores to the experimental manipulation without reference to possible other confounding variables. The Ladouceur et al.

(2000) study scored 14 on the quality assessment tool. Key difficulties with this study were that the experimental manipulation appeared to manipulate certainty rather than intolerance of uncertainty. There was also no baseline assessment of potential confounders and it was not clear that the worry measure was a reliable and valid means of assessing state worry. To improve validity of rating, a subsection (2 papers) of papers were chosen at random to be rated by a second person. There was 94% agreement between raters.

5. CONCLUSION

The current systematic review discussed cognitive constructs commonly associated with pathological worry and examined experimental evidence for the causal role of these constructs in worry. This included an examination of the methods used to manipulate these cognitive constructs and the methods used to measure worry in the laboratory.

5.1 Overview of findings

This review examined the causal relationship of the following cognitive constructs and worry: information processing biases (interpretation and attentional biases), attentional control, mentation style (verbal vs. imagery), positive and negative beliefs about worry, intolerance of uncertainty, and goal directed worry rules. Evidence for a causal relationship with worry was found for all constructs except positive and negative beliefs about worry.

5.1.2 Cognitive constructs involved in the initiation of worry

There is evidence to support the causal relationship between information processing biases (interpretation and attention) and measures of worry. Training participants (both high worriers and those with GAD) to have a benign interpretation of ambiguous scenarios as compared to a sham training condition, showed those in the benign training group to have reduced negative thought intrusions after worry (Hayes, Hirsch, Krebs et al., 2010; Hirsch et al., 2009). The fact that the training effect with high worriers in the Hirsch et al.

(2009) study was replicated in the study with individuals with GAD (Hayes, Hirsch, Krebs et al., 2010) suggests it is a robust effect and importantly, an effect which translates to a clinical population.

The manipulation of attentional bias also has a causal effect on worry outcomes where high worriers have been trained to ignore threat information (Hayes, Hirsch, & Mathews, 2010), or attend to pleasant stimuli (Sass et al., 2017) and this has reduced worry related negative intrusions, relative to a control condition. However, findings from the Sass et al (2017) study should be interpreted with caution as they measured worry at a screening session approximately 30 days prior to the study and then after the attention bias manipulation. Thus the change in PSWQ scores cannot be attributed to the experimental manipulation alone. Training a non high trait worry population to attend to threat (relative to a control condition) has also shown a causal effect on negative intrusions (Krebs et al., 2010) and manipulating engagement and disengagement from threat meanings has casually influenced negative intrusions (Hirsch et al., 2011).

Only one study was included in the review when examining the relationship between attentional control and worry (Rapee, 1993). Here the manipulation of different aspects of working memory showed that one task, which employed both the central executive and phonological loop aspects of working memory reduced worry when compared to worry when not performing the task. This review also reported on two experiments (Hirsch et al., 2015; Stokes & Hirsch, 2010) which demonstrated a causal relationship between the normal, verbal nature of worry (vs. thinking in mental imagery) and number of negative intrusions in a worry breathing focus task.

5.1.3 Beliefs about worry

The present review examined a number of beliefs about worry that have been hypothesised to causally influence worry. One of these is the cognitive construct of intolerance of uncertainty (IU). The IU model proposes a direct link between intolerance of uncertainty and

worry (Dugas, Gosselin, & Ladouceur, 2001). The present systematic review discusses two experiments (Ladouceur et al., 2000; Meeten et al., 2012) that used different techniques to increase and decrease intolerance of uncertainty, observing that the raised intolerance of uncertainty group reported significantly greater levels of worry on the two worry outcome measures than the decrease intolerance of uncertainty group. Arguably, the construct manipulation in the Ladouceur et al. (2000) study lacked specificity and focused more on the manipulation of certainty rather than intolerance of uncertainty per se. Future research might usefully focus on replicating this effect with a manipulation technique that is specific to intolerance on uncertainty. Meeten et al. (2012) extended work by Ladouceur et al. (2000) by showing that the IU manipulation has an impact on a worry task that is unrelated to the IU manipulation.

Contrary to Well's metacognitive model of GAD (Wells, 1995, 2006), there was no evidence to support a causal relationship between positive or negative beliefs about worry and worry. There is a lack of good quality studies examining this purported link. One possibility is that valid methods of experimentally manipulating negative beliefs about worry have not yet been established. Prados (2011, experiment 1) attempted to manipulate positive and negative beliefs about worry using persuasion messages. However, there was no manipulation check, thus the efficacy of this approach is unknown. Research that devises a method of manipulating positive and negative beliefs about worry would be helpful to elucidate whether or not there is evidence for a causal relationship. A second possibility is that positive and negative beliefs about worry do not have a causal relationship with worry. Although negative beliefs about worry are implied to have a causal relationship with meta-worry in the metacognitive model of GAD (Wells, 1997, 2006), it is conceivable that these types of beliefs are a consequence of pathological worry rather than a cause.

There was evidence to support a causal relationship between goal directed worry rules ('as many as can' stop rules) in conjunction

with negative mood and worry as measured by the catastrophising interview (Davey, 2006; Vasey & Borkovec, 1992). Startup & Davey (2001) found that high trait worriers (who were in a significantly greater negative mood than low trait worriers) produced higher numbers of catastrophising steps when using an 'as many as can' stop rule. This relationship between 'as many as can' stop rule use and negative mood and its effect on worry perseveration was replicated in the study by Meeten & Davey (2012).

5.2 Impact of the review findings on our understanding of the role of cognitive constructs in the initiation and perseveration of worry

Perhaps the most surprising finding from this review is the relative paucity of studies examining the causal relationship between cognitive constructs and worry. The number of articles returned from the literature search was small (N = 13), arguably providing a limited evidence base for some of these cognitive constructs, despite their prominence in theories of pathological worry. Where only one experiment has been found to support the relationship between a cognitive constructs and worry, replication studies are warranted.

Considering first factors that are thought to have a role in the initiation of worry (e.g. Davey & Meeten, 2016; Hirsch & Mathews, 2012) the relationship between interpretation and attentional biases is supported and research evidence is of good quality (Hayes, Hirsch, Krebs et al. 2010; Hayes, Hirsch, & Mathews, 2010; Hirsch et al., 2009; Hirsch et al., 2011; Krebs et al., 2010), although there are some limitations associated with the Sass et al. (2017) study (discussed above). As well as being causally related to worry, it is likely that these information processing biases interact with each other and also maintain worry. This proposed interaction is called the combined cognitive bias hypothesis (Hirsch, Clark, & Mathews, 2006; Hirsch & Mathews, 2012). Hayes and Hirsch (2007) suggest that attention to threat could be captured by a cue in the environment and once threat representations are activated, an individual with pathological worry

may interpret emotionally ambiguous information in a threatening manner, which in turn increases threat perception and so the cycle may continue, resulting in a full-blown worry episode. This proposed interplay between attention and interpretation biases is supported by research which demonstrated that training individuals to have biased attention toward threat was linked to subsequent negative interpretation of ambiguity (White, Suway, Pine, Bar-Haim, & Fox, 2011). Hirsch & Mathews (2012) suggest that as these ways of thinking become more engrained, cognitive biases will also maintain worry by interacting with the content of a worry bout. Further research in this area will help to elucidate the dynamic integration of these biases with each other and with worry symptoms.

As discussed above, only one study (Rapee, 1993) has provided evidence in support of the causal relationship between attentional control and worry. Extant research suggests that poor trait attentional control is a risk factor for pathological worry (e.g. Wessel et al., 2008), but that worry also has a deleterious effect on attentional control (e.g. Hayes et al. 2008; Leigh & Hirsch, 2011). One possibility is that there is a bi-directional relationship between attentional control and worry. Individuals who have low trait attentional control may have less top-down resources to manage and dismiss perceived threats, which in turn leads to initiation of worry. Equally, once worry has begun, the worry process depletes attentional control resources, thus making it hard to disengage from a worry bout.

The final construct examined as relating to initiation of worry is mentation style. Evidence from this review confirmed that verbal processing (as opposed to imagery based processing) is causally related to worry (Hirsch et al., 2012; Stokes & Hirsch, 2010) and the evidence is of good quality. This finding supports the view that engaging in verbal processing once a threat has been perceived is more likely to result in worry than thinking about that threat using imagery. Verbal worry (as opposed to the use of images) has also been linked to greater attentional bias to threat (Williams et al., 2014). One

possibility is that while there is a causal relationship between verbal worry and number of negative intrusions in the worry breathing focus task, once a worry bout commences this serves to augment attention to threat cues, which in turn will provide access to more threat stimuli, thereby keeping the worry bout alive.

Evidence examining maladaptive beliefs and their relationship with worry (discussed here as possible drivers of worry perseveration after threat perception and worry initiation) is mixed. Once threat activation has occurred there are a number of beliefs and responses to worry that pathological worriers are thought to hold and may differentiate chronic and pathological worry from normal worry. One of these is the cognitive construct of intolerance of uncertainty (IU). IU is proposed to influence worry directly and also through three other processes, namely positive beliefs about worry, negative problem orientation and cognitive avoidance (Koerner & Dugas, 2006). The present review examined two studies that assessed the causal relationship between IU and worry. Both the Ladouceur et al. (2000) and Meeten et al. (2012) studies found support for the causal relationship between IU and worry. However the Ladouceur et al., (2000) study had some notable methodological issues (discussed above). Goal directed worry stop rules in conjunction with negative mood were also found to be causally related to worry (Meeten & Davey, 2012; Startup & Davey, 2001). However, both mood and worry stop rule was only manipulated in one study (Meeten & Davey, 2012) with the Startup & Davey study experimentally manipulating stop rules in high and low worriers. Again, replication of the examination of both IU and goal directed worry rules and their relationship with worry would seem to be an important future endeavour. Finally, although there was no evidence of a causal relationship between positive and negative belief about worry and worry outcomes, a number of theories of worry highlight the importance of positive beliefs about worry in the maintenance of worry (e.g. the intolerance of uncertainty model of worry (Koerner & Dugas, 2006) and the mood-

as-input account of worry (Davey, 2006; Meeten & Davey, 2011). One possibility is that positive beliefs about worry do not causally relate to worry per se, but do influence worry perseveration through their relationship with other cognitive constructs (e.g. Davey & Meeten, 2016).

