University of Southampton

Faculty of Environmental and Life Sciences

School of Psychology

Examining the Relationship Between Cognitive Flexibility and Constructs of Anxiety

by

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Thesis for the degree of

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Abstract

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Theories addressing the links between emotion and cognition commonly specify the role of executive functions in anxiety processes. Cognitive flexibility is a component of executive functioning and is often used synonymously with shifting/switching ability. A growing area of research investigating general anxiety processes and cognitive flexibility has yielded mixed findings. As a result, a systematic review was undertaken to explore the relationships between general anxiety constructs and performance of tasks measuring cognitive shifting/switching abilities. Twenty-one studies were included in the review that measured trait and state anxiety, worry or generalised anxiety disorder symptoms, along with the use of a cognitive shifting/switching paradigm. This review found evidence that increased trait anxiety is associated with reduced shifting ability, particularly decreased processing efficiency. The review highlighted the potential for targeting cognitive flexibility in clinical interventions for anxiety.

The empirical paper explored associations between cognitive flexibility and transdiagnostic anxiety processes. Cognitive flexibility, intolerance of uncertainty and worry were measured using an online version of the Wisconsin Card Sorting Test (WCST), questionnaire measures and a task requiring participants to generate consequences from uncertain future events. Sixty participants, recruited from the community, took part in this web-based study. Results indicated that reduced cognitive flexibility, indicated by performance on the WCST, was associated with higher intolerance of uncertainty. Implications for the addition of intolerance of uncertainty in models of emotion-cognition are discussed along with the use of transdiagnostic measures in neuropsychological settings. Future research should employ longitudinal designs to explore these relationships further.

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Research Thesis: Declaration of Authorship

Print name:	Genevieve Warriner-Gallyer

Title of thesis:	Examining the Relationship Between Cognitive Flexibility and Constructs of Anxiety

I declare that this thesis and the work presented in it are my own and has been generated by me as the result of my own original research.

I confirm that:

1. This work was done wholly or mainly while in candidature for a research degree at this University;
2. Where any part of this thesis has previously been submitted for a degree or any other qualification at this University or any other institution, this has been clearly stated;
3. Where I have consulted the published work of others, this is always clearly attributed;
4. Where I have quoted from the work of others, the source is always given. With the exception of such quotations, this thesis is entirely my own work;
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6. Where the thesis is based on work done by myself jointly with others, I have made clear exactly what was done by others and what I have contributed myself;
7. None of this work has been published before submission

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Finally, I would like to dedicate this to my father. I know if you were here you would have tried to take me to every conference or talk about cognition you could find. Whenever I wanted to do anything you would commit yourself wholeheartedly to the cause and this doctorate would have been no different. I hope I make you proud.

Abbreviations

ACCE - Attentional Control Capacity for Emotion Task

ACS - Attentional Control Scale

ACT - Attentional Control Theory

ADHD - Attention Deficit Hyperactivity Disorder

ASC - Autistic Spectrum Conditions

ASQ - Attributional Style Questionnaire

BAI - Beck Anxiety Inventory

BRIEF - Behaviour Rating Inventory of Executive Function

CAS++ - Cognitrom Assessment System

CFI - Cognitive Flexibility Inventory

CFS - Cognitive Flexibility Scale

CIDI-SF - The Composite International Diagnostic Interview – Short Form

DAT - Delayed Alternation Test

EF - Executive Functioning

EMAS - The Endler Multidimensional Anxiety Scale

EPHPP - Effective Public Health Practice Project

ERGO - Ethics and Research Governance Online

GAD - Generalised Anxiety Disorder

GAD-7 - *Generalised Anxiety Disorder Questionnaire*

ID/ED - Intra/extradimensional Shift

IQR - Interquartile Range

IU - Intolerance of Uncertainty

IUS-12 - Intolerance of Uncertainty Scale – Short Form

MDD - Major Depressive Disorder

MINI - The Mini International Neuropsychiatric Interview

OAT - Object Alternation Test

OCD - Obsessive Compulsive Disorder

PAI-ANX - Personality Assessment Inventory – Anxiety Scale

PET - Processing Efficiency Theory

PHQ-9 - The Patient Health Questionnaire

PSWQ - The Penn State Worry Questionnaire

PTSD - Post-Traumatic Stress Disorder

RDoC - The Research Domain Criteria

RFFT - Ruff Figural Fluency Test

RT - Reaction Times

SCAN - Schedules for Clinical Assessments

STAI - State-Trait Anxiety Inventory

STAI-S - State-Trait Anxiety Inventory – State subscale

STAI-T - State-Trait Anxiety Inventory – Trait subscale

STICSA - The State-Trait Inventory of Cognitive and Somatic Anxiety

TMT-B - Trail Making Task – Part B

UAMA - Uncertainty and Anticipation Model of Anxiety

VAS - Visual Analogue Scales

VAT - Vertical Arrow Technique

WCST - Wisconsin Card Sorting Test

Chapter 1: The relationship between general anxiety and cognitive shifting/switching ability in clinical and non-clinical adult samples: A systematic review

1.1 Introduction

1.1.1 Anxiety

Anxiety has an enormous impact on human life and has a role in nearly every identifiable form of pathology (Levitt, 2015). Anxiety disorders have been argued to be the most prevalent psychiatric disorder in western cultures, with one third of the population experiencing an anxiety disorder at some point during their lifetime (Bandelow & Michaelis, 2015). There has been a growth in research exploring the interactions between anxiety and cognition (Dolcos, Iordan and Dolcos, 2011; Pessoa, 2008), aiming to understand potential cognitive mechanisms that may contribute to the development of, maintain or be affected by, various psychopathologies, and in turn impact the effectiveness of their clinical interventions (Crocker et al. 2013).

1.1.1.2 Delineation of anxiety.

Within the research literature, anxiety has been argued to be delineated into two trait dimensions; anxious apprehension and anxious arousal (Heller et al. 1995, 1997; Heller & Nitschke, 1998; Keller et al. 2000), each associated with a distinct pattern of neural activity (Engels et al. 2007, 2010; Nitschke, Heller, Palmieri & Miller, 1999). Anxious apprehension has been described as a trait reflecting the tendency to engage in a pattern of negative, repetitive thinking, such as worry, and has been found to be associated with increased activity in the left inferior frontal gyrus (Broca's area) (Engels et al. 2007, 2010). Anxious arousal is the enduring propensity to experience the physical

sensations of fear more readily, marked by a persistent pattern of hyper-arousal of the sympathetic nervous system to stressors, and hypervigilance to potential threat (Nitschke et al. 1999). This has been associated with increased activity in the right inferior temporal gyrus (Engels, 2007, 2010). Both traits have been argued to be separable from the transient phenomena of state anxiety, described as the emotional experience of acute worry, panic or fear triggered by situations of heightened threat (Sharp, Miller & Heller, 2015).

1.1.1.3 Anxious apprehension and worry.

Anxious apprehension is a dimension closely associated with worry and is described as a persistent pattern of repetitive negative thinking about perceived threats (Crocq, 2017). Worry is recognised as a phenomenon most people experience and exists on a spectrum, becoming pathological if perceived as uncontrollable, excessive and negatively impacting social, occupational and familial functioning (Davey & Meeten, 2016). Worry is a symptom appearing across multiple emotional disorders and is specifically a central feature of the diagnostic criteria for Generalised Anxiety Disorder (GAD; American Psychiatric Association, 2013).

1.1.1.4 Measuring anxiety and worry.

Self-report measures of negative affectivity are quick and simple to use tools widely used in psychological research to screen for the presence and severity of psychopathology (Balsamo et al. 2013). A frequently used measure of anxiety severity has been the State-Trait Anxiety Inventory (STAI: Spielberger & Gorsuch, 1983). This subjectively measures the individual's current anxious arousal as well as more stable features of anxiety proneness. Research investigating the validity of this measure however, has shown that it is relatively poor at discriminating between anxiety and depressive states (Bados, Gómez-Benito & Balaguer, 2010; Balsamo et al. 2013).

Another commonly used self-report measure of anxiety symptoms and the degree of distress caused by these symptoms is the Beck Anxiety Inventory (BAI: Beck, Epstein & Brown, 1988). This has been found to correlate less with symptoms of depression compared with the STAI, although has still been found to correlate moderately with depression scales (e.g., correlation with Beck Depression Inventory r = 0.61; Balsamo et al. 2013). Some authors have argued that measures of trait anxiety assess an underlying vulnerability to emotional distress rather than a specific proneness to anxiety (e.g., Nordahl, Hjemdal, Hagen, Nordahl, & Wells, 2019). This is a limitation when using trait anxiety measures due to the difficulties in discriminating between dimensions of anxiety and depression when drawing conclusions about associations.

The Penn State Worry Questionnaire (PSWQ: Meyer, Miller, Metzer & Borkovec, 1990) is a popular measure of pathological worry, and has been "the most widely used measure of the frequency, intensity and uncontrollability of worry" (Startup & Erikson, 2006, p.101) in psychological research. The PSWQ has been shown to have high internal consistency, temporal stability and discriminant validity (Brown, Antony & Barlow, 1992; Meyer et al. 1990).

1.1.3 Executive Functioning

1.1.3.1 Models of executive functioning.

Executive Functions (EFs) are a set of multidimensional mechanisms involved in the successful navigation of nearly all aspects of daily life (Diamond, 2013), culminating in higher-order abilities such as planning, sequencing and problem solving in the service of goal-directed behaviour (Snyder, Miyake & Hankin, 2015). It has been proposed that some of the cognitive abilities that make up EF include inhibition, working memory and cognitive flexibility (Diamond, 2013; Miyake et al. 2000). Cognitive flexibility has often been used synonymously with shifting or switching ability (see review by Ionescu, 2012).