5.3 Areas for future research development

As a relatively small number of papers were included in the final review, this highlights the fact that even though many of the links between cognitive constructs and pathological worry are assumed, there is relatively little research demonstrating these causal links. Experimental psychopathology techniques are a valuable tool through which to model potentially causal relationships between cognitive constructs and measures of worry. Of course, in order for the model to be useful, both the construct being measured and the worry outcome measure must have construct validity (Vervliet & Raes, 2013). For this reason, experiments that had a single-item worry measure as a dependent variable were excluded from the review, as they are unlikely to have acceptable validity or reliability. Both the behavioural measures of worry examined in this review (worry breathing focus task and the worry catastrophising interview) have been shown to differentiate performance of non-clinical worriers from clinical worriers, suggesting good construct validity. In future research, behavioural assessments of worry in the lab may be augmented by psychophysiology measures such as heart rate variability which is a physiological correlate of worry (Chalmers, Heathers, Abbott, Kemp, & Quintana, 2016; Ottaviani, Shahabi, et al., 2015).

It is important to note that while experimental designs can account for confounding variables such as levels of trait worry, age, sex etc., these experiments cannot account for the possibility that manipulating one cognitive construct, will also influence another, which remains unmeasured. Understanding more about how cognitive constructs relate to each other as well as to measures of worry will

provide further knowledge about the development and maintenance of pathological worry. Future experiments may usefully include mediation models to help elucidating further information about nature of the relationships between these cognitive constructs and worry.

Effect sizes in the majority of experiments were large, suggesting that these were robust effects. However, effect sizes were not universally reported (where missing they were calculated by the author of this paper) and it will improve our understanding of the relationships between manipulated constructs and outcome measures if this information is routinely included in research articles. As with many published psychology studies, the majority of experiments in this review recruited university students for their study sample. Ecological validity of findings may be improved by future studies recruiting a community sample. Although not always requested by academic journals, this research area would benefit from a discussion of power and subsequently sample sizes in experimental psychopathology research. Often researchers may be developing novel techniques to examine a construct and this can make sample size calculation feel imprecise with little previous literature to provide estimation of effect size. However, discussion of these issues would be informative in providing a guide as to how sample size considerations had been resolved.

5.4 Limitations

The present review has some limitations. The review was conducted by one researcher with a second researcher quality control scoring only a subset of articles. Although there was high agreement between the two reviewers, best practice would be to double rate all articles in order to avoid bias by one individual. A second limitation is that 'grey' literature was not sought from researchers in this field. Publication bias in favour of significant findings may be skewing the knowledge base in this area, thus examination of grey literature such as unpublished findings would enable us to consider this possibility.

5.6. Conclusion

In conclusion, this systematic review examines the evidence base for the causal relationship between cognitive constructs thought to be important in pathological worry and questionnaire-based and behavioural measures of worry. Support was found for a causal relationship between all constructs examined and worry, except for positive and negative beliefs about worry. The relationship between these cognitive constructs and worry was discussed in relation to existing cognitive models of worry. Future research should ensure that measurement and manipulation of cognitive constructs and assessment of worry has good construct validity. Future research may also usefully examine how these constructs relate to each other as well as to worry. High quality experimental psychopathology research can help us to better understand the mechanism that drive pathological worry and in turn, provide knowledge that will influence treatments that target mental health disorders such as GAD.

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7. APPENDICES

1: Quality assessment tool

2: Worry breathing focus task description

3: Worry catastrophising interview

7.1 Appendix 1

Quality assessment tool

Authors:

1. Is the hypothesis/aim/objective of the study clearly described?

Yes	1
No	0
Don't know	0
N/A	-

2. Was there an appropriate comparator/control group?

Yes the control group was appropriate	2
Yes there was a control group but it could have been more appropriate for the study	1
No	0
Don't know	0
N/A	-

3. Outcome: can you identify the primary outcome?

Yes	1
No	0
Don't know	0
N/A	-

4. Can you identify the construct to be manipulated?

Yes	1
No	0
Don't know	0

N/A	1
-----	---

5. Was the sample randomised if appropriate to do so?

How did randomization occur (do not score on this)?

Yes	1
No	0
Don't know	0
N/A	1

N/A = may not be appropriate to randomise e.g. comparing high vs. low worriers so in this case score 1

6. Was experimental manipulation well-described and appropriate?

Yes – well described AND appropriate	2
Yes – well described but questionable appropriateness for study	1
No	0
Don't know	0
N/A	-

7. Were participant characteristics reported e.g. age, sex, cohort (community sample/student sample) level of education?

Yes	1
No	0
Don't know	0
N/A	-

N.B. At least two of the above need to be reported to score

8a. Were groups similar at baseline on relevant measures? e.g. similar in age, sex, baseline measures of worry, mood?

Yes	1
-----	---

No	0
Don't know	0
N/A	1

N. B. Here groups may be different at baseline by design e.g. high low worry groups. If so, score N/A = 1

8b. Were any statistically significant differences adjusted for e.g. by matching in design of study or controlled for in the analysis?

Yes	1
No	0
Don't know	0
N/A	1

9. Are the main findings clearly described? E.g. mean scores with measures of variance (SD, SE, or CI)

Yes	1
No	0
Don't know	0
N/A	-

10. Are you confident with author/s choice and use of statistical methods? E.g. to the best of your knowledge are the statistical methods appropriate for the aims of the study?

Yes	1
No	0
Don't know	0
N/A	-

11. Dependent variable: Was the outcome measure appropriate?

Yes: worry measure previously piloted and valid/reliable and represents state changes in worry	2
Yes: but unsure about validity/reliability and appropriateness as worry outcome measure	1
No	0
Don't know	0
N/A	-

12. Conclusions: Were conclusions supported by results?

Yes	1
No	0
Don't know	0
N/A	-

13. Did the authors identify any limitations?

Yes	1
No	0

Score ---/17

Notes for discussion or to clarify responses.

7.2 Appendix 2

Worry breathing focus task

Hirsch and colleagues (Hayes et al. 2010; Hayes, Hirsch, & Mathews, 2010; Hirsch et al., 2011, 2009; Hirsch et al., 2015; Krebs et al., 2010; Stokes & Hirsch, 2010) employed the worry breathing focus task as a behavioural measure of worry. This task is adapted from a behavioural measure of worry developed by Borkovec, Robinson, Pruzinsky, and DePree (1983) and refined by Ruscio and Borkovec (2004). Typically, the task involves 3 phases. Two 5 minute breathing phases take place before and after a 5 minute worry period.

The task is described below by Hirsch et al. (2009, p.47-48)

“During each 5-min breathing focus period, participants were instructed to focus their attention on their breathing, and a computer-generated tone sounded at random intervals of between 20 and 30 s, generating a total of 12 tones during each breathing focus period. At each of these tones, participants indicated whether their attention was focused on their breathing or if at that moment they had experienced a thought intrusion. If they had an intrusion, they then rated whether it was positive, neutral, or negative in content and gave a brief description (e.g., “positive—going out tonight”). At the end of each breathing focus period, participants completed mood rating scales (see above) and answered three questions related to the breathing focus period: “Estimate the percentage to which you were able to focus on your breathing (0% not at all–100% all of the time)”; “Rate how difficult you found focusing on your breathing (0 not at all difficult–100 extremely difficult)”; and “Estimate the percentage of time you worried during the last 5 minutes (0% none of the time–100% all of the time).”

“After the first breathing focus period, participants identified a current worry topic which they then discussed briefly with the experimenter to ensure that it was related to a potentially negative future situation.

The experimenter wrote down a brief summary of the worry topic. Participants were then asked to continue to silently worry about this topic for 5 min, at which point the experimenter left the room. At the end of 5 min, the experimenter returned, the second breathing focus period was completed, and ratings were made (as above). Following this, participants completed retrospective mood rating scales in relation to the worry period and answered the following three questions: “Estimate the percentage of time that you were able to spend worrying (0% not at all–100% all of the time)”; “Rate how difficult you found it to worry for 5 minutes (0 not difficult at all–100 extremely difficult)”; and “Rate how stressed you were whilst worrying (0 not stressed at all–100 extremely stressed).”

Finally, participants were asked to provide fuller descriptions of the thought intrusions reported during the breathing focus periods. For each identified thought intrusion, the experimenter read aloud the participants’ summaries and asked them for a fuller description of what was going through their minds at the moment they originally had the thought intrusion. Thought expansions generated by participants were digitally recorded for later rating by an assessor.”

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7.3 Appendix 3

Worry catastrophising interview

This task is worry task was modeled on an interview designed by Vasey & Borkovec (1992) and modified by Davey & Levy (1998). Here, the dependent variable is the number of responses generated in a catastrophising interview on a personal worry topic.

The task is described below by Meeten (2010, p. 34).

“The catastrophising interview technique developed by Vasey & Borkovec (1992) asks participants to identify a current main worry. The experimenter then asks the participant, “what is it that worries you about X?”, where X is the current worry topic. When the participant gives an answer the experimenter then takes that answer and asks the same question, “what is it that worries you about X?”, but substituting the original problem with the answer just given. The dependent variable is the number of catastrophising steps generated by the individual. The interview is terminated either when the participant cannot think of another response, or when the same or similar answer is given three or more times. Using this interview format allows the depth of the worry and the amount of time spent ruminating on a worry to be assessed (Davey et al., 1996).”

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PART 2
EMPIRICAL RESEARCH PROJECT

**Modification of interpretation biases in worry:
an examination of cognitive and physiological
responses**

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Table of Contents

1. ABSTRACT.....	76
2. INTRODUCTION.....	77
3. METHOD.....	82
3.1 Design.....	82
3.2 Participants.....	82
3.3 Ethical considerations.....	83
3.4 Materials	83
3.4.1 Emotional assessment instruments.....	83
3.4.2 Visual analogue scales.....	84
3.5 Heart rate variability assessment.....	84
3.6 Interpretation bias assessment tasks.....	85
3.6.1 Online task: Completed at pre and post CBM-I training	85
3.6.2 Offline task	87
3.7 Interpretation bias manipulation task (CBM-I).....	88
3.8 Worry breathing focus task	88
3.9 Procedure	89
4. RESULTS.....	90
4.1 Baseline trait and anxiety, worry, and mood measures.....	90
4.2 CBM-I training task	91
4.2.1 Accuracy on CBM-I training task and sham control task.....	91
4.2.2 Bias assessment during training using test trials	91
4.3 Self report mood at baseline and post training.....	91
4.4 Interpretation bias assessment using online task.....	92
4.4.1 Task completion accuracy.....	92
4.4.2 Online bias assessment.....	93
4.5 Interpretation bias assessment using offline task.....	93
4.6 Heart Rate Variability.....	95
4.7 Far transfer: Breathing focus task	96
4.8 Debrief questionnaire data	97
5. DISCUSSION.....	97
5.1 Overview and discussion of findings.....	97
5.1 Limitations.....	103
5.2 Future directions.....	104
5.3 Conclusions.....	105
6. REFERENCES	106
7. APPENDICIES.....	113
7.1 Appendix 1	114
7.2 Appendix 2	117
7.3 Appendix 3	118
7.4 Appendix 4	119
7.5 Appendix 5	122

List of Tables

Table 1	93
Table 2	95

1. ABSTRACT

This study investigated whether facilitating a benign interpretation bias in participants with high trait worry, affected interpretation of ambiguous information at two different stages of information processing. The bias assessment tasks (completed before and after participants received either a benign interpretation bias training or a control condition sham training) examined fast, reflexive interpretations of ambiguity (online task) and slower reflective interpretations (offline task). The effect of benign interpretation bias training on negative thought intrusions after a worry period and on heart rate variability (HRV) was also assessed. Participants were randomly allocated to benign interpretation bias training or a control condition sham training. There was an effect of training condition on training test trials in the expected direction where the benign condition interpreted ambiguous scenarios in a more positive manner than the control condition. There was no effect of training condition on online or offline bias assessment tasks, or on number of negative thought intrusions in the worry breathing focus task. There was a significant increase in HRV from pre to post interpretation bias training in the benign training condition, but not the control condition. Potential explanations as to why there was no effect of interpretation bias training on the online and offline bias assessment tasks are discussed, as are directions for future research.

2. INTRODUCTION

Everybody worries from time to time and worry is typically defined as transient and limited in scope (Ruscio, 2002). In contrast, pathological worry is considered to be negatively valenced, uncontrollable (Borkovec et al., 1983) and predominately verbal (Borkovec, Ray, & Stober, 1998). Excessive and uncontrollable worry is the defining feature of generalised anxiety disorder (GAD; American Psychiatric Association, 2013). Individuals who experience high levels of worry (either with or without a GAD diagnosis) experience poor perceived physical health and increased levels of sleep difficulties (Kertz & Woodruff-Borden, 2011). Excessive worry thus has a significant impact on psychological and occupational functioning. Developing a better understanding of the mechanisms that contribute to the development and maintenance of worry is vital.

Cognitive models of worry (e.g. Davey & Meeten, 2016; Hirsch & Mathews, 2012) highlight the role of information processing biases (both interpretation biases and attention biases) in the onset and maintenance of worry in GAD. For example, biases in attention contribute to excessive and pathological worry by enhancing the ability to detect and selectively attend to threat cues (Mathews, 1990). Individuals who experience excessive and uncontrollable anxiety have been shown to attend to threat-relevant information at the expense of benign or positive information (Mathews & MacLeod, 1994; Andrew Mathews & MacLeod, 2002). The role of attentional biases in worry and GAD have been recently discussed by Goodwin, Yiend, and Hirsch (2017).

The focus of the present study will be on the role of interpretation biases in pathological worry. Ambiguity is a normal part of daily life. However, research has shown that people with GAD interpret ambiguous scenarios in a more threatening manner than a non-anxious control group (Butler & Mathews, 1983). Using a recognition task, Eysenck, Mogg, May, Richards and Mathews (1991) asked individuals with GAD, recovered clinically anxious individuals,

and a non-clinical control group to listen to sentences that were ambiguous (e.g. “your boss calls you into their office to talk to you about the quality of your recent work”) and could thus be interpreted in either a threatening or a benign manner. Participants were then shown sentences that were similar in theme to the original sentences but were unambiguously non-threatening (‘Your boss calls you into their office to congratulate you on your work’) or unambiguously threatening (‘Your boss calls you into their office to say they are disappointed with your work’) and were asked to rate how similar the sentence was to the original ambiguous scenario. Individuals with GAD endorsed more ambiguous scenarios as being threatening than the recovered anxious participants and the non-anxious control group. Mathews and Mackintosh (2000) also used a recognition task with social scenarios after positive and negative interpretation bias had been induced. They found that positively induced participants were more likely to endorse positive targets, but negatively induced participants were equally likely to endorse positive and negative targets.

There is now robust evidence to suggest that interpretation biases can be modified (cognitive bias modification of interpretation; CBM-I) such that individuals with high trait worry and those with GAD can be trained to interpret ambiguity in a benign manner (e.g. Hayes, Hirsch, Krebs, & Mathews, 2010; Hirsch, Hayes, & Mathews, 2009). These methods have been used to examine the effect of interpretation bias manipulation on near transfer tasks (near transfer tasks examine whether cognitive bias manipulation training transfers onto a measure of the bias itself, such as the recognition task; cf. Mathews & Mackintosh, 2000; Salemink & van den Hout, 2010) and on far transfer tasks (far transfer tasks examine whether cognitive bias manipulation training transfers onto a task that examines a core component of GAD symptomology, such as intrusive worry thoughts (cf. Hayes et al. 2010; Hirsch et al. 2009). However, when examining how CBM-I affected an

assessment of the bias itself (near transfer tasks), none of these previous studies took baseline measures of the bias into account.

CBM-I techniques have provided evidence of the causal role of this bias in worry. However, little is known about the mechanisms through which these biases operate. For example, in pathological worry it is not known whether the interpretation bias occurs as a quick, automatic judgement when ambiguity is first encountered (known as an online judgement), or as a more thoughtful reflective process after there is opportunity for reflection (known as an offline judgement). In their review of interpretation biases in emotional disorders, Hirsch, Meeten, Krahe and Reeder (2016) highlight differences between offline and online biases. Offline paradigms such as self-report questionnaires and memory based recognition tasks allow participants to select from a range of interpretations rather than the first one that comes to mind. There is correlational and experimental evidence to support the idea that interpretation biases operate at the offline processing stage in pathological worry through use of a reflective processing tasks such as the recognition task (Eysenck et al., 1991; Mathews & Mackintosh, 2000; Salemink & van den Hout, 2010) or a sentence completion task (Hayes, Hirsch, Krebs, et al., 2010). Online paradigms examine interpretations made when the ambiguity is first encountered and are likely to be relatively automatic. In the social anxiety disorder literature online tasks have included a speeded lexical decision task (Hirsch & Mathews, 2000) and examining event related potentials (Moser, Huppert, Foa, & Simons, 2012). Making the distinction between these different stages of interpretation is important if we are to better understand the mechanism through which interpretation biases contribute to pathological worry. In social anxiety disorder, research has shown that individuals with high trait social anxiety interpret ambiguous situations more negatively than a control group in an offline context, but less positively in an online context (Foa, Kozak, Salkovskis, Coles, & Amir, 1998; Hirsch & Mathews, 2000; Stopa & Clark, 2000). A better

understanding of the manner in which interpretation biases operate in pathological worry may lead to interventions that target the point at which the threat interpretation occurs.

One way of assessing a relatively automatic online interpretation bias is to ask participants to identify a positive or negative word fragment using a speeded task where the interpretation judgement is made in under 2000ms (cf. Hirsch & Mathews, 2000). Salemink & van den Hout (2010) trained non-high trait anxious participants to make positive or negative interpretations of ambiguous information. They assessed near transfer in two ways. One assessment employed the recognition task (as described above). A second assessment looked at reaction time to solve word fragments that disambiguated an ambiguous scenario e.g. faster reaction time to positive words would indicate a positive bias and vice versa with negative words. In the Salemink & van den Hout (2010) study, participants were not asked to make very quick judgements about the word (e.g. under 2000ms) so it is unclear whether this data captured reflective offline processing or quick automatic online judgements. However, the mean reaction times ranged from 1303ms – 1453ms, indicating that participants were able to make speeded decisions to identify a word fragment. Salemink and van den Hout (2010) reported that CBM-I was successful at modifying interpretation bias whereby the positive bias training group solved positive word fragments faster than negative and there was a trend for the opposite pattern of results in the negative bias training group. In the recognition task, participants in the positive group interpreted the ambiguous information as being significantly more positive than negative and again the opposite was the case for the negatively trained group.

Hirsch et al. (2016) suggest that online assessment of interpretation biases should also include biological paradigms. Although unable to examine interpretation per se, examining heart rate variability (HRV) before and after bias training may provide a more general physiological assessment of ways in which CBM-I

training can influence processes that operate outside of conscious awareness. Pathological worry is consistently related to low heart rate variability (HRV), which is a risk factor for poor cardiovascular health (Brosschot, Gerin, & Thayer, 2006; Brosschot, Pieper, & Thayer, 2005; Ottaviani & Shapiro, 2011; Thayer, Friedman, & Borkovec, 1996; Verkuil, Brosschot, Gebhardt, & Thayer, 2010). Low HRV is associated with a rigid and inflexible autonomic response to threat and cognitive rigidity as seen in pathological worry is thought to mirror autonomic inflexibility (Ottaviani, Medea, Lonigro, Tarvainen, & Couyoumdjian, 2015; Ottaviani, Shapiro, & Couyoumdjian, 2013). As highlighted by Park and Thayer (2014), low resting HRV is associated with maladaptive cognitive responses to emotional stimuli. Specifically, high levels of worry have been associated with reduced HRV and HRV has been hypothesised to be a biomarker of worry (Chalmers et al., 2016). Where CBM-I training has previously reduced worry symptoms (Hirsch et al. 2009), one possibility is that a physiological correlate of reduced worry is an increase in HRV. By examining heart rate variability (HRV) pre and post CBM-I training, one can examine whether training participants to have a benign interpretation style is associated with a change in HRV.

As outlined above, literature examining interpretation biases in clinical and subclinical populations document the presence of interpretation biases in worry. However, the mechanism through which these biases function, remains poorly understood (Clarke, Chen, & Guastella, 2012). The aim of this experiment is thus to examine interpretation biases in a high trait worry sample at both the online and offline stages of processing after CBM-I training as compared to a sham control training. By completing bias assessment before and after training, we can examine how interpretation bias changes as a result of CBM-I training. In addition, we will also examine whether CBM-I training has a physiological correlate by assessing HRV pre and post training. Finally, to examine the clinical implications of interpretation bias modification and to replicate previous findings in this area ,the

experiment will assess far transfer of the CBM-I training by using a worry breathing focus task (Hirsch et al., 2009).

Hypotheses

1. It is predicted that participants in the CBM-I training condition will show a reduction in negative interpretations at the offline and online stages of interpretation after CBM-I training, but that no post-training shift in interpretation will be evident in the sham control condition.
2. It is predicted that CBM-I training to interpret ambiguous information in a benign manner will result in an increase in HRV whereas sham-control training will not.
3. It is predicted that there will be a significant difference in negative thought intrusions as measured by the worry breathing focus task post CBM-I training. The benign condition, who receive benign CBM-I training will report significantly fewer negative intrusions as compared to the control group.