Lower-order EF elements of inhibition, working memory and cognitive shifting have been shown to have separable as well as overlapping components (Snyder, Miyake & Hankin 2015), described as the Unity/Diversity Framework of EF (Friedman et al. 2008; Miyake et al. 2000; Miyake & Friedman, 2012). This model has focused on these three key EF factors of *shifting* (flexibly switching between tasks or mental sets), *updating* (rapid monitoring, adding and deleting content held in working memory) and *inhibition* (deliberately overriding previously used or dominant responses) (Miyake et al. 2000), as well as a common EF factor that bridges all three composed of a combination of abilities common across these three EFs (Miyake & Friedman, 2012).

This model has been supported by correlational research using confirmatory factor analysis showing that abilities of shifting, inhibition and updating have all correlated with each other (unity) but not fully, and therefore were also separable (diversity) (Friedman, Miyake, Robinson, & Hewitt, 2011; Miyake et al. 2000). This model is one of the most well-validated and replicated models in the literature (Madian, Bredemier, Heller & Warren, 2018). Miyake and Friedman (2012) proposed an updated bi-factor model outlining two main constructs of set shifting and updating. This has also been supported by correlational research using confirmatory factor analysis showing the inhibition component being fully accounted for by a common EF factor (Friedman et al. 2008; Friedman et al. 2011). Set shifting and updating were shown to have their individual unity and diversity from this common EF factor.

1.1.4 Cognitive Shifting/Switching Function

Miyake et al. (2000) described shifting as the ability to engage and disengage with appropriate task sets and to "perform a new operation in the face of proactive interference" (p.56). Five categories of shifting of attention have been outlined by Wager, Jonides and Reading (2004). For example, shifting between *location* is used in tasks that

contrast shifting of spatial locations with comparable non-shift control conditions. *Attribute switches* were identified in tasks involving shifting attention from one feature of an object to another (e.g. from shape to colour). *Rule switches* are utilised in tasks where learned responses to stimuli are reversed or reassigned, but the stimuli remains the same. *Object switches* apply to tasks in which the stimulus only is switched. Lastly, *task switches* relate to tasks requiring the switch between response sets or switching which operations are applied to which stimuli.

1.1.4.1 Commonly used measures of shifting/switching.

There are multiple neuropsychological measures that have been used in research to assess shifting ability. Snyder, Miyake and Hankin (2015) put forward a description of commonly used neuropsychological measures and specific EF measures that can be used to assess shifting processes. These include neuropsychological measures such as the Wisconsin Card Sorting Test (WCST), the Trail Making Task – Part B (TMT-B) and the Object Alternation Test (OAT)/ delayed alternation test (DAT). More specific shifting/switching measures include category switch tasks, number-letter switch tasks, colour-shape switch tasks and intra/extradimensional shift (ID/ED) tasks. Snyder, Miyake and Hankin (2015) also outlined commonly used measures of inhibition and updating such as the colour-word Stroop task and *n*-back tasks. Research by Miyake et al (2000) using structural equation modelling found that performance on the Wisconsin Card Sorting Test (WCST) was most strongly related to shifting/switching abilities compared to other neuropsychology tasks of operation span, random number generation and the Tower of Hanoi Task.

Performance on task-switching paradigms has commonly been measured in terms of reaction times (RT) and error rates and a robust finding has been that both measures are superior on task repetitions compared to task switches (Meiran, 1996; Monsell, 2003).

Inferior performance on these indicators have been termed switch costs and have generally been considered a direct measure of the cognitive control processes required in shifting/switching paradigms (Dreisbach, 2012).

1.1.5. Psychopathology and Executive Functioning.

Meta-analyses and systematic reviews have shown various forms of psychopathology to be associated with impairments in components of Executive Functioning (EF) including the shifting, inhibition or updating functions, such as schizophrenia (Stefanopoulou et al. 2009); major depressive disorder (MDD) (Snyder, 2013); obsessive compulsive disorder (OCD) (Abramovitch, Abramowitz, & Mittelman, 2013) and post-traumatic stress disorder (PTSD) (Polak, Witteveen, Reitsma, & Olff, 2012). It has been argued that these relationships indicate EF deficits may be a transdiagnostic risk factor for emotional and behavioural disorders (Snyder, Miyake & Hankin, 2015)

1.1.5.1 Psychopathology and shifting/switching ability

Impaired cognitive shifting/switching ability has been specifically associated with a range of psychiatric difficulties. In particular, a meta-analysis carried out by Snyder, Kaiser, Warren and Heller (2015) found individuals with a diagnosis of Obsessive Compulsive Disorder (OCD) were more impaired on a range of neuropsychological EF tasks including cognitive shifting, compared to healthy controls. Impaired shifting/switching ability, indicated by poorer performance on the WCST, has been reported in individuals diagnosed with, and in recovery of, Anorexia Nervosa and Bulimia Nervosa, compared to healthy controls in a systematic review (Tchanturia et al. 2012).

A systematic review carried out by Morris and Mansell (2018) looked at associations between switching/shifting ability and various transdiagnostic constructs present across a range of psychopathologies and found rumination to be specifically associated with

task-switching difficulties, which persisted even when controlling for depression. This review also found associations between deficits on task switching and other transdiagnostic processes such as perfectionism highlighting the possibility of shifting/switching playing a key role in processes present across disorders.

1.1.5.2 Anxiety and executive functioning.

There has been much less research looking at the relationships between anxiety disorders and components of EF (Snyder, Miyake & Hankin, 2015). This is despite anxiety being recognised as one of the most common and costly neuropsychiatric disorders involving prominent disturbances of cognition and emotion and argued to fundamentally be a disorder of the emotional-cognitive brain (Okon-Singer, Hendler, Pessoa, & Shackman, 2015).

Research that has investigated associations between components of EF and anxiety disorders has shown mixed findings (Snyder, Miyake & Hankin, 2015). For example, a meta-analysis conducted by Moran (2016) reviewed studies investigating working memory capacity and self-reported trait anxiety and found that increased self-reported trait anxiety was associated with reduced working memory abilities. In contrast, a study looking at cognitive functioning in a student sample meeting criteria for GAD found no differences on EF tasks assessing working memory, inhibition and planning compared to non-anxious controls (Leonard & Abramovitch, 2019). A study looking at a community sample of young people reported a mixed pattern of findings. For example, it was found contrary to prediction that those with marked anxiety symptoms actually performed better on a shifting task compared to those with minimal anxiety symptoms. Young people with increased anxiety symptoms took longer on tasks requiring planning ability compared to those with no anxiety symptoms, however there were no differences in planning accuracy between these groups (Murphy, Luke & Brennan, 2018).

A recent study investigating four facets of negative affect; anxiety, depression, worry and rumination and their associations with EF found that trait worry was the only construct associated with reduced EF ability. This association was only with a general EF factor however, and worry was found to not be associated with specific EF abilities of shifting/switching or updating (Gustavson et al. 2019).

1.1.6 Cognitive Models Linking Anxiety, Worry and Executive Functioning

1.1.6.1 Attentional Control Theory (ACT).

Attentional Control Theory (ACT) (Derakshan and Eysenck, 2009; Eysenck et al. 2007; Eysenck & Derakshan, 2011) developed from Processing Efficiency Theory (PET) (Eysenck & Calvo, 1992), is a model put forward to help understand the detrimental effects of anxiety on cognitive performance. PET separated the processes of '*performance effectiveness*' (response accuracy) and '*processing efficiency*' (the cognitive effort or resources spent in relation to response accuracy) when describing performance on cognitive tasks and is a central assumption of ACT.

ACT hypothesises that anxious individuals will allocate more attentional resources to threat-related stimuli, and that this can be either internal (such as worrisome thoughts), or external (any threatening stimuli) (Eysenck et al. 2007). Anxiety impairs attentional control even when there is no threatening stimulus because if an individual perceives themselves to be under threat, it is a safer strategy to allocate attentional resources widely rather than maintain a high focus of attention on one specific stimulus, and this is hypothesised to impair processing efficiency over and above performance effectiveness (Eysenck et al. 2007). ACT goes on to predict that anxiety will have a direct impact on the shifting and inhibition function as these processes are directly related to executive control (Eysenck & Derakshan, 2011).

This model has been supported by a meta-analysis looking at attentional biases in anxious individuals (Haim, Lamy, Bakermans-Kranenburg & van Ijzendoorn, 2007). This found that adult and child participants with clinically diagnosed anxiety disorders such as GAD, OCD and PTSD and those with high levels of self-reported anxiety using a state-trait anxiety measure demonstrated an attentional bias towards threat-related material and that this bias was not observed in non-anxious controls (Haim, Lamy, Bakermans-Kranenburg & van Ijzendoorn, 2007). This model has also been supported by a study by Stout, Shackman, Johnson and Larson (2015) who found trait worry to be associated with difficulties preventing threat-related (e.g. fearful) emotional faces used as distracters, from entering working memory. This indicated that anxious individuals were more likely to allocate more storage space in working memory to threatening stimuli, even when it was not relevant for the completion of the task. This effect has been supported by research with children using a dot-probe paradigm, for example, Susa, Pitica, Benga and Miclea, (2012) found that those who paid more attention to threat-containing stimuli had reduced attentional control abilities and increased levels of anxiety.

1.1.6.2 Cognitive model of anxious apprehension.

Hirsch and Matthews (2012) put forward a cognitive model outlining the development and maintenance of pathological worry and the role that attentional control, including shifting ability has within this, and shares common features with ACT

The model consists of two processes which combine to contribute to the development and maintenance of pathological worry, however evidence supporting these processes being causal of pathological worry is inconclusive (Hirsch & Matthews, 2012). One of these processes is biases in how emotional information is attended to and processed, for example selective attention to internal information such as bodily sensations, worry thoughts, or worry images and the tendency to make threatening

interpretations from ambiguous information (Hirsch & Matthews, 2012). The second process involves impairment of attentional control, such as shifting ability. This is described as a "top-down" process as is it under intentional voluntary control and is in contrast to "bottom-up" involuntary captures of attention which are unintentional. The model describes how emotional processing biases increases the likelihood of threat representations initially coming in to conscious awareness in a "bottom-up", involuntary manner. Worry episodes can then develop from emotional processing biases becoming habitual and "top-down" attentional resources being captured by the threatening content. Insufficient attentional control increases the difficulty of shifting attention away towards alternative topics and disengage from the worry (Hirsch & Matthews, 2012).

Evidence supporting aspects of this model has come from a systematic review by Goodwin, Yiend and Hirsch (2017). This demonstrated that adults with high trait worry/GAD showed an attentional bias to threat stimuli compared to non-worry controls in the majority of included studies. Less research has been conducted looking specifically at worry and impaired attentional control however a study by Hayes, Hirsch and Matthews (2008) lends support to this hypothesis. This study found that in a small student and staff sample, those with high self-reported worry had lower working memory capacity when thinking about worries compared to low worriers. Working memory capacity was assessed in this study using a random number generation task which has been reported to relate to the inhibition and updating components of executive function (Miyake et al. 2000).

1.1.7 Study Aims

To date, there have been no systematic reviews of studies looking specifically at the relationships between shifting/switching ability and general anxiety, despite an increase in the amount research being carried out in this area. The development of The

Research Domain Criteria (RDoC) is encouraging research investigating dimensional constructs of psychopathology that integrate psychological and biological knowledge, whilst remaining open to categorical constructs that so far have been more predominant in the literature (Sharp, Miller & Heller, 2015). In line with this framework, this systematic review aims to evaluate studies looking at constructs of general anxiety that extend over pathological and non-pathological anxiety and its relationship to cognitive abilities most closely associated with the shifting/switching construct of executive functioning.

1.2 Methods

1.2.1 Search Strategy

The online databases of Web of Science, PsychInfo and PubMed were searched for articles published between 1st January 1970 and 20th January 2019. The search terms used for general anxiety and cognitive shifting/switching are reported in Appendix A. The search terms for cognitive flexibility were informed by work from Dajani and Uddin (2015) and Ionescu (2012) who outlined a range of terms used within the literature to describe cognitive flexibility.

Database searches yielded a total of 502 papers with limiters applied to search for studies published in peer reviewed journals using a human population and written in English. A systematic selection process was then carried out to screen titles, abstracts and full text articles. The review question and inclusion and exclusion criteria were developed through this process of screening articles. Full text articles generated from the first database search of Web of Science that included any measure of cognitive flexibility, both self-report and direct cognitive assessment, were initially considered for inclusion. Due to the variation in language used to describe cognitive flexibility and methodology to measure this, it was difficult to assess the number of potential studies from scoping searches alone. Initially studies also included child and older adult populations. Once this initial database search had been reviewed it was possible to refine the review question and to develop inclusion and exclusion criteria for subsequent database searches. After relevant articles were found via database searches, an additional 21 articles were identified through a hand search of reference lists from these full text articles and were screened using the identified inclusion and exclusion criteria.

1.2.2 Inclusion and Exclusion Criteria

Inclusion criteria were met if studies were empirical, published in a peer-reviewed journal, written in English and sampled a human adult population (18-65 years). Studies were required to have a self-report measure of anxiety or worry or a measure of GAD based on diagnostic criteria made by a healthcare professional. Studies were included if cognitive shifting/switching ability was measured through the use of a cognitive task. Studies using either experimental or non-experimental study designs were also included.

Studies were excluded if the sample population were primarily reported to meet diagnostic criteria for any other anxiety disorder apart from generalised anxiety, such as panic disorder, social anxiety disorder and obsessive-compulsive disorder. Studies using a population meeting criteria for any other psychiatric condition, such as bipolar disorder, psychosis or depression; a physical health condition such as cancer, hepatitis and diabetes; neurological condition such as epilepsy, traumatic brain injury and multiple sclerosis; or any neurodevelopmental difference such as Autistic Spectrum Conditions (ASC) or Attention Deficit Hyperactivity Disorder (ADHD), were also excluded.

Studies were excluded if the cognitive task that was used, primarily measured a function other than cognitive shifting/switching. For example, studies using the Stroop Test, Flanker Task and Go/No-Go Task were excluded as this have been reported in the literature to primarily be measures of inhibition (Snyder, Miyake & Hankin, 2015; Zetsche, Bürkner & Schulze, 2018). Studies using tasks that primarily measured working memory, sustained attention and planning were also excluded. Studies that only used a self-report measure of shifting/switching ability assessed by questionnaires such as the Cognitive Flexibility Scale (CFS; Martin & Rubin, 1995), the Attentional Control Scale (ACS; Derryberry & Reed, 2002) and the Behaviour Rating Inventory of Executive Function (BRIEF; Gioia, Isquith, Guy & Kenworthy, 2000) were also excluded. This was

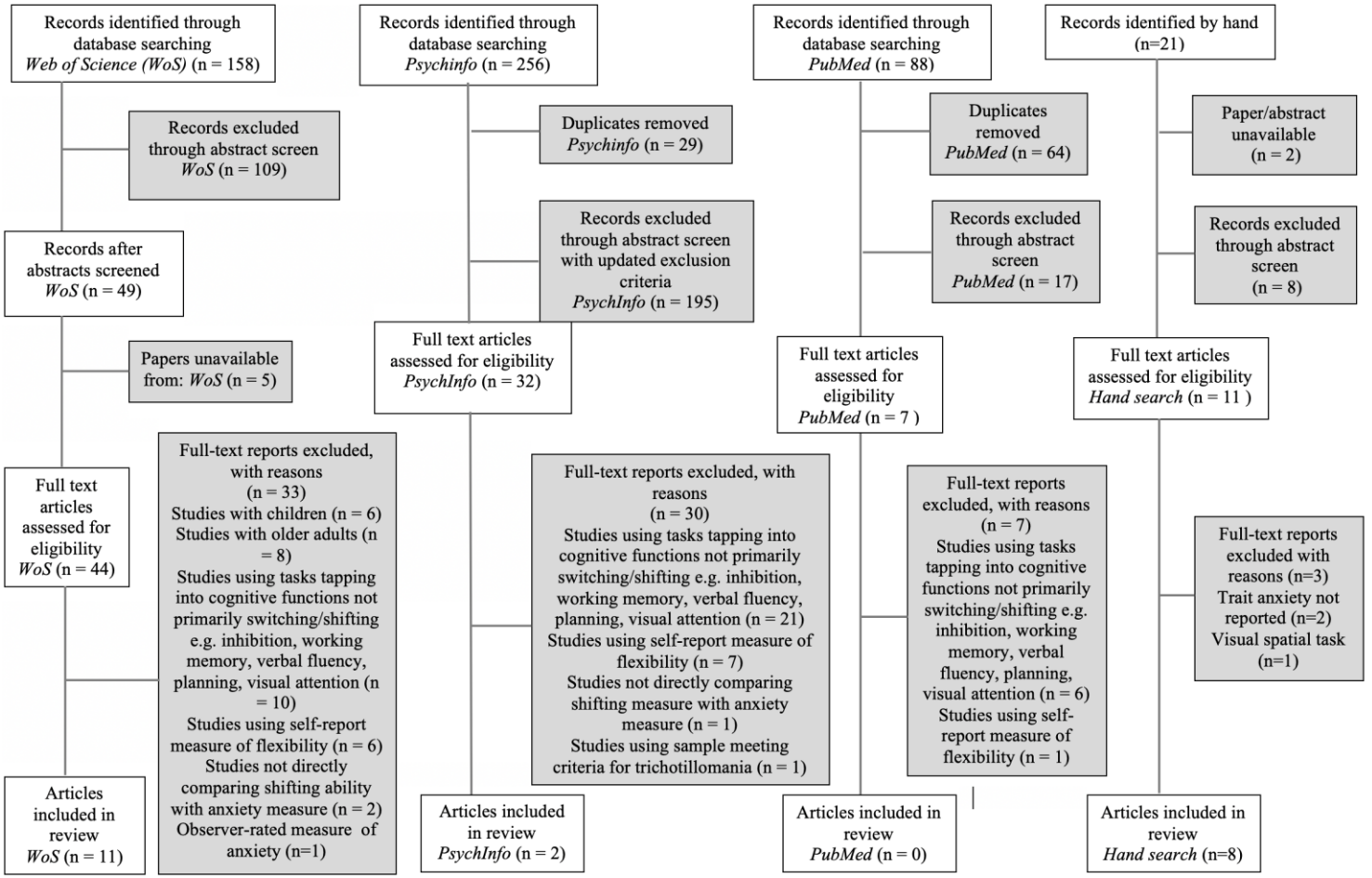
informed by research reporting a low association between performance on neuropsychological tests and self-report measures of cognitive flexibility and shifting/switching ability (Buchanan, 2015; Johnco, Wuthrich and Rapee, 2014; Lounes, Khan and Tchanturia, 2011; Williams, Rau, Suchy, Thorgusen & Smith, 2017), suggesting a different aspect of functioning being captured by self-report measures compared to direct cognitive assessment.

Studies that used an intervention design were only included if a baseline measurement of shifting/switching ability and anxiety were analysed and reported. Following this selection procedure, 21 articles were included in the review (see Figure 1).