3. METHOD

3.1 Design

The experiment involved four phases. Phase one was a baseline assessment phase that includes demographics, state and trait mood measures, online and offline interpretation bias assessments and a 5-minute HRV resting state assessment. Phase two was an interpretation bias training task, where participants received either benign CBM-I training or sham (50/50 benign and negative stimuli) training depending on their group allocation. Phase three was post induction assessment of HRV and online and offline interpretation bias measures. Phase four was the worry breathing focus task.

3.2 Participants

Participants were recruited via adverts in the King's College research participation forum and via a Gumtree advert seeking high worriers. Volunteers completed the Penn State Worry Questionnaire (PSWQ; Meyer, Miller, Metzger, & Borkovec, 1990) and responded to screening questions concerning age (participants had to be over 18

years of age), current medication usage and whether they had English as a first language. Participants were invited to take part in the study if they were not taking medication (for the purpose of HRV assessment), had English as a first language (due to the nature of the bias assessment tasks) and had a score of ≥ 56 on the PSWQ (Meyer et al., 1990). This cut-off score was chosen as a score of 56 falls one standard deviation below the mean for individuals diagnosed with GAD (Molina & Borkovec, 1994). Fifty one participants completed the PSWQ (Meyer et al., 1990) again on the day of the study to check that they met the cut-off criteria and two participants were subsequently excluded. Participants were randomised into either the benign CBM-I benign training group ($n = 25$) or the control (sham-training) group ($n = 24$), 36 participants were female and there was no significant difference between numbers of males and females in each condition ($p = .69$). There was no significant difference in age between the benign ($M = 24.32, SD = 6.99$) and the control ($M = 25.88, SD = 5.30$) group, $t(47) = .85, p = .40$. The average level of education reached was Bachelor Degree in both groups, with no significant difference in educational level between groups, $t(47) = .67, p = .51$.

3.3 Ethical considerations

Ethical approval to carry out the study was granted by King's College Research Ethics Committee (see Appendix 3 for ethics approval letter). At the end of the study all participants were offered an information sheet which included NHS guidelines about management of worry should they feel concerned about the amount of worry they were experiencing and signposting to self help resources.

3.4 Materials

3.4.1 Emotional assessment instruments

Penn State Worry Questionnaire: The PSWQ (Meyer et al. 1990) is a measure of trait worry. The PSWQ consists of 16-items (e.g. 'Once I start worrying I cannot stop'), which are rated on a 5-point Likert scale

ranging from (1) 'not at all typical of me' to (5) 'very typical of me'. The PSWQ has good test-retest reliability ($r = .74-.93$; Molina & Borkovec, 1994), internal consistency ($\alpha = .90$; Brown, Antony, & Barlow, 1992), and discriminant validity (Meyer et al., 1990).

State-Trait Anxiety Inventory (STAI): The STAI-trait (Spielberger, Gorsuch, Lushene, Vagg, & Jacobs, 1983) assessment was used as a measure of trait anxiety. There are 10 questions to assess trait anxiety. On a four point scale from 'almost never' to 'almost always' participants are asked to think about how they generally feel and respond to questions such as 'I feel like a failure'. The STAI-trait/state scale has good internal consistency with coefficients in the range of $\alpha = 0.86$ to 0.95 and good test-retest reliability $r = 0.65$ to 0.75 over a 2-month interval (Spielberger et al., 1983).

3.4.2 Visual analogue scales

Three 100mm visual analogue scales (VAS) measuring current mood state of sadness, anxiety, and happiness were completed at the baseline phase and post CBM-I training. Visual analogue scales have good reliability, validity and internal consistency as measures for mood and depression (Hicks, & Nino-Murcia, 1991; Lingjaerde & Foreland, 1998).

3.5 Heart rate variability assessment

Heart rate (HR) was recorded as beat-to-beat intervals in ms with the Bodyguard 2 (Firstbeat) HR monitor. Heart rate is measured by placing a light-weight device attached to a disposable electrode just below the right collar bone, with a second electrode placed on the left rib-cage. The experimenter demonstrated the placement of the electrodes and the participant then placed the device themselves. Participants wore the device for the duration of the study. At the end of the study the participant removed the disposable electrodes and device and were offered a fragrance free wipe to remove any remaining electrode gel.

HRV was assessed pre and post training in 5 minute resting-state blocks. During this time the participant was asked to remain seated and as still as possible while also remaining comfortable and to allow their mind wander to any topic that they usually think about. Kubios HRV software (Tarvainen, Niskanen, Lipponen, Ranta-aho, & Karjalainen, 2014) was used to manually check the data for artefacts and perform the HRV analysis. Artefacts were defined as beat-to-beat intervals corresponding to a HR < 30 bpm or > 200 bpm as well as any intervals resulting in an increase or drop in heart rate by > 30% between successive intervals¹. Where an artefact occurred near the beginning or end of a time period, that section was excluded from the analysis providing the time period did not fall below 4 minutes (Munoz et al., 2015). Where the artefact was in the middle of the time period, correction to the data was applied until the data was in the required ranges (Task-force, 1996). Correction to the data was necessary on three occasions. HRV was estimated using the root mean square successive difference (RMSSD) measure, a reliable parameter for assessing vagally-mediated HRV (Task Force, 1996).

3.6 Interpretation bias assessment tasks

3.6.1 Online task: Completed at pre and post CBM-I training

The online task is adapted from Mathews and Mackintosh (2000) and Salemink & van den Hout (2010) to assess online (< 2000ms) interpretation of ambiguous scenarios. A pilot project was completed in order to aid choice of scenarios for the task (see Appendix 1 for overview of pilot data). Sixty scenarios based on topics identified in the Worry Domains Questionnaire (Tallis, Davey, & Bond, 1994) were used in the main task. The online, offline and CBM-I training tasks were created using E-Prime 2.0 software (Psychology Software Tools, Pittsburgh, PA). During the online task, participants saw a scenario on a

¹ Decision on the range of acceptable HRV interval values for artefact calculation was based on personal communication with Dr Cristina Ottaviani.

computer screen presented one line at a time. Participants pressed the space bar when they were ready to move to the next line so reading was self-paced. The scenario remained ambiguous in valence until the final word, which appeared as a word fragment. The participant was asked to press the space bar when they knew what the word was. As this task purposefully sought quick judgments, participants had 2000ms to respond. If they did not respond in this time, they heard a short tone to signal an error. When a response was given (or after 2000ms) a message appeared asking participants to type in the missing letter. Two lists (List A and B) were prepared containing 30 scenarios and within each list participants saw 15 scenarios with a positive outcome and 15 with a negative outcome and the dependent variable was time to respond to words which disambiguated the scenario in a positive manner and a negative manner. List A or B were presented in counter balanced order at baseline and after the CBM-I assessment. An example scenario is “You are in a hurry and have forgotten to buy your brother a birthday present. On your way to meet him you stop at a shop to pick something up. You watch him open it and can tell by the look on his face that he is pleased/dissatisfied”. The dependent variable is the reaction time (RT) response to resolving the disambiguating word. It is assumed that bias can be inferred by RT where a slower RT is incongruent to the participant’s immediate online comprehension of the scenario (e.g. participants with a negative online interpretation bias would be faster to recognise negative as opposed to positive words). Prior to analysis, participant data was excluded if they responded that they knew the word, but then provided an incorrect letter for the word fragment, or if they reported they know the word in 50ms or less as this was unlikely to be a meaningful response (Ledgeway & Hutchinson, 2008). Finally, if 6 or more (out of 15) negative or positive responses were incorrect, the participant’s data for that block of the task was entered as missing as only a small number of responses would be representing the median reaction time. If a participant had more than 50% of their data missing, they were removed from the analysis. This resulted in 4 participants

data being removed from the analysis.

3.6.2 Offline task

The offline interpretation measure was a recognition task (based on Eysenck et al., (1991) and Mathews & Mackintosh (2000)). During the encoding phase, participants read 10 scenarios. Each scenario had a title and was presented one line at a time. The final word was completed as a word fragment (as described in the online task), but in this task the scenario remained ambiguous and participants were not asked to make a quick judgement about what the word was. If they did not make a decision within 8 seconds they heard an error tone and a comprehension question appeared on the screen. To ensure that participants had engaged in reading the scenario, once they completed the word fragment (or once the time limit was reached), they saw a comprehension question requiring a yes/no answer. Once the participant had seen all the scenarios, they began the recognition phase. Here, they were presented with the title of the previously seen scenario and four 'descriptions' of the scenario. Two descriptions were positive or negative 'target' sentences and matched the meaning of the scenario and two were positive and negative 'foil' sentences (e.g. sentences that match in valence to target sentences, but do not match a possible interpretation). Participants are required to rate each sentence from 1 (very different in meaning) to 4 (very similar in meaning) as to how related the meaning is to the original scenario. The dependent variable is mean ratings of target sentences e.g. a mean high rating of negative targets would suggest negative interpretation of the ambiguous scenarios and vice versa for positive target sentences. Two versions of this task were prepared each containing different ambiguous scenarios and participants completed them in counterbalanced order before and after the CBM-I manipulation. The recognition task as an offline assessment of interpretation bias is considered to be relatively free from demand effects and selection bias (Hirsch et al., 2016).

3.7 Interpretation bias manipulation task (CBM-I)

The CBM-I task employed 100 scenarios (10 were test trials), again based on a range of worry domains (Tallis, Davey, & Bond, 1994), but different scenarios to those seen in the online and offline tasks. Scenarios were presented on a Lenovo laptop computer screen in 5 blocks of 18 training scenarios and 2 test trials with a short break offered between each block. Scenarios were based on those devised by Krahe, Mathews, Whyte and Hirsch (2016). Scenarios were presented over headphones (cf. Hirsch et al., 2009) and remained ambiguous in valence until the final word. Scenarios were presented aurally as previous research has suggested that training scenarios presented in auditory rather than text format better maintain participant interest and concentration (Holmes, Mathews, Dalgleish, & Mackintosh, 2006). An example benign scenario that the participants heard is “You have taken an exam as part of an evening course and feel you did well. At the next class the grades are on the notice-board and everyone is looking at them. The thought of others comparing your grade with theirs makes you feel happy”. After participants heard each scenario, they saw a comprehension question on a computer screen (e.g. “Were you upset that others could compare their grade with yours?”). Once a response was detected a feedback message was provided for 1000ms. If correct the answer remained on the screen under the question and if incorrect a short tone was heard and the correct response appeared below the question. If the participant did not respond a message “no response detected “ appeared and the next trial started. In the benign training group participants always heard scenarios with a benign outcome and in the sham training (control condition) participants heard 50% of scenarios with a benign outcome and 50% with a negative outcome.

3.8 Worry breathing focus task

To assess whether there was a transfer effect of CBM-I training onto a worry task, participants also completed a worry breathing focus task. The task is based in a behavioural measure of worry developed by

Borkovec, Robinson, Pruzinsky, and DePree (1983) and Ruscio & Borkovec (2004) and previously used as an assessment of far transfer of CBM-I on worry symptoms (e.g. Hayes, Hirsch, Krebs, & Mathews, 2010; Hirsch et al., 2009). The current version of the task had 2 phases, a 5 minute worry period and a 5 minute breathing focus period. During the worry period participants were instructed to think of a current worry topic. This was briefly discussed with the experimenter to ensure that it was related to a potentially negative future situation. The experimenter wrote down a brief summary of the worry topic and the participant was asked to silently worry about this topic for 5 minutes and the experimenter left the room during this time. During the breathing focus period participants were instructed to focus on their breathing and every 20-30 seconds a computer-generated tone would sound. There were 12 tones in each breathing focus period. At the tone, participants were asked whether their attention was focused in their breathing or whether their mind had wandered. If they had experienced a thought intrusion, they were asked whether the valence of the thought intrusion was negative, neutral or positive in content and for a brief description e.g. "negative – upcoming exams". At the end of the breathing focus task participants completed two visual analogue scales (rating from 0-100) asking them to estimate the percentage of time they focused on their breathing during the 5 minute period and how difficult it was to focus on their breathing. At the end of the task, participants were asked to rate the extent to which they were able to focus on their breathing during the task (where 0% was not at all and 100% was all of the time) and the extent to which they had difficulty focusing on their breathing (where 0% was not at all difficult and 100% extremely difficult).

3.9 Procedure

Participants completed an online screening phase that consisted of a study information sheet, consent to complete the screening phase, the PSWQ, the STAI-Y2 trait anxiety questions and screening questions (see above). If participants met the study inclusion criteria they were

invited to take part in the study. Within 24 hours prior to their participation of the study participants completed an online assessment of worry and anxiety (PSWQ and STAI-Y2 trait questions). On arrival at the laboratory, participants completed a consent form and then completed VAS mood ratings (sadness, anxiety, happiness), they then completed a 5-minute resting state HRV assessment. Participants then completed the baseline online then offline interpretation assessment bias tasks. At this point participants were randomised to either the benign or control training condition. Participants completed the CBM-I training (benign training or sham training), further mood measures and another 5 minute resting state HRV assessment. Finally, participants were provided with instructions for the worry breathing focus task. They practiced the breathing focus section of the task and provided 3 practice examples of their thoughts in 45 seconds. Once they had understood the task, they completed the worry period and the breathing focus task. After all study tasks were complete, participants completed a short questionnaire to ascertain whether they know what the purpose of the study was and to rule in/out demand effects (see Appendix 2 for a copy of the questionnaire). Participants were then debriefed as to the purpose of the study, thanked for their time and completed a payment form for £20.

4. RESULTS

Effect sizes are reported using Pearson's correlation coefficient r as an effect size measure and partial eta squared η_p^2 . Using Cohen's (1988) criteria, a small effect size is reflected by an r of .10, medium by .30, and large by .50. Using partial eta squared, a small effect size is reflected by a measure of .01, medium by .06, and large by .14 (Stevens, 2002)

4.1 Baseline trait and anxiety, worry, and mood measures

Trait worry as measured by the PSWQ (Meyer et al., 1990) was $M = 65.78$, $SD = 6.79$ in the whole sample ($N = 49$). There was no significant difference in PSWQ scores between the benign ($M = 67.68$, $SD = 6.81$) and the control ($M = 64.92$, $SD = 5.52$) conditions, $t(47) = 1.56$, $p = .13$.

PSWQ scores in at baseline were also significantly negatively correlated with baseline HRV, $r = -.33$, $p = .02$. Thus as one would expect, higher HRV at baseline was associated with lower trait worry. Trait anxiety as measured by the STAI-Y2 trait questions (Spielberger et al., 1983) was $M = 49.32$, $SD = 3.45$ in the whole sample and STAI-Y2 trait scores did not differ between the benign CBM-I ($M = 49.92$, $SD = 2.98$) and control ($M = 48.75$, $SD = 3.85$) conditions, $t(47) = 1.19$, $p = .24$. There were no significant differences between self-reported sadness, anxiety, or happiness at baseline between the two conditions (all $ps > .05$).

4.2 CBM-I training task

4.2.1 Accuracy on CBM-I training task and sham control task

Comprehension questions presented after each training scenario required participants to select the correct “yes/no” answer. The CBM-I condition had 93.07% accuracy and the control condition had 91.46% accuracy. There was no significant difference in accuracy $t(46) = 1.49$, $p = > .05$ between the two conditions.

4.2.2 Bias assessment during training using test trials

The number of ambiguous test trials resolved with a benign interpretation (as opposed to a threat interpretation) were significantly greater in the benign ($M = 7.80$, $SD = 2.02$) as compared to control ($M = 5.87$, $SD = 1.46$), training conditions $t(46^2) = 3.77$, $p = <.001$, $r = .49$. This suggests that CBM-I training was successful in training the benign (but not the control) condition to interpret ambiguous scenarios in a benign manner within the training task.

4.3 Self report mood at baseline and post training

A mixed model ANOVA was carried out on the mood ratings³ recorded at the baseline phase and after the CBM-I training. The

² One participant’s training data was deleted in error

³ Normality was assessed using the Kolmogorov-Smirnov test (cf. Field, 2009). Of 12 potential data points, 9 were normally distributed. The decision was taken not to transform the data.

between factor was training condition (benign vs. control) and the repeated measure factor was time (baseline vs. post CBM-I training). On sadness ratings there was a no main effect of time $F(1,47) = 2.50, p = .12, ns$. There was no main effect of condition $F(1,47) = .002, p = .97, ns$. There was a significant interaction effect, $F(1,47) = 4.64, p = .04, \eta_p^2 = .09$. However, post hoc t-tests revealed no significant difference between self-reported sadness at baseline between the benign and control condition $t(47) = .61, p = .54, ns$ (benign condition: $M = 27.28, SD = 25.12$ vs. control condition: $M = 23.33, SD = 19.43$) or at post CBM-I training, $t(47) = .65, p = .52, ns$ (benign condition: $M = 26.16, SD = 26.70$ vs. control condition: $M = 30.63, SD = 21.17$). When conducted on anxiety ratings there was no significant main effect of time, $F(1,47) = 2.24, ns, \eta_p^2 = .05$, no significant main effect of condition $F(1,47) = < 1, ns, \eta_p^2 = .001$, there was also no interaction effect, $F(1,47) = 2.09, ns, \eta_p^2 = .04$. When conducted on happiness ratings there was a significant main effect of time, $F(1,47) = 7.98, p = .007, \eta_p^2 = .15$ where happiness ratings decreased from baseline to post training (baseline: $M = 55.65, SE = 25.12$ vs. post CBM-I/sham training: $M = 51.71, SE = 2.80$). There was no significant main effect of condition, $F(1,47) = < 1, ns, \eta_p^2 = .009$, nor any significant interaction between condition and time $F(1,47) = < 1, ns, \eta_p^2 = < .001$.

In summary, there was no effect of CBM-I or sham training on self reported sadness and anxiety. There was a significant main effect of time for self reported happiness where, regardless of training condition, participants reported a reduction in happiness from baseline to post-training.

4.4 Interpretation bias assessment using online task

4.4.1 Task completion accuracy

During the online task when resolving the final word, accuracy in entering the correct letter at baseline was 96.09% and post training was 97.83% on average for the CBM-I group, and 96.28% at time 1 and 98.84% at time 2 on average for the sham training condition. When

comparing the two conditions at baseline or post-training, there were no significant differences (all $ps > .05$).

4.4.2 Online bias assessment

Analysis of online task data was performed on median latencies for correct responses to threat and non-threat stimuli (cf. Hirsch & Mathews, 1997), see Table 1 for reaction time (RT) data. An examination of latencies at baseline assessment did not show any difference in RT to threat and non-threat words $t(44) = < 1$, ns , $r = .12$. To examine whether CBM-I training had an effect on RT to threat and non-threat stimuli a 2(time: pre vs. post training) x 2 (valence: threat vs. non-threat stimuli) x 2 (condition: benign training vs. sham training) mixed model ANOVA was performed. There was no significant main effect of time, $F(1,42) = < 1$, ns , $\eta_p^2 = .007$, no significant main effect of valence, $F(1,42) = 2.06$, ns , $\eta_p^2 = .05$, no significant main effect of condition, $F(1,42) = < 1$, ns , $\eta_p^2 = < .001$ and no significant interaction effect, $F(1,42) = < 1$, ns , $\eta_p^2 = .01$. There were also no other significant effects.

Table 1

Means and standard deviations in parentheses of the median reaction times to threat and non-threat word fragments

Stimuli type	CBM-I training ($n = 22$)	Sham training ($n = 22$)
Time 1 Non-threat	751.55 (283.31)	783.41 (218.83)
Time 1 Threat	757.93 (280.56)	752.75 (227.59)
Time 2 Non-threat	794.68 (229.58)	788.50 (248.58)
Time 2 Threat	773.80 (217.62)	764.59 (230.16)

4.5 Interpretation bias assessment using offline task

There was no baseline difference between responses to positive ($M = 2.60$, $SD = 0.41$) and negative ($M = 2.45$, $SD = 0.49$) targets e.g. no indication of a general negative bias, $t(47) = 1.50$, ns , $r = .21$. It was

predicted that after CBM-I training, participants who received benign training would endorse more non-threat targets than threat targets. It was also predicted that all participants would endorse more target sentences than foils sentences indicating that they were not choosing responses at random. A mixed ANOVA⁴ was performed with condition (CBM-I vs. sham training) as the between-group factor and three repeated measures factors of time (pre vs. post training), valence (threat vs. non-threat), and target (possible interpretation vs. foil). See Table 2 for mean recognition test ratings by each condition. There was a large significant main effect of valence, $F(1,45) = 307.75, p < .001, \eta_p^2 = .87$, indicating that non-threat sentences ($M = 2.52, SE = 0.4$) were endorsed significantly more than threat sentences were ($M = 1.68, SE = 0.5$). There was also a significant main effect of target, $F(1,45) = 12.61, p < .001, \eta_p^2 = .22$, indicating that target responses ($M = 2.21, SE = 0.5$) were endorsed a significantly greater amount than foil sentences ($M = 2.00, SE = 0.4$). These effects were qualified by a significant valence x target interaction, $F(1,45) = 5.85, p = .02, \eta_p^2 = .12$. This interaction effect was neither predicted nor relevant to the hypotheses so is not discussed further. There were no other significant effects (all $p_s > .05$).