1.2.3 Quality Assessment

A quality assessment check for the included articles was carried out using the Effective Public Health Practice Project (EPHPP) Quality Assessment Tool for Quantitative Studies (EPHPP, 1998). This was completed by the author (GW-G) and an independent rater. Ratings were compared and discussed until a consensus was reached to give one final agreed rating outcome for each article (Appendix H). This tool was chosen as the quality criteria could be applied to both experimental and non-experimental study designs.

Figure 1
Study Selection Procedure Flowchart



1.3 Results

A summary of study and participant characteristics from studies included in this review (n=21) are presented in Table 1, along with a summary of study measures and outcomes outlined in Table 2. Data extracted from these studies include descriptive study characteristics, measures of anxiety and cognitive shifting/switching, indexes of cognitive shifting/switching ability and the relationship between anxiety and worry on shifting/switching ability.

1.3.1 Descriptive Characteristics of Studies

An overview of the descriptive characteristics of each study included in this review is presented in Table 1. As can be seen, research investigating the links between trait anxiety and cognitive shifting/switching has increased considerably since 2004. Two studies that met inclusion/exclusion criteria for this review were reported prior to this, in 1992 and 1995 (Gershuny and Sher, 1995; Goodwin and Sher, 1992). The majority of these studies were carried out in the United States of America (n=11; Caselli, Reiman, Hentz, Osborne and Alexander, 2004; Gershuny and Sher, 1995; Goodwin and Sher, 1992; Gustavson, Altamirano, Johnson, Whisman and Miyake, 2017; Johnson, 2009; Muraven, 2005; Robinson, Ode and Hilmert, 2011; Salters-Pedneault, Suvak and Roemer, 2008; Whitmer and Banich, 2007; Zainal and Newman, 2018a; Zainal and Newman, 2018b), followed by the United Kingdom (n=3; Ansari & Derakshan, 2011; Ansari, Derakshan, & Richards, 2008; Derakshan, Smyth and Eysenck, 2009) and Australia (n=2; Edwards, Edwards and Lyvers, 2015; Edwards, Moore, Champion and Edwards, 2015). Individual studies have also been conducted in Sweden (Airaksinen, Larsson, & Forsell, 2005), Belgium (Beckwé, Deroost, Koster, De Lissnyder, & De Raedt, 2014), The Netherlands (Gulpers, Lugtenburg, Zuidersma, Verhey & Voshaar, 2018), Italy (Tempesta, et al. 2013) and Romania (Visu-Petra, Miclea and Visu-Petra,

2013). The majority of studies recruited a student population (n=15) and healthy volunteers from population-based cohorts (n=5). One study targeted a specific population and recruited participants with a diagnosis of GAD from a psychiatric outpatient clinic and compared this with a control group of students and university workers. Sample sizes differed substantially between studies, ranging from 27 to 83,994 participants (Median=84, IQR=66).

Sample sizes varied both within and between study design types. The majority of studies utilised a between-group design (n=7) and a non-experimental correlational design (n=6). A smaller proportion of studies used a mixed-factorial design (n=3; Beckwé et al. 2014; Derakshan et al. 2009; Ansari & Derakshan, 2011), a within-subjects design (n=2; Gustavson et al. 2017; Robinson et al. 2011) and a non-experimental population-based cohort design (n=2; Gulpers et al. 2018; Zainal and Newman, 2018a). This type of study design in particular recruited the most participants (n=83994; n=2605). There was only one study that used a non-experimental cohort design (see Table 1; Caselli et al. 2004).

The age of participants reported within these studies ranged from 18 to 55 years, with an overall mean of 32.6 years (SD=12.0). Seven articles did not report data regarding age of participants. The majority of studies reported information regarding the gender proportion of study participants (n=18), and this showed a trend towards more female participants being recruited in to these studies than males (Female M=62.6%, SD=11.9, range 39-87%).

Table 1.

Summary of Study and Participant Characteristics of Articles Included in the Review

Name	Year	Country	Sample Size (N)	Mean Age (SD)	Female Number (%)	Participants	Study Design
Airaksinen et al.	2005	Sweden	GAD group (N = 7) Control group (N = 175)	GAD group M=41.7 (11.8) Control group M=43.9 (12.3)	GAD group N=5 (71) Control group N=86 (49)	Swedish citizens	Causal comparative design with control group
Ansari et al.	2008	UK	N=59	M=31.9 (7.5)	Not reported	Staff and students	Quasi-experimental, causal comparative, no control group
Ansari & Derakshan	2011	UK	N=32	M=24.4 (5.06)	Not reported	Students	Quasi-experimental, causal comparative, no control group
Beckwe et al.	2014	Belgium	N = 84	M=19.0 (2.39)	N=56 (66)	Students	Quasi-experimental causal comparative no control group
Caselli et al.	2004	USA	N=126	M=55.0 (8.2)	N=87 (69)	Self-selected sample from Newspaper advertising to undergo APOE genotyping	Quasi-experimental causal comparative no control group
Derakshan et al.	2009	UK	N=59	Not reported	Not reported	Undergraduate Students	Quasi-experimental causal comparative no control group
Edwards et al.	2015	Australia	N=90	M=24.1 (8.31)	N=72 (80)	Undergraduate psychology students	Non-experimental correlational design
Edwards, Moore et al.	2015	Australia	N=70	M=24.2 (7.64)	N=61 (87)	Undergraduate students	Non-experimental correlational design
Gershuny et al.	1995	USA	Checking group (N=19); Anxious Non-checking (N=16); Non-anxious Controls (N=12)	Not reported	Checking group N=11(58) Anxious non-checking: N=11 (69) Control group N=6 (50)	Undergraduate psychology students	Causal comparative design with control group
Goodwin and Sher	1992	USA	Checking group (N=11); Non checking	Not reported	N=16 (59)	Students	Quasi-experimental causal comparative no control group

Name	Year	Country	Sample Size	Mean Age (SD)	Female Number (%)	Participants	Study Design
Gulpers et al.	2018	The Netherlands	GAD group (N = 3371) Total Anxiety disorder (N = 5522); Control group (N=75,101)	GAD group not reported Total anxiety disorder group M=44.2 (11.7); Control group M=44.2(12.4)	Total Anxiety disorder group N=3893(71) Control group N=43,311(58)	Lifelines population-based cohort recruited from GP practices	Causal comparative design with control group
Gustavson et al.	2017	USA	N=91	Not reported	N=55 (60)	Undergraduate Students	Non-experimental correlational design
Johnson	2009	USA	N=91	M=19.49 (2.23)	N=62 (68)	Undergraduate Psychology Students	Non-experimental correlational design
Muraven	2005	USA	N=112	Not reported	N=44 (39)	Undergraduate Students	Non-experimental correlational design
Robinson et al.	2011	USA	N=42	Not reported	N=20 (48)	Undergraduate Students	Quasi-experimental causal comparative no control group
Salters-Pednault et al.	2008	USA	N=60	M=22.93 (7.54)	N=40 (67)	Students	Quasi-experimental causal comparative no control group
Tempesta et al.	2013	Italy	GAD (N = 40) Control group (N = 31)	GAD-p group M=32.7 (7.49); GAD group M=30.4 (7.50); Controls M=32.7 (7.49)	GAD Group N=24 (60) Control Group N=21 (68)	Psychiatric outpatients with diagnosis of GAD Control group – university students and workers	Causal comparative design with control group
Visu-Petra et al.	2013	Romania	N=97	M=22.5 (4.18)	N=44 (45)	Psychology students	Non-experimental correlational design
Whitmer & Banich Experiment 1	2007	USA	N=43	Not reported	N=26 (60)	Students	Non-experimental correlational design

Name	Year	Country	Sample Size	Mean Age (SD)	Female Number (%)	Participants	Study Design
Zainal & Newman	2018(a)	USA	N=2605	M=55.2 (11.4)	N=1,446 (56)	Midlife Development in the United States (MIDUS) study	Non-experimental population-based cohort design
Zainal & Newman	2018(b)	USA	GAD N=69; Control group N=102	M=19.0 (1.16)	N=138 (81)	Students	Causal comparative design with control group

Notes: GAD: Generalised Anxiety Disorder; GAP-p: Generalised Anxiety Disorder with prescribed medication.

1.3.2 Psychological Measures of Anxiety

A summary of study measures and outcomes is presented in Table 2. The majority of studies used a self-report psychological measure of trait anxiety (n=13/21) as a main anxiety measure. Five different measures of trait anxiety were used across these studies with the State-Trait Anxiety Inventory - Trait subscale (STAI-T; Spielberger, Gorsuch, Lushene, Vagg & Jacobs, 1983) being the most commonly used (n=9/12). Other measures of trait anxiety included the Personality Assessment Inventory – Anxiety Scale (PAI-ANX; Morey & Boggs, 1991) (used in Caselli et al. 2004); The State-Trait Inventory of Cognitive and Somatic Anxiety (STICSA; Ree, French, MacLeod, & Locke, 2008) (used in Edwards, Edwards and Lyvers, 2015); The Beck Anxiety Inventory (BAI; used in Gustavson et al. 2017) and The Endler Multidimensional Anxiety Scale (EMAS; used in Visu-Petra et al. 2013).

State anxiety was measured in a third of studies (n=7/21) using three different psychological measures, with the STAI-State being the most commonly used measure (n=5/7). The other two measures of state anxiety were the STICSA and the EMAS (see Table 2).