⁴ An ANOVA was conducted that included list type as a variable as there were two versions of the online task (list A and list B) which participants saw in counterbalanced order pre and post training. There was no significant effect of list thus analysis was conducted without this variable.

Table 2

Mean recognition ratings by each condition for threat and non-threat target sentences and foil sentences

	CBM-I training ($n = 23$)	Sham training ($n = 24$)
Time 1 Non-threat Target	2.64 (0.42)	2.55 (0.41)
Time 1 Threat Target	2.39 (0.42)	2.50 (0.46)
Time 1 Non-threat Foil	1.60 (0.43)	1.81 (0.36)
Time 1 Threat Foil	1.58 (0.48)	1.73 (0.36)
Time 2 Non-threat Target	2.67 (0.50)	2.78 (0.50)
Time 2 Threat Target	2.27 (0.46)	2.35 (0.45)
Time 2 Non-threat Foil	1.77 (0.60)	1.83 (0.49)
Time 2 Threat Foil	1.57 (0.47)	1.58 (0.38)

4.6 Heart Rate Variability

It was predicted that those in the benign training condition would have higher HRV after training than those in the control condition. A mixed condition (CBM-I/Sham training) x time (pre/post training) Analysis of Covariance (ANCOVA) was carried out on HRV at baseline (time 1) and straight after the CBM-I training (time 2) where BMI and age were included as covariates in the model. There was no significant main effect of time, $F(1,43) = 1.13$, ns , $\eta_p^2 = .03$, or a significant main effect of condition, $F(1,43) = 1.35$, ns , $\eta_p^2 = .03$. There was a significant condition x time interaction, $F(1,43) = 4.18$, $p = .05$, $\eta_p^2 = .09$. Post-hoc pairwise comparisons show a significant increase in

HRV from baseline ($M = 37.09$, $SD = 18.03$) to post CBM-I training ($M = 48.09$, $SD = 24.52$), $t(24) = 3.95$, $p = .001$, $r = .58$ in the benign training condition. There was no significant change in HRV from baseline ($M = 34.67$, $SD = 12.32$) to post sham-training ($M = 37.46$, $SD = 15.80$) in the control condition $t(22) = 1.27$, ns , $r = .26$.

As an exploratory measure correlations were performed between HRV at resting state 2 (post training) and outcome variables. There was a significant negative correlation between HRV and post training negative targets in the benign training condition, $r = -.48$, $p = .02$ but not the sham training condition. This suggests that in the benign training condition higher HRV at resting state 2 was associated with fewer endorsements of negative targets in the offline task post CBM-I training.

4.7 Far transfer: Worry breathing focus task

It was hypothesised that there would be less negative intrusions experienced by participants in the benign CBM-I condition as compared to the sham condition. Data was assessed for normality and the number of negative intrusions in the benign training condition was found to be normally distributed, but data for this variable in the control condition was not normally distributed. A log transformation was applied to the data (Field, 2009) and this resulted in correction whereby the control condition now had normally distributed data. Unfortunately as a result of the applied correction, the CBM-I training condition had non-normally distributed data. The decision was taken to use the original non-transformed data and consequently, due to non-normality in the control condition, these findings should be interpreted with caution. An independent t-test indicated that there was no significant difference in number of negative intrusions experienced in each condition, $t(46^5) = < 1$, $p = ns$, $r = .09$ (CBM-I group $M = 2.48$, $SD = 1.98$ and sham training condition $M = 2.17$, $SD = 2.01$). There was no significant difference between ratings of the percentage

⁵ One participant could not complete the breathing focus task due to a technical difficulty.

of time the two conditions reported being able to focus on their breathing during the task, sham training condition = 57% and CBM-I training condition = 56 %, $p = .84$. There was also no significant difference in ratings of difficulty focusing on breathing during the task, sham training condition = 47% and CBM-I training condition = 57 %, $p = .16$.

4.8 Debrief questionnaire data

In response to the question “what did you think was the purpose of the experiment?” only 8% of participants identified the study as examining response times to positive and negative interpretations of ambiguous scenarios. None of the participants made a link between the bias assessment tasks, the CBM-I/sham training and the post training biases assessments. Furthermore, none of the participants made a link between the CBM-I/sham training and the worry breathing focus task.

5. DISCUSSION

5.1 Overview and discussion of findings

The aim of this study was to extend knowledge of the role of interpretation biases in the onset and maintenance of pathological worry. Previous research indicates that individuals high in trait worry demonstrate threat interpretation biases at the offline, reflective stage of information processing (Eysenck et al. 1991; Mathews & Mackintosh, 2000; Salemink & van den Hout, 2010). The study sought to examine whether threat interpretation of ambiguous scenarios also occurred at a reflexive, online stage of processing. Regarding Hypothesis 1, the CBM-I training appeared to be successful in that participants in the CBM-I training group endorsed significantly more benign outcomes on the test trials during training than did the sham training group (cf. Hayes et al., 2010). However, there was no effect of training on the online or offline outcome measures, possible reasons for this will be discussed below. Hypothesis 2 was supported. Results indicated a significant increase in HRV in the benign training condition, but not in the sham training condition and this was independent of

mood change. There was also a significant negative correlation between HRV post training (but not at baseline) and number of negative target endorsements in the offline recognition task in the benign condition but not the sham condition. This suggests that an increase in HRV is associated with fewer negative interpretations of ambiguous scenarios at an offline stage of processing. Finally, there was no support for Hypothesis 3. There was no significant difference in number of negative thought intrusions in the worry breathing focus task by the CBM-I condition as compared to the sham training condition.

A key question is thus why was there no evidence of the CBM-I benign training procedure on the online and offline interpretation bias assessment tasks? CBM-I training appeared to be successful, in that those in the benign training condition made significantly more benign interpretations in the test trials than those in the sham condition. However, training effects did not transfer onto the online or offline interpretation bias assessment tasks. There is little previous literature examining online interpretation bias tasks in a high trait worry population. One possibility is that the interpretation bias does not occur at the online stage. However, information processing biases in pathological worry are assumed to be to some extent automatic in nature (e.g. Hirsch & Mathews, 2012). There is evidence for the automaticity of interpretation biases in social anxiety disorder (SAD) where individuals with SAD made less positive online interpretations than participants without SAD (Hirsch & Mathews, 2000). Using a similar word fragment task to the online task used in the present study, Salemink and van den Hout (2010) found an effect of CBM-I training on reaction time with those who received positive training being significantly faster to solve positive than negative word fragments. Salemink and van den Hout (2010) reported a trend effect with a small effect size ($p = .09$, $d = .22$) for the negatively trained group to be faster to identify negative than positive word fragments. However, the effect in the negative condition is arguably weak. Despite

the fact that this task was not purposefully speeded like the one in the present study, the mean reaction times in the negatively and positively trained groups were below 2000ms, which suggest that inferences may have been made relatively spontaneously. Key differences between the Salemink and van den Hout (2010) study and the present one is that they trained non high anxious participants to adopt a positive or negative interpretation bias, whereas the present study training high trait worry participants to adopt a benign bias, which was then compared to a sham training group. One possibility is that a different participant population may respond differently to CBM-I training. Arguably, one is also likely to observe a greater difference in reaction time to positive and negative words when groups have been explicitly trained to interpret ambiguity in a positive or negative manner rather than examining benign CBM-I training as compared to a sham training condition.

A second possibility as to why there was no effect of CBM-I training on the online task is that the task was not a sensitive measure of spontaneous inferences. As noted above, pilot testing of the online task materials was conducted to identify ambiguous scenarios that differentiated high and low worriers in their interpretation of the scenario. However, of the 120 scenarios assessed, only 27 scenarios were found to be significantly related to trait worry and tendency to provide positive and negative responses. Thus the remainder of the scenarios were based on these exemplar scenarios, but were not re-piloted due to time constraints. This may have meant that the scenarios were not a sensitive measure of negative and positive online inference generation.

Previous literature has found that training participants to make positive interpretations of ambiguous scenarios has had a causal effect on interpretation as measured by an offline recognition test (Mathews & Mackintosh, 2000; Salemink & van den Hout, 2010). The present study did not find a causal effect of benign training on negative or positive targets as compared to the sham training group. Both the

previous studies that used this task used non high anxious samples and one possibility is that the CBM-I training was less effective for this population. However this seems unlikely given that Hirsch et al. (2009) and Hayes et al. (2010) have used CBM-I training in a high trait worry sample and a GAD sample and found an effect of training on a far transfer worry breathing focus task. One possibility is that completing this task twice (although with novel scenarios each time), once at baseline and once post CBM-I induction affected the way participants responded to the task when completing it the second time that interfered with training effects. However, none of the participants highlighted this in the debrief questionnaire. A second possibility is that time from training to completion of the offline task was too long and that completing the HRV resting state and the online task first diluted the effects of training. Again this seems unlikely as CBM training prior to watching a traumatic film was found to reduce distress over the next week (Woud, Postma, Holmes, & Mackintosh, 2013), suggesting that CBM training effects can be relatively long-lived.

A further noteworthy point is to consider why there were no group differences between the CBM-I training condition and the sham training control condition. The control condition received training where they were exposed to scenarios that were ambiguous until the final word and here the final word stimuli were 50% benign and 50% threat relevant (cf. Hayes et al., 2010; Hirsch et al., 2009). One possibility is that experiencing training where 50% of the stimuli were positive actually gave them a dose of positive training. As highlighted by Menne-Lothmann et al. (2014) and discussed by Hirsch et al. (2016) sham training has previously been found to result in a small, but significant reduction in negative mood and thus this type of control training may be more active than expected. However, in the present study there was no effect of sham training on mood. Furthermore, even if the sham training condition did provide some active benign training, one might still expect to see significant pre – post changes on

bias assessment measures in the CBM-I group and this was not observed.