Level of worry was assessed in less than half of the studies (n=8/21), using three different self-report measures. The Penn State Worry Questionnaire (PSWQ) was the most commonly used measure of worry, assessing aspects of trait worry (n=6/8). One study used an author-constructed measure of daily worry consisting of two self-report 5-point likert scale ratings, reported to have reasonable levels of reliability (alpha = 0.71) (Robinson et al. 2011). The PAI-ANX included a specific worry subscale and therefore this was also included as a measure of worry.

Four studies assessed participants' anxiety using DSM-IV-based criteria for Generalised Anxiety Disorder (GAD) rather than via self-report questionnaire

(Airaksinen et al. 2005; Gulpers et al. 2018; Zainal and Newman, 2018a; Zainal and Newman, 2018b). These assessments were all conducted in an interview format by a mental health professional. Two studies (Gulpers et al. 2018; Zainal and Newman, 2018b) used The Mini International Neuropsychiatric Interview (MINI; Sheehan, et al. 1998). The remaining two studies used the Schedules for Clinical Assessments (SCAN; Wing et al. 1990) (Airaksinen et al. 2005) and The Composite International Diagnostic Interview – Short Form (CIDI-SF; Kessler et al. 1998) (Zainal and Newman, 2018a).

Four studies used a combination of an anxiety measure (either state, trait or a GAD diagnostic measure) and a separate worry measure to assess the relationship between anxiety and cognitive shifting/switching (see Table 2; Beckwé et al. 2014; Gershuny and Sher, 1995; Gustavson et al. 2017; Zainal and Newman, 2018b).

Table 2
Summary of Study Measures and Outcomes of Articles Included in Review

Name	Year	Anxiety Measure	Worry Measure	Shifting/Switching Measure	Index of Shifting/Switching	Key Findings
Airaksinen et al.	2005	Schedules for Clinical Assessments (SCAN)	None	Trail Making Test - Part B	Accuracy Score; Completion Time	Specific GAD Group showed no reliable effects on TMT-B completion time (Fs<1) as compared with healthy controls Persons affected by an anxiety disorder needed more time to complete than health controls.
Ansari et al.	2008	STAI - Trait	None	Anti- and Pro-Saccade Task	Latency Switch Cost; % Error Rate	Low anxiety group showed a switch benefit in anti-saccade latency but not in high anxiety group. No difference in pro-saccade trials between groups No anxiety-related effects on saccade accuracy.
Ansari & Derakshan	2011	STAI-Trait	None	Anti- and Pro-Saccade Task	Mean Latencies of valid correct saccades; % Error Rate	When there was little time to prepare before target onset, high anxiety group were slower on anti-saccade switch compared to low anxious group. No difference in pro-saccade trials between groups. No significant anxiety group-related differences in saccade accuracy.
Beckwe et al.	2014	STAI – State and Trait	PSWQ	Internal Shift Task	Internal Switching Cost calculated from response times	High worriers had slower response times than low worriers on internal switch task when the negative words were personally relevant. Effect of worry on internal switch cost remained significant after controlling for state anxiety.
Caselli et al.	2004	Personality Assessment Inventory (PAI): Anxiety Scale		WCST	Total Categories Completed; Total Errors Made; Total number of Perseverative Errors	The cognitive component of trait anxiety, which includes excessive worrying and concern, did not interfere with any aspect of WCST performance in either group.

Name	Year	Anxiety Measure	Worry Measure	Shifting/Switching Measure	Index of Shifting/Switching	Key Findings
Derakshan et al.	2009	STAI – State and Trait	None	Mathematical Task Switching	RT; Errors	For state anxiety, high anxiety group were slower on switch trials compared to repetitive trials. No difference in Error Rates between high and low anxiety groups.
Edwards et al.	2015	STICSA – State and Trait Cognitive Subscale	None	WCST	Performance Effectiveness; Processing Efficiency	At higher effort, higher trait anxiety was associated with poorer efficiency in both the high and low stress conditions. At lower effort, trait anxiety did not predict efficiency in the low stress condition, however the relationship was highly significant and most pronounced for those in the high stress condition. Anxiety and stress did not predict performance effectiveness.
Edwards, Moore et al.	2015	STAI-Form Y-State and Trait	None	Task Shifting Paradigm*	% of Correct Trials; % of Correct Responses; Mean Reaction Times	Under high situational stress conditions, higher levels of trait anxiety were associated with lower processing efficiency. Correlations between performance effectiveness and depression, trait anxiety and situational stress were all non-significant.
Gershuny & Sher	1995	STAI- Trait	PSWQ	WCST	No. of Completed Trials; Total Correct; Total Errors; Perseverative Responses; % Perseverative Errors; Failures to Maintain Set; Time to Complete Task	Checking Group had higher levels of worry than Anxious Control group. Checking group had sig. fewer correct responses than anxious group and completed fewer trials. Combined anxious group failed to maintain sets sig. more than Non-Anxious Control group (error measure)

Name	Year	Anxiety Measure	Worry Measure	Shifting/Switching Measure	Index of Shifting/Switching	Key Findings
Goodwin and Sher	1992	STAI - State	None	WCST	Total and Perseverative Errors; Time to complete	Correlation between STAI and WCST - At time 1, state anxiety was significantly related to total errors, perseverative errors, and time to complete all trials when controlling for checking status. Not at 5 month follow up.
Gulpers et al.	2018	Mini Neuropsychiatric Interview (MINI) – Assessment of DSM-IV criteria for GAD	None	Ruff Figural Fluency Test	Total number of unique designs generated	GAD Group was associated with worse executive functioning, but this was fully explained by comorbid depressive disorder compared to non-anxious, non-depressed controls.
Gustavson et al.	2017	Beck Anxiety Inventory (BAI) – Trait Anxiety	PSWQ	Asymmetric Task Switching Task	RT; Error Rate	Worry was unrelated to performance on the asymmetric switching task. For both RT and error data, worry did not generally interact with any experimental factors. Individuals with higher trait anxiety exhibited greater difficulty in switching away from more effortfully established task sets than those with lower trait anxiety. No relationship with anxiety and error rates
Johnson	2009	STAI - Trait	None	Attentional Control Capacity for Emotion Task; Shape-line Switching Task	Switch Cost from Reaction Time	Trait anxiety significantly predicted Switch Cost when shifting internally between neutral to emotional mental sets.

Name	Year	Anxiety Measure	Worry Measure	Shifting/Switching Measure	Index of Shifting/Switching	Key Findings

Muraven	2005	STAI - Trait	None	Task switching paradigm**	RT	Trait generalised anxiety was found to not be significantly related to Reaction Time
Robinson et al.	2011	None	Daily worry measure	Rule Shift Task***	RT	Cortisol reactivity and task switching costs interacted significantly to predict daily worry. Switching costs alone did not predict daily worry.
Salters-Pednault et al.	2008	None	PSWQ	WCST	Total Error Raw Score	No significant differences between high and low worriers on error scores on WCST
Tempesta et al.	2013	STAI – State and Trait	None	WCST	Total number of errors; perseverative errors; non-perseverative errors	The GAD-P and GAD groups made a higher number of overall and non-perseverative errors compared to the control group; GAD-P group made more perseverative errors compared to control group; No effect of STAI score on number of errors, perseverative errors and non-perseverative errors.
Visu-Petra et al.	2013	Endler multidimensional anxiety scales – State and Trait	None	Cognitrom assessment system (CAS++) Rule switching task	Completion Time; Number of Correct Switches	Cognitive-Worry dimensions of state anxiety was the only significant predictor of switch efficiency, beyond the influence of RT. No relationship between anxiety and accuracy indexes.
Whitmer & Banich Experiment 1	2007	None	PSWQ	Task switching paradigm****	RT; Set-switching Cost	Level of worry did not significantly predict set-switching costs.

Name	Year	Anxiety Measure	Worry Measure	Shifting/Switching Measure	Index of Shifting/Switching	Key Findings
Zainal & Newman	2018 (a)	Composite international diagnostic interview: short form (CIDI-SF) - Assessment of DSM-IV criteria for GAD	None	Brief Test of Adult Cognition administered by telephone - Stop-and-Go Switch Task	Accuracy; Latency Scores	Latency scores on the Stop-and-Go Switch Task was positively longitudinally associated with heightened GAD 9 years later. Accuracy did not predict GAD diagnosis/severity 9 years later.
Zainal & Newman	2018 (b)	Mini International Neuropsychiatric Interview - DSM-IV criteria for GAD; Generalised Anxiety Disorder Questionnaire (GAD-Q-IV)	PSWQ	WCST	Number of Correct Responses (Accuracy)	No significant difference between GAD and control group on accuracy on the WCST at baseline.

Notes: *Internal Shift Task (IST) (based on Garavan, 1998); **Task Shifting Paradigm based on Sternberg (1966); ***Rule Shift Task based on Meiran, Chorev & Sapir (2000); ****Task switching paradigm based on Mayr & Keele, (2000); WCST: Wisconsin Card Sorting Test; GAD: Generalised Anxiety Disorder; GAP-p: Generalised Anxiety Disorder with prescribed medication; PSWQ: Penn State Worry Questionnaire; STAI: State-Trait Anxiety Inventory; RT: Reaction Times

1.3.3 Cognitive Measures of Shifting/Switching

From the studies included in this review (n=21), 14 different tasks were used to assess cognitive shifting/switching performance and many of these were author-adapted versions of previously used shifting/switching paradigms (see Table 2). The most commonly used task was the Wisconsin Card Sorting Task (WCST; Heaton, 1981; Appendix B), used in a third of included studies (n=7; Caselli et al. 2004; Edwards et al. 2015; Gershuny and Sher, 1995; Goodwin and Sher, 1992; Salters-Pedneault, 2008; Tempesta et al. 2013; Zainal and Newman, 2018b). For the purpose of this review, tasks have been categorised in to four shifting/switching subtypes, informed by descriptions put forward by Wager, Jonides and Reading (2004).

The most common measures of shifting/switching ability were based on a rule-switching paradigm (n=10/21), whereby participants are required to reverse or reassign previously learned responses whilst the stimulus stays the same. This included the WCST; a rule switching measure taken from the Cognitrom Assessment System (CAS++; Miclea, Porumb, Cotârlea & Albu, 2009); a Rule Shift Task (based on Meiran, Chorev & Sapir, 2000) and the Stop-And-Go Switch Task as part of the Brief Test of Adult Cognition (Tun & Lachman, 2006; Appendix C), administered by telephone (see Table 2).

Task-switching paradigms, where participants switch between different response sets, were used in five studies. These included a modified version of a Task-Shift Task (based on Sternberg, 1966); a computerised version of a Mathematical Task-Switching Task (based on Rubenstein, Meyer & Evans, 2001); an Asymmetric Task Switching Task (based on Cohen, MacWhinney, Flatt & Provost, 1993; Appendix D); and two Task Switching paradigms, one based on work done by Mayr and Keele, (2000) and one that was author created (Muraven, 2005).

Object switching tasks, where only the stimuli is switched in a task, were used in four studies. These included the Trail Making Test – Part B (TMT-B; Reitan, 1959; Reitan & Davidson, 1974; Appendix E); The Ruff Figural Fluency Test (Ruff, 1988); The Internal Shift Task (based on Garavan, 1998) and the Attentional Control Capacity for Emotion Task (ACCE; Johnson, 2008; Appendix F).

Two studies used an anti- and pro-saccade task (Ansari et al. 2008; Ansari & Derakshan, 2011; Appendix G), an example of a location-switching paradigm, where participants are required to shift between objects appearing in different spatial locations.

One study used a task switching paradigm involving switching from an internal self-focus to an external stimuli (Muraven, 2005), all other tasks used externally based stimuli from which to switch/shift attention.

1.3.4 Indexes of Cognitive Shifting/Switching

A variety of indexes were used across studies to indicate cognitive shifting/switching abilities. These indexes typically related to either performance *effectiveness* e.g. accuracy or error scores; or processing *efficiency*, e.g. response times. Less than half of the studies reviewed (n=10/21) included an index of both performance effectiveness and processing efficiency to directly compare (see Table 3). Ten studies used just a single index of shifting/switching ability; either processing efficiency (n=5) or performance effectiveness (*accuracy*) (n=6).

Table 3

Summary of Key Findings from Studies Included in Review

Study Author	Measure of Anxiety			
	State	Trait	GAD	Worry
Airaksinen et al. (2005)			- -	
Ansari et al. (2008)		*↓ -		
Ansari & Derakshan (2011)		*↓ -		
Beckwe et al. (2014)				*↓
Caselli et al. (2004)		-		
Derakshan et al. (2009)	*↓ -			
Edwards et al. (2015)		*↓ -		
Edwards, Moore et al. (2015)		*↓ -		
Gershuny et al. (1995)		*↓		
Goodwin & Sher (1992)	*↓ *↓			
Gulpers et al. (2018)			*↓	
Gustavson et al. (2017)		*↓ -		- -
Johnson (2009)		*↓		
Muraven (2005)		-		
Robinson et al. (2011)				-
Salters-Pednault et al. (2008)				-
Tempesta et al. (2013)	-	-	*↓	
Visu-Petra et al. (2013)	*↓ -	- -		
Whitmer & Banich (2007)				-
Zainal & Newman (2018a)			*↓ -	
Zainal & Newman (2018b)			-	

Notes: GAD: meeting diagnostic criteria for generalised anxiety disorder

Key:
- Processing Efficiency
- Performance Accuracy
- *↓ Significant negative association
- \- No significant association
- No measure reported

1.3.5 Relationship Between Anxiety and Cognitive Shifting/Switching

1.3.5.1 Trait anxiety.

Table 3 provides an overview of the key findings of each study included in this review. In total, 14/21 studies found a significant negative association between anxiety and performance on shifting/switching tasks. Trait anxiety was the most commonly used measure to assess the relationship between anxiety and shifting/switching and was used in 11/21 studies (see Table 3). Of these, n=7/11 studies found higher trait anxiety to be significantly associated with reduced performance on shifting/switching tasks (Ansari et al. 2008; Ansari & Derakshan, 2011; Edwards et al. 2015; Edwards, Moore et al. 2015; Gershuny et al. 1995; Gustavson et al. 2017 and Johnson, 2009). Three of these studies reported a measure of effect size or strength of relationship (Edwards et al. 2015; Edwards, Moore et al. 2015 and Gustavson et al. 2017). Edwards et al. (2015) and Edwards, Moore et al. (2015) reported the beta co-efficient which showed a weak relationship between higher trait anxiety and reduced switching performance across both studies. Gustavson et al. (2017) used partial eta-squared as a measure of effect size and reported a medium positive association between trait anxiety and reaction times on a task-switching task.

Studies used measures of processing *efficiency* and/or performance *accuracy* as indicators of shifting/switching ability. Eight studies compared trait anxiety with outcomes on processing efficiency and nine studies compared trait anxiety with performance accuracy. Trait anxiety was found to be significantly negatively associated more frequently with processing *efficiency* (n=6/8) than performance *accuracy* (n=1/9) (see Table 3). This indicates that higher levels of trait anxiety corresponded with slower switching/shifting times but not at the cost of accuracy. These findings are in line with the predictions made from Attentional Control Theory (ACT; Derakshan and Eysenck,

2009; Eysenck et al. 2007; Eysenck & Derakshan, 2011) which predicts anxiety impairs the efficiency of attentional control resources such as shifting ability over and above accuracy of performance. One study contradicted this and reported higher trait anxiety to be significantly associated with reduced performance *accuracy* on the WCST as measured by increased failures to maintain sets (Gershuny et al. 1995).

Three studies reported no significant relationship between trait anxiety and indexes of shifting/switching ability (Caselli et al. 2004; Muraven 2005; Tempesta et al. 2013). Muraven (2005) found trait anxiety to not be significantly related to reaction times (performance *efficiency*) on a task-switching paradigm which required participants to alternate their attention between an internal, self-focus and an external stimuli. Both Tempesta et al. (2013) and Caselli et al. (2014) found no effects of trait anxiety score on indexes of performance *accuracy* on the WCST.

Studies that measured trait anxiety varied in their study designs and therefore results should be interpreted with caution. More than half of the studies that measured trait anxiety (n=6/11) used a non-experimental correlational design (Edwards et al. 2015; Edwards, Moore et al. 2015; Gustavson et al. 2017; Johnson, 2009; Muraven, 2005 and Visu-Petra et al. 2013). The remaining studies used a causal comparative design without a control group (n=3; Ansari et al. 2008; Ansari & Derakshan, 2011 and Caselli et al. 2004) and with a control group (n=2; Gershuny et al. 1995 and Tempesta et al. 2013). It is not possible therefore to infer causality from these studies to fully support the assumptions from ACT that anxiety causes impairment to cognitive shifting ability. Studies using group comparisons assigned participants to groups based on anxiety severity and therefore it is not possible to control for the impact of extraneous variables on shifting ability which would be unknown.

1.3.5.2 State Anxiety.

State anxiety and performance on shifting/switching tasks were compared in four studies (Derakshan et al. 2009; Goodwin & Sher, 1992; Tempesta et al. 2013; Visu-Petra et al. 2013) (see Table 3). All studies that compared a measure of processing *efficiency* (n=3) found high state anxiety to be significantly associated with lower processing *efficiency* on switching tasks (Derakshan et al. 2009; Goodwin & Sher, 1992; Visu-Petra et al. 2013). The majority of studies reported no significant relationship between state anxiety and *accuracy* indexes (n=3/4) (Derakshan et al. 2009; Tempesta et al. 2013; Visu-Petra et al. 2013). One study did report a significant positive relationship between state anxiety and performance *accuracy* (errors made) on the WCST and in the same study also found a positive association between state anxiety and completion time (a measure of processing *efficiency*) (Goodwin & Sher, 1992). These findings also appear to be in line with predictions made from ACT however it cannot be inferred from these studies that state anxiety directly affects shifting efficiency due to the nature of the study designs used, only that a relationship between state anxiety and shifting efficiency appears to exist in these studies.

1.3.5.3 Generalised Anxiety Disorder (GAD).

The relationship between participants meeting criteria for a diagnosis of GAD and shifting/switching ability was assessed in five studies (Airaksinen et al. 2005; Gulpers et al. 2018; Tempesta et al. 2013; Zainal & Newman, 2018a; Zainal & Newman, 2018b) and findings from these studies appear more mixed (see Table 3). Participants diagnosed with GAD performed significantly less accurately on shifting tasks compared to non-anxious controls in two studies (Gulpers et al. 2018; Tempesta et al. 2013). In this study by Gulpers et al. (2018) however it was found that those meeting criteria for GAD performed worse on the Ruff Figural Fluency Test, an object switching task, on number of unique

designs generated (performance *accuracy*) compared to non-anxious controls, however this difference was fully explained by comorbid depressive symptoms and not by GAD classification alone.

Zainal and Newman (2018a) conducted a retrospective longitudinal study and found higher latency scores (slower processing efficiency) on the Stop-And-Go Switch task to be positively longitudinally associated with GAD diagnosis and severity nine years later, however performance *accuracy* was not associated with future GAD. This is the only study that used a longitudinal design and suggests impairments in shifting ability may be a risk factor for future GAD development. As this is the only study to demonstrate this, further research is needed employing the same design to examine the direction of the relationship between GAD and shifting ability.