HRV data indicated that the benign CBM-I training condition experienced a significant increase in HRV from pre-post training than the sham training condition. This is an interesting finding as (to the author's knowledge) it is the first time that HRV has been assessed before and after CBM-I training in a high trait worry population. Grisham, Becker, Williams, Whitton and Makkar (2014) measured HRV when using CBM to reduce responsibility in a high-checking student sample. They reported that participants who received positive CBM training showed increased HRV from a baseline measure to a post-training measure. Grisham et al. (2014) suggest that increased HRV may represent a more adaptive physiological responding to a stressor task that was completed by participants post CBM-I training. In the present study a significant pre-post CBM-I induction shift in HRV in the benign training condition but not the sham training condition may represent a shift to responding to ambiguity in a more flexible manner as opposed to a more ridged response style that is likely typical of a high trait worry sample. Unfortunately the observed shift in HRV did not result in a causal impact on near or far transfer tasks. If increased HRV is associated with more adaptive cognitive responses to emotional stimuli (e.g. Park & Thayer, 2014), one may have expected to see less negative intrusions after a worry period in the benign CBM-I condition as compared to the sham training condition, but this was not the case. In the benign training condition (but not the sham condition) there was a negative correlation between HRV post training and number of negative targets in the offline task post training. This does suggest that there may be some relationship between HRV and responding to ambiguous scenarios. However, this is correlational data and causal relationships cannot be implied and there may be other factors that are influencing this association, thus replication would be warranted before any firm conclusions can be drawn.

There was no effect of benign CBM-I training on the far transfer worry breathing focus task. As there was no near transfer effect of CBM-I training, it is unsurprising that there was no far transfer effect. Previous research using a high trait worry sample had found an effect of benign CBM-I training on the worry breathing focus task (Hirsch et al., 2009) with the benign training group reporting fewer negative thought intrusions after a worry period than the sham training condition. One possibility is that completing the online and offline tasks prior to the worry breathing focus task somehow influenced or diluted the original CBM-I training effect. A second possibility is that the study was underpowered. This however seems unlikely as the power experiment had an adequate sample size to achieve 80% power with an alpha of .05. The power calculation for the study was based on data from the breathing focus task from the Hirsch et al. (2009) study and thus should be representative of hypothesised effects in the present study.

Finally, a discussion of why the online and offline tasks did not indicate the presence of a negative interpretation bias at baseline is warranted. One possibility (as noted above) is that the online task was not a sensitive assessment of the presence of interpretation bias and thus no negative bias was observed on this measure at baseline. However, there was also no baseline negative bias observed on the offline recognition task and (based on previous research) this was not predicted. Data from previous research using the recognition task (Eysenck et al., 1991) found that participants with GAD, but not those who had recovered from GAD or a non-anxious control group showed a significant bias in their interpretation of ambiguous sentences. This suggests that naturally occurring interpretation biases may only be observable in clinical populations rather than sub-clinical high trait worry populations. One recent suggestion to improve successful facilitation of cognitive bias training is to activate the bias prior to training by asking participants to engage in worry (Hirsch et al., 2016). It is possible that by activating worry prior to assessing the bias at

baseline, we may have observed a negative bias. However, this would need to be examined in a future study. This does of course raise the issue of how much change one might expect to see from baseline to post CBM-I training on a task, if the negative bias was not initially observed. One possibility is that as there was no observable negative bias at baseline, this explains why there was no effect of training on the online and offline tasks. However, despite the fact that bias was not observed at baseline, the test trial data suggested that the training task trained a shift toward a benign bias (in the experimental condition) and there was a significant effect of training on the HRV data. Thus, despite the lack of evidence for a negative bias at baseline, one might still expect to see an effect of training a benign bias from pre to post training on data. Certainly an experiment (Hirsch et al. 2009) using a similar method where a high trait worry population received benign training or sham training showed that benign training had a subsequent effect on number of negative intrusions in a worry breathing focus task. Arguably, if we have evidence to suggest that benign interpretation bias training induces a shift towards a benign bias in an experimental group (that is not observed from sham training in a control group), then we can still attempt to observe whether the training affects change at the online or offline stages of processing.

5.1 Limitations

There are a number of limitations to the present study. One possibility is that no effect of CBM-I training was found on the recognition task due to dilution of training effect when first completing the online task. While this seems unlikely, one possibility would have been to counterbalance the order of the online and offline tasks at baseline and after CBM-I such that half the participants completed the offline task first and online task second. This option was discussed by the study team, but as the experiment already involved counterbalancing the stimuli lists A and B for the online and offline task, it was felt that this would be an additional layer of potential

complication. Furthermore, even if there was an effect of training on the offline task when presented directly after training, the experiment would be underpowered as only 50% of participants would see this task directly after training. A second limitation is that the scenarios used in the online task (as discussed above) were not re-piloted due to time constraints. It is thus possible that the task was not sensitive to online assessment on interpretation bias. Finally, participants were not asked to rate the amount of time they were able to worry or how difficult they found to worry in the worry breathing focus task (cf. Hirsch et al. 2009). This means that there was no manipulation check for the worry section of the worry breathing focus task.

5.2 Future directions

This experiment was unable to provide conclusive evidence in support of an online or offline interpretation bias in a high trait worry sample. Future research in this area could seek to improve the online task by performing further pilot work and ensuring all scenarios are sensitive to both plausible negative and positive outcomes. Hirsch et al. (2016) suggest the use of biological paradigms such as Event Related Potential (ERP) techniques to further explore online inferences that may occur outside of awareness. ERP techniques would be a useful addition to the present experiment in order to provide an insight into automatic inferences. Future work in this area should also attempt to replicate the HRV assessment in order to confirm whether this is a robust effect in CBM-I training in a high trait worry sample. If indeed HRV is a biomarker of worry (Chalmers et al., 2016) it would be interesting to see whether in future experiments the relationship between benign CBM-I training and HRV can be replicated. CBM-I is a widely used method of manipulating interpretation biases (Menne-Lothmann et al., 2014). However, there is individual variation in the degree to which individuals are able to alter their processing biases (Clarke et al. 2012). If CBM-I techniques are to continue to develop and to be harnessed as effective treatment methods, it would be crucial to

better understand the factors that may contribute to individual differences in cognitive bias malleability.

5.3 Conclusions

In summary, the current study did not find evidence of a shift in online and offline interpretation biases after CBM-I training in a high trait worry sample. Benign CBM-I training appeared to be successful in inducing a positive interpretation bias as compared to a sham training condition, but this did not have a causal effect on online or offline near transfer tasks, or on a far transfer worry breathing focus task. There was a significant increase in HRV from pre-post training in the benign CBM-I trained condition, but not the sham training condition. Future research is required to examine whether modification of interpretation bias occurs at the automatic online stages of processing as well as at offline processing stages. A better understanding of the mechanisms that underlie CBM-I might enable it to be a valuable tool in the treatment of GAD.

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7. APPENDICES

7.1 Online study pilot data

7.2 End of study questionnaire

7.3 Ethics approval letter

7.4 Study information sheet

7.5 Study consent form

7.1 APPENDIX 1

Pilot data for the online task

Aims

When assessing interpretation of ambiguous information, the ambiguous materials used should be capable of generating both benign or threat related outcomes that are related to a measure of trait worry.

Method

Ambiguous scenarios were selected from a large database of scenarios compiled for the purposes of a research trial in the lab. In order to examine whether materials elicited both benign and threat outcomes and that these related to trait worry, 120 ambiguous statements with the final disambiguating word missing were presented completed by participants through the MTurk website. The statements represented a range of worry domains (Tallis, Davey, Bond, 1994). In order to reduce participant burden, three surveys were set-up with and 50 participants were required to complete each survey, where they completed 40 statements each. Due to a technical error, one survey had 43 respondents. Participants read the statement and were asked to provide one word that completed the statement. Participants also completed a measure of measure of trait worry (Penn State Worry Questionnaire; Meyer, Miller, Metzeger & Borkovec, 1990) and a measure of general anxiety symptoms (Generalised Anxiety Disorder questionnaire (GAD-7; Spitzer, Kroenke, Williams, & Löwe, 2006). Participants received a small fee for completing the survey.

Once survey results were collected, a researcher in the lab (SD) coded the one word answers as negative or positive in valence, if the answer completed the sentence in a coherent manner. Where the one word answer did not provide a coherent ending to the sentence, this response was not included in the analysis. A subset of responses from each survey were coded by a second researcher (FM) to check inter-rater reliability there was 98.25% agreement between the two sets of

ratings. In three cases, scenarios received only benign or threat responses, which indicated that they were not ambiguous in nature and they were excluded from the analysis.

Data analysis

In each survey, the relationship between trait worry and tendency to provide positive and negative responses were examined. Responses in each survey were then assessed for their relationship to worry. In order to explore the data, a logistic regression was used to examine whether a continuous measures of trait worry (PSWQ) predicted a dichotomous outcome. As a second exploratory approach we split the dataset by those high on worry (PSWQ > 56 and low on worry (PSWQ < 34) and used a chi square test to look at the relationship between worry group and response (negative/benign).

Participant demographics

Mean PSWQ across all three surveys was 46.48 (SD = 15.66). See Table 1 for the mean (standard deviation in parentheses) PSWQ and GAD 7 scores for those who completed each survey.

Table 1

Mean (standard deviation in parentheses) PSWQ and GAD 7 scores for those who completed each survey.

Survey number	PSWQ (SD)	GAD 7 (SD)
1 (N = 50)	45.44 (15.33)	5.90 (6.02)
2 (N = 50)	48.52 (17.82)	6.36 (5.94)
3 (N = 43)	45.33 (13.32)	5.07 (4.87)

Relationship between trait worry and number of negative and positive responses to ambiguous scenarios

We examined the relationship between trait worry scores (PSWQ) and the number of negative and positive responses to scenarios in each survey.

Table 2

Correlations between trait worry scores (PSWQ) and the number of negative and positive responses to scenarios in each survey

PSWQ	Number of benign responses	Number of negative responses
Survey 1 PSWQ total	-.458**	.384**
Survey 2 PSWQ total	-.619**	.644**
Survey 3 PSWQ total	-.177	.173

** correlation is significant at 0.01 level (two tailed)

Using the criteria outlined above we used 6 scenarios from Survey 1 and 19 scenarios from Survey 2 and 2 scenarios from Survey 3. As a less stringent guideline we also employed scenarios that were correlated with PSWQ scores at a trend or significant level and used these scenarios. Finally we used the scenarios where the outcome was significantly predicted by PSWQ scores as exemplars and consulted the database of ambiguous scenarios created for a larger related study and extracted scenarios which were similar to those predicted by PSWQ scores, or modified existing ambiguous scenarios to be more like those where the positive or benign outcome had been predicted by PSWQ scores. In total we used 60 scenarios, 30 in each list of which 15 had negative and 15 had positive outcomes.

Example scenarios

Negatively resolved scenario

While driving, you notice a strange sound coming from your car. You drive on to the nearest garage to have it checked. As the mechanic looks over your car, he says repairing it will be expensive

Positively resolved scenario

You are at your child's nursery talking to their nursery teacher. The nursery teacher tells you about your child's behaviour and suggests that it may be due to your parenting style that they are behaving so: well

7.2 Appendix 2

END OF STUDY QUESTIONNAIRE

Please answer the following questions as honestly as possible:

1. What did you think was the purpose of the experiment?
Please list as many purposes of the experiment that occurred to you DURING the experiment.

2. Why did you think you were asked to identify word fragments?

3. Why did you think you were asked to read the different scenarios and respond to questions?

4. Are there any other comments you would like to make about the experiment and your experience of participating in this study?

Thank you for your participation

7.3 Appendix 3

Ethics approval letter

Dr Frances Meeten

Institute of Psychiatry, King's College London, De Crespigny Park, Denmark Hill
London
SE5 8AF

14 April 2016

Dear Frances,

Reference Number: HR-15/16-2300

Study Title: Modification of interpretation biases in worry: where does change occur?

Review Outcome: Approval with Provisos

Thank you for submitting your application for the above project. I am pleased to inform you that your application has now been approved with the proviso specified below.

1. For future reference, please ensure all amendments are explained in the appropriate sections of the application as well as the covering letter.

All changes must be made before data collection commences. The Committee does not need to see evidence of these changes, however supervisors are responsible for ensuring that students implement any requested changes before data collection commences.

Please ensure that you follow all relevant guidance as laid out in the King's College London Guidelines on Good Practice in Academic Research (<http://www.kcl.ac.uk/college/policyzone/index.php?id=247>).

For your information, ethical approval is granted until 14th April 2019. If you need approval beyond this point, you will need to apply for an extension at least two weeks before this. You will be required to explain the reasons for the extension. However, you will not need to submit a full re-application unless the protocol has changed. If you have been granted approval for only 12 months, you will not be sent a reminder when it is due to lapse.

Ethical approval is required to cover the data-collection phase of the study. This will be until the date specified in this letter. However, you do not need ethical approval to cover subsequent data analysis or publication of the results.

For secondary data-analysis, ethical approval is applicable to the data that is sensitive or identifies participants. Approval is applicable to period in which such data is accessed or evaluated.

Please note you are required to adhere to all research data/records management and storage procedures agreed to as part of your application. This will be expected even after the completion of the study.

If you do not start the project within three months of this letter please contact the Research Ethics Office.

Please note that you will be required to obtain approval to modify the study. This also encompasses extensions to periods of approval. Please refer to the URL below for further guidance about the process:

<http://www.kcl.ac.uk/innovation/research/support/ethics/applications/modifications.aspx>

Please would you also note that we may, for the purposes of audit, contact you from time to time to ascertain the status of your research.

If you have any query about any aspect of this ethical approval, please contact your panel/committee administrator in the first instance (<http://www.kcl.ac.uk/innovation/research/support/ethics/contact.aspx>)

We wish you every success with this work.

Yours sincerely,

James Patterson - Senior Research Ethics Officer

For and on behalf of

Professor Gareth Barker, Chair

PNM Research Ethics Subcommittee

Cc: Colette Hirsch

7.4 Appendix 4

Study information sheet

INFORMATION SHEET FOR PARTICIPANTS

REC Reference Number: HR15/162300

YOU WILL BE GIVEN A COPY OF THIS INFORMATION SHEET

Understanding thought patterns in worry

We would like to invite you to participate in this original research project, funded by King's College. You should only participate if you want to; choosing not to take part will not disadvantage you in any way. Before you decide whether you want to take part, it is important for you to understand why the research is being done and what your participation will involve. Please take time to read the following information carefully and discuss it with others if you wish. Ask us if there is anything that is not clear or if you would like more information.

What is the purpose of the study?

This study is designed to help us understand why some people find it difficult to stop worrying. Most people worry from time to time, but usually this passes fairly quickly. However, some people find that once they start worrying, it is very difficult to stop. Research studies have shown that, rather than helping to resolve personal problems, focusing on negative topics during a worry bout usually causes anxiety and worry to get worse and to persist longer. However, we know very little about why or how some people are able to control negative thinking such as worry while others find it so difficult. In the present study we hope to learn more about what can make negative thoughts in worry so persistent and what people can do to prevent such thoughts getting out of control. Gaining a better understanding of these issues is important if we are to develop more effective psychological treatments for worry in the future.

Why have I been invited to take part in this study?

You have been invited to take part in the study because you are between 18 and 65 years of age and have English as a first language. You have completed an online worry questionnaire and have been invited to take part in the main study. The study is not suitable for people who have a psychiatric diagnosis, an acute or chronic health condition, or are taking medication.

What will happen if I take part?

If you decide you would like to take part in the study, you will be asked to attend one session at King's College London, Denmark Hill at a date/time convenient for you. The study will last approximately 2hrs 15 mins. During the session you will be asked to complete some questionnaires which will ask for details about yourself (age/height/current health etc.), your worries and emotions. We will then ask you to wear a small heart rate monitor which attaches by two disposable sticky pads. One pad goes just below your right collar bone and one on your left rib-cage. We will

explain to you where to put the pads and you attach them yourself. We will then ask you to complete some tasks on a computer. Task 1 will ask you to read some scenarios and individual words. In the next task, you will be asked to read scenarios and then be presented with a number of sentences. You will rate how similar the sentences are to the original scenario. You will be asked to complete these tasks twice during the study. In a 3rd task you will be asked to listen to some short scenarios and answer some questions. At certain points during the study you will be asked to focus on your breathing for 5 minutes, and from time to time briefly saying what you're thinking about. Afterwards, we will ask you for a bit more detail about those thoughts. At another point, you will be asked to identify a topic that you are currently worrying about that you are comfortable talking about and to describe it briefly to us (verbally or in writing). After that, we will then ask you to worry about that topic for a few minutes as you normally would. At the end of the study you will be debriefed. You will have an opportunity to talk to the experimenter about the study and ask any questions that you may have and you will be asked to complete a form that will ensure that you are paid for taking part in the study.

What are the possible disadvantages of taking part?

The study involves thinking about some current worries. Some people might find some of these tasks uncomfortable or mildly distressing, but that feeling will go away once the task stops and will have no long-term impact. The study does not provide any diagnostic information about physical or mental health conditions. If the study brings up any concerns, you will have the opportunity to discuss them with the researcher at the end of the study and all participants who take part in the study will receive a standard debrief sheet which provides information about what to do if you are feeling concerned about your health.

What are the possible benefits of taking part?

We hope that you will find it interesting to take part in this research. Also, the information we get from this study should help us to understand more about why some people cannot stop worrying. Because research of this kind addresses questions to which we do not yet know the answers, it is impossible to know if taking part will be personally helpful, although we certainly hope that some of the techniques involved will help participants to worry less. Finally, we are happy to provide full information about the results of the study in which you took part, so that you can be informed of any methods that proved especially helpful. If you would like a copy of the research findings, please let the researcher know, and we will arrange for a copy of the final written report to be sent to you as soon as it is available.

Will my taking part in this study be kept confidential?

Information which is collected about you during the course of the research, including audio recordings, your answers to questionnaires and computer based tasks, will be kept strictly confidential. This means, you will be given a participant number and that the only way to identify you will be by your numerical ID, to ensure anonymity. All information will be kept strictly confidential unless any information is disclosed which could seriously affect the welfare of yourself or others, in which case a third party may have to be contacted for legal reasons.

These data will be stored securely in anonymised form in King's College London for up to seven years, in either a locked filing cabinet or storage facility if in paper format, or on a password protected computer if in electronic format, all in anonymised form. This information will only be seen by members of the research team.

What will happen to the results of the research study?

The findings will be used to improve psychological treatments for worry and anxiety. The results of the study will be published in a peer reviewed journal, presented at conferences and discussed at other public events. Individual data will not be reported and you will not be identified in any report or publication.

Who has reviewed the study?

The research has been approved by the Psychiatry, Nursing and Midwifery (PNM) Research Ethics Subcommittee (RESC) at King's College London (ref no. *HR15/162300*).

It is up to you to decide whether to take part or not. Please take time to think about whether you would like to take part in the study. If you decide to take part you will be given this information sheet to keep and be asked to sign two copies of the consent form, one of which you will keep. If you decide to take part you are still free to withdraw at any time and without giving a reason.

For general queries about the study, please contact Dr Fran Meeten by email: frances.meeten@kcl.ac.uk, or at the following address: Department of Psychology, PO 77, Institute of Psychiatry, De Crespigny Park, London SE5 8AF. If this study has harmed you in any way you can contact the study supervisor, Dr Colette Hirsch, Senior Lecturer, Colette.hirsch@kcl.ac.uk, 02078480697

7.5 Appendix 5

Study consent form

CONSENT FORM FOR PARTICIPANTS IN RESEARCH STUDIES

Please complete this form after you have read the Information Sheet and/or listened to an explanation about the research.

Title of Study: Understanding thought patterns in worry

King's College Research Ethics Committee
Ref: _____

Thank you for considering taking part in this research. The person organising the research must explain the project to you before you agree to take part. If you have any questions arising from the Information Sheet or explanation already given to you, please ask the researcher before you decide whether to join in. If you decide to take part in the study, you will be emailed a copy of the Information Sheet and the Consent Form to keep and refer to at any time.

I confirm that I understand that by ticking each box I am consenting to this element of the study. I understand that it will be assumed that unclicked boxes mean that I DO NOT consent to that part of the study. I understand that by not giving consent for any one element I may be deemed ineligible for the study.

- 1. *I confirm that I have read and understood the information sheet 'Understanding thought patterns in worry' dated [Version number 1 – 16.02.16] for the above study. I have had the opportunity to consider the information and asked questions which have been answered satisfactorily.**
- 2. *I understand that my participation is voluntary and that I am free to withdraw at any time without giving any reason. Furthermore, I understand that I will be able to withdraw my data up to 4 weeks after completing the study.**
- 3. *I consent to the processing of my personal information for the purposes explained to me. I understand that such information will be handled in accordance with the terms of the UK Data Protection Act 1998.**

4. *I understand that my information may be subject to review by responsible individuals from the College for monitoring and audit purposes.
5. I understand that confidentiality and anonymity will be maintained and it will not be possible to identify me in any publications
6. I agree to be contacted in the future by King's College London researchers who would like to invite me to participate in follow up studies to this project, or in future studies of a similar nature.
7. I understand that I must not take part if I fall under the exclusion criteria as detailed in the information sheet and explained to me by the researcher.
8. I consent to completing questionnaires and reading scenarios that may cause mild anxiety.
9. I consent to wearing a small heart rate monitor during the study
10. I consent to discussing a worry topic in the study that may be personally relevant to me. I understand that I can stop the task at any time without giving a reason.

Name of Participant Signature	Date
Name of Researcher Signature	Date