Zainal and Newman (2018b) found no significant differences between a GAD group and non-anxious controls on performance *accuracy* on the WCST when assessing group baseline differences. In a separate study, Airaksinen et al. (2005) found that in a group of participants meeting criteria for GAD, there were no reliable effects on completion time (processing *efficiency*) on the TMT-B compared to non-anxious healthy controls. However, they did find that in participants meeting criteria for any anxiety disorder, these groups took longer to complete the TMT-B as a whole compared to non-anxious controls. This suggests that a possible underlying transdiagnostic anxiety process present across these anxiety disorders may be related to shifting/switching performance however this was not measured in this study.

1.3.5.4 Worry.

The relationship between worry and cognitive shifting/switching ability was assessed in five studies (Beckwe et al. 2014; Gustavson et al. 2017; Robinson et al. 2011; Salters-Pednault et al. 2008; Whitmer & Banich, 2007). Worry appeared to be unrelated

to any index of shifting/switching ability in the majority of studies (n=4/5) (see Table 3). One study (Beckwe et al. 2014) found that high worriers had significantly slower response times (processing *efficiency*) on an Internal Shift Task, an object switching paradigm, compared to low worriers and that this effect remained significant after controlling for state anxiety. This relationship was only apparent however, when the task stimuli contained personally relevant material.

1.4 Discussion

1.4.1 Summary of findings

This systematic review included 21 studies that had data relating to the association between general anxiety and cognitive shifting/switching performance in clinical and non-clinical adult samples. The aim of this review was to examine the research looking at the relationship between general anxiety processes, ranging from non-pathological to pathological, and cognitive shifting/switching ability.

The majority of studies found higher levels of anxiety were significantly associated with impaired shifting/switching ability. Studies used different outcomes for assessing shifting ability, either by using a measure of task efficiency or task accuracy or a combination of both. Fifteen studies measured performance efficiency and sixteen studies measured performance accuracy. When separating these, 73% of studies that measured performance efficiency (n=11/15), found higher anxiety was significantly related to slow processing efficiency on shifting tasks. This can be compared to studies that measured performance accuracy, whereby only 25% of studies (n=4/16) reported higher anxiety to be significantly related to low performance accuracy on shifting tasks. This is in line with predictions from ACT, which states that processing efficiency will be disrupted by anxiety, but not at the cost of performance accuracy (Derakshan and Eysenck, 2009; Eysenck et al. 2007; Eysenck & Derakshan, 2011). These findings also support the hypothesis in ACT that anxiety impairs the shifting function of attentional control however the majority of the designs used in the included studies are non-directional and therefore it is not possible to infer whether anxiety causes an impairment to cognitive shifting or whether impairments in shifting may cause anxiety.

1.4.2.1 Worry and shifting performance.

Studies varied in how anxiety was measured and could be split in to measures of state anxiety, trait anxiety, worry and meeting criteria for Generalised Anxiety Disorder (GAD). To assess the relationship between worry and shifting/switching ability, studies could be grouped by their use of an explicit measure of worry (e.g. the Penn State Worry Questionnaire) or by their inclusion of participants meeting criteria for GAD, a disorder characterised by pathological worry. This was intended to encompass the range of pathological and non-pathological symptoms of worry. Ten studies could be grouped in this way, and of which only four (40%) reported a significant negative association between worry or GAD and shifting performance. However, when this was separated into worry and pathological worry (GAD), three out of five studies which looked at GAD and shifting ability found a significantly negative association compared to only one out of five studies which looked at worry and shifting. This suggests that high levels of pathological worry are associated with disruption with attentional control abilities rather than lower levels of worry. This is in line with predictions from ACT and Hirsch and Matthews (2012) Cognitive Model of Worry, which both outline the impact of pathological levels of anxiety on attentional control such as shifting/switching ability. Both models describe impairment to attentional control resources associated with high levels of anxiety or worry and therefore the studies which only measured worry may not have had high enough levels of worry or anxiety to show a relationship with shifting/switching ability.

1.4.2.2 State and trait anxiety and shifting performance.

Studies that used a measure of state or trait anxiety reported more significant associations between anxiety and decreased performance *efficiency* on shifting tasks compared to performance *accuracy*. Trait anxiety was more commonly measured than

state anxiety. When looking at trait anxiety, 64% (n=7/11) of studies reported a significant relationship between trait anxiety and decreased shifting performance, and specifically decreased performance efficiency (n=6/11). State anxiety was also associated with decreased shifting efficiency in 75% of studies (n=3/4). These findings add to a growing body of literature examining the links between anxiety and domains of attentional control and support the findings of a meta-analysis by Moran (2016) who reported anxiety to be moderately associated with reduced working memory capacity, a component of attentional control. This was based on studies where performance on working memory tasks was compared between high and low anxious groups as well as anxiety measures correlated with working memory performance. In this review, both worry and anxiety arousal symptoms were related to working memory performance however anxious arousal was measured using either an explicit measure or by a disorder characterised by anxious arousal such as panic disorder. This makes it harder to make firm conclusions about the relationship between separable anxiety dimensions and working memory performance. Based on the correlational nature of the study designs causality is not able to be inferred.

1.4.3 Evaluation of findings

These findings are consistent with some of the predictions made by ACT (Eysenck et al. 2007; Derakshan and Eysenck, 2009; Eysenck and Derakshan, 2011). In particular, the hypothesis that anxiety will have a detrimental impact on attentional control and be associated to a higher degree with decreased processing efficiency compared to performance effectiveness on attentional tasks. ACT also predicts that anxiety will have a direct impact on the shifting function as this process is directly linked to executive control. This review lends support to this prediction as the majority of studies found a significant association between anxiety and shifting ability, however due to the

nature of the study designs included, there is an inability to determine whether anxiety causes a decrease in shifting ability or whether lower shifting ability may increase anxiety. The majority of studies compared differences between groups with high and low anxiety or looked at associations between measures of anxiety and cognitive performance. None of the studies experimentally induced anxiety to explore causality of the direct impact of anxiety on cognitive performance. One study found that reduced switching efficiency predicted onset of GAD nine years later (Zainal & Newman, 2018a), which provides some evidence that reduced shifting ability may be a risk factor in the development of general anxiety, however more research is needed to explore this further. Research using longitudinal designs would provide more evidence to examine the direction of this relationship over time to see whether impairments in shifting/switching ability may be a risk factor to severity of anxiety processes such as worry or whether these anxiety process might directly impact shifting/switching performance.

The finding that worry did not appear to be related to shifting/switching performance appears to be inconsistent with predictions made by ACT which hypothesises that worrying thoughts (internal task-irrelevant stimuli) would attract attention away from tasks and impair performance. However, ACT outlines that this is in conjunction with anxiety and therefore levels of anxiety may not have been high enough to affect task performance. This fits with the finding that there appeared to be an association with those meeting diagnostic criteria for GAD and decreased shifting ability. This pattern of findings also appears to be consistent with Hirsch and Matthews (2012) cognitive model of pathological worry. This hypothesises that reduced attentional control, such as the ability to shift attention from one set of stimuli to another, can lead to the development of pathological worry and in turn, pathological worry can then have a detrimental impact on attentional control.

1.4.4 Strengths and limitations of the included studies

The studies included in this review showed a range of diverse methodologies, which may decrease the generalisability of these findings. The most common study design used was a between-groups design (Ansari et al. 2008; Edwards et al. 2015; Edwards, Moore et al. 2015; Goodwin & Sher, 1992; Johnson, 2009; Muraven, 2005; Salters-Pedneault et al. 2008; Zainal & Newman, 2018b), the disadvantages of which are the increased amount of individual variation in cognitive ability that will naturally occur within participant groups possibly impacting the reliability of findings. The majority of studies used a self-selected, student sample with a higher proportion of female participants to male, reducing the potential generalisability of findings to the wider population.

An issue to consider when interpreting scores from cognitive assessments is the importance of capturing information regarding possible influences on performance for example mood, fatigue, motivation and environmental distractors. None of the studies had gathered information relating to motivation or effort from participants and only one study controlled for psychotropic drug use, alcohol use or physical health (Gulpers et al. 2018), all of which are factors which could potentially affect performance on cognitive tasks and reduce the amount of internal validity of the studies.

Similarly, low mood has been shown to correlate with anxiety and is associated with performance deficits on executive function tasks (Gustavson et al. 2016). Co-morbid symptoms of low mood were controlled for in less than half of the studies (n=9/21; Edwards et al. 2015; Edwards, Moore et al. 2015; Goodwin and Sher, 1992; Gulpers et al. 2018; Gustavson et al. 2017; Tempesta, et al. 2013; Whitmer and Banich, 2007; Zainal and Newman, 2018a; Zainal and Newman, 2018b) reducing the ability to make firm conclusions about the specific relationship between anxiety and the shifting/switching

function. A further issue to consider is the statistical power in the included studies. Only two studies reported being adequately powered (Zainal & Newman, 2015a; Zainal and Newman, 2015b). The remaining studies did not refer to a power analysis. The majority of studies may have therefore not been sufficiently powered to detect an effect.

A strength of the included studies were the consistent use of measures of anxiety which have been shown to have good validity and reliability (for example the PSWQ; STAI; BAI). Only one study used a measure of worry developed by the author (Robinson et al. 2011) and although was reported to have moderate reliability, the validity of the measure was not reported (Robinson et al. 2011).

A quality assessment check for the included articles was carried out by two independent raters, using the Effective Public Health Practice Project (EPHPP) Quality Assessment Tool for Quantitative Studies (EPHPP, 1998) (Appendix H). These ratings were then compared and a consensus was reached to give a final agreed outcome. This quality assessment tool was chosen as the quality criteria could be applied to both experimental and non-experimental study designs. The majority of the studies included received 'weak' ratings, two studies were rated as 'moderate' (Tempesta et al. 2013; Zainal and Newman, 2018a) and none of the studies were given an overall 'strong' rating. The strongest aspects identified from articles were the consistent use of valid and reliable primary outcome measures (rated as 'strong' in n= 19/21 articles) and the identification and control of confounding variables (rated as 'strong' in n=10/21 articles). Weak ratings were mainly driven by selection bias, as the majority of studies used a self-selected sample of participants (n= 19/21). This increases the risk of bias towards a narrow section of the population and reduces generalisability of findings to the wider population. As noted by Protogerou and Hagger (2018), there are no quality assessment tools developed specifically for survey designs. The EPHPP (1998) tool is weighted towards randomised

controlled trials and therefore the studies included in this review would likely receive moderate to weak ratings based on the nature of the tool as for a study to be rated strong overall there must be no weak ratings given for each criteria.

1.4.5 Strengths and Limitations of the Review Process

An important limitation is the lack of consistency in how cognitive processes being measured by different assessments are described within the cognitive literature. This resulted in difficulties selecting and synthesising appropriate studies that examined the relationship between constructs of general anxiety and cognitive shifting/switching abilities as well as uncertainty around whether the cognitive assessments included were valid measures of shifting/switching processes. An example to highlight this issue is the use of the Ruff Figural Fluency Test (RFFT). The RFFT was reported by an included study (Gulpers et al. 2018) to represent an overall measure of executive functioning and was described as being a test that did not incorporate shifting attention (Gulpers et al. 2018). Within the literature however, the RFFT has been described as a measure of the ability to shift between different cognitive tasks (Ruff, 1996; Ruff, Light & Evans, 1987) and as a measure examining the ability shift cognitive sets (Sbordone & Saul, 2000). It has also been reported to be a non-verbal measure of flexibility (Gardener, Vik & Dasher, 2013) and used as a measure to reflect non-verbal fluency (Foster, Williamson & Harrison, 2005). Evidence has also shown that in a healthy population, the number of unique designs generated on the RFFT correlates significantly with the Trail Making Test-Part B (TMT-B) (Ross, 2014). Studies were therefore included which used methods not specifically reported as a measure of the shifting/switching function.

The TMT-B is another instrument which has been widely used as a measure of executive function and which there has been uncertainty around which cognitive mechanisms are being primarily measured (Sánchez-Cubillo et al. 2009). These authors

found the TMT-B to primarily reflect working memory ability and task-switching ability secondarily. Other research has shown performance on the TMT-B to be significantly associated with switch costs on a set-switching task (Arbuthnott & Frank, 2000) and a measure sensitive to deficits in cognitive flexibility (Kortte, Horner & Wingham, 2002). In this review however, the TMT-B was used by Airaksinen et al. (2005) as a general measure of executive functioning rather than to represent shifting or cognitive flexibility. The wide variation in how constructs and their corresponding cognitive tasks have been described within the literature may means that some studies could have been overlooked. The sensitivity of the search criteria could have been increased by adding more variations of search terms such as from thesauruses within relevant articles (Bramer, de Jonge, Rethlefsen, Mast & Kleijnen, 2018).

1.4.5.1 The task impurity problem.

This lack of clarity around which tests have specificity and sensitivity to which cognitive processes reflect the task impurity problem, in that many cognitive mechanisms, both executive and nonexecutive, will be contributing to performance on a cognitive task (Burgess, 1997; Miyake et al. 2000). This leads to difficulties when interpreting studies that use a single cognitive task, as in this review, as it is unclear what proportion of variance is due to cognitive processes other than shifting/switching (for example motor speed, processing speed, colour vision and reading ability). This problem has been argued to be overcome by using multiple measures of the target cognitive process, to evaluate whether similar patterns emerge across tasks (Friedman, 2016), as well as using latent variable analysis (Friedman & Miyake, 2017). Using a latent variable approach, Miyake et al. (2000) focused on the shifting, updating and inhibition functions and found that shifting ability contributed most strongly to performance on the WCST, over and above inhibition and updating. This has been supported by Friedman and Miyake

(2017) who reported that the tasks which loaded most highly on the shifting-specific factor were all from task-switching paradigms whereby participants were required to rapidly shift between two tasks according to cues. The studies included in this review only used one task as a measure of the cognitive process of interest and therefore it is difficult to make conclusions around which functions are primarily operating, however all tasks involved shifts between subtasks.

This review only included studies that used objective measures of cognitive shifting/switching performance and excluded studies that used self-report questionnaire measures, such as the Attentional Control Scale (ACS; Derryberry & Reed, 2002). This was due to research indicating that outcomes on self-report measures were not correlating with behavioural performance on analogous cognitive tests (Williams, Rau, Suchy, Thorgusen & Smith, 2017). This suggests that subjective measures of cognition may be capturing a different process and further research is needed to understand what this may be. Only studies reported in English were included in this review and all were conducted in Western countries decreasing the ability to generalise these findings to non-western cultures.

A strength of this review is the comprehensive and transparent search strategy that was used, both in the range of search terms and use of multiple databases. This yielded articles that were appropriate and relevant to answering the review question and led to the refinement of the inclusion and exclusion criteria so that studies included specifically addressed this. This review used an approach that acknowledged both diagnostic and transdiagnostic emotional processes within a continuum and is in line with the research framework encouraged by RDoC.

1.4.6 Implications for Clinical Practice

1.4.6.1 Management of anxiety.

The findings from this review lend support to the incorporation of metacognitive approaches, such as developed by Wells (1995), in clinical settings with those experiencing an enduring pattern of anxious apprehension. If difficulties with cognitive flexibility and switching of attention are indicated as part of a clinical presentation, for example rigid thinking styles and perseveration on certain topics then using tools to help develop this ability, such as attention training techniques, might be a useful addition to psychological interventions.

1.4.6.2 Neuropsychological assessment.

This review also highlights the potential link between anxiety and performance on neuropsychological assessments of executive function and therefore results should be interpreted in line with this in clinical settings. The use of a validated measure of trait and state anxiety when conducting neuropsychological assessments could help with the interpretation of patterns of results particularly related to executive function tasks requiring speed, as the findings here indicate an association with anxiety and processing efficiency deficits more than performance accuracy.

1.4.7 Recommendations for Future Research

Future research should aim to build on the work by Miyake et al. (2000) exploring whether other objective cognitive measures are associated more highly with some underlying cognitive process compared to others. More research using validated measures of worry and standardised tests of cognitive flexibility is needed to investigate the relationship between worry and components of cognitive flexibility, as the findings from this review appeared mixed. In particular, findings from this review suggest more research using participants who span the spectrum of pathological and non-pathological

worry and both objective and subjective measures of shifting/switching ability and comparing outcomes with those of a non-anxious control group so that this relationship may become clearer. Future reviews in this area should consider using longitudinal designs to help determine whether deficits in shifting/switching ability might predispose someone to developing high levels of anxiety. Randomised controlled research designs where anxiety is induced and the impact on cognitive shifting/switching ability is assessed might provide directional evidence in understanding the relationship between anxiety and cognitive flexibility.

1.4.8 Conclusion

In conclusion, this review aimed to understand the relationship between non-pathological and pathological general anxiety and the cognitive shifting/switching function. In general, findings suggest that increased anxiety is related to decreased shifting ability, particularly decreased processing efficiency on switching tasks rather than performance accuracy. These findings lend support to Attentional Control Theory (ACT; Derakshan and Eysenck, 2009; Eysenck et al. 2007; Eysenck and Derakshan, 2011), which outlines the detrimental impact anxiety has on the shifting function of executive control. When the relationship between worry and shifting/switching was explored the findings were more mixed and indicated a possibility that pathological worry may be more associated with deficits in shifting/switching compared to non-pathological worry. More research is needed in this area to explore the relationship between worry and shifting/switching using standardised measures and participants who span the spectrum of pathological and non-pathological worry, however findings from this review appear to also lend support to Hirsch and Matthews (2012) Cognitive Model of Pathological Worry. The variation in how cognitive processes are described and measured, along with previous mixed findings relating to which cognitive processes relate most highly with

which task, means a synthesis of research in this area is difficult. This review lends support to a growing body of literature identifying the role of EF's, and in particular shifting/switching ability, in psychological processes underlying psychopathology.

Chapter 2: Examining the role of cognitive flexibility in worry and intolerance of uncertainty

2.1 Introduction

Within the clinical psychology literature there has been a move towards dimensional, rather than categorical approaches to researching psychopathology, reflected by the development of the Research Domain Criteria (RDoC) framework (Cuthbert & Kozak, 2013; Insel & Cuthbert, 2015; Insel, Cuthbert, Garvey, Heinssen, Pine, Quinn et al. 2010). This has encouraged the study of transdiagnostic constructs to help integrate findings from psychological and biological research to progress our understanding of the aetiology, maintenance, treatment and prevention of psychopathology (Sharp, Miller & Heller, 2015). Two transdiagnostic domains proposed within the RDoC Matrix are the 'Negative Valence Systems' (within which Potential Threat "Anxiety" and Acute Threat "Fear" are included as constructs) and 'Cognitive Systems' (including Cognitive Control as a construct).

2.1.1 Anxious Apprehension

Anxious apprehension and anxious arousal have been identified as two distinct trait dimensions of anxiety (Engels et al. 2010; Nitschke, Heller, Imig, McDonald & Miller, 2001; Nitschke, Heller, Palmieri & Miller, 1999) separate from acute state anxiety (Sharp et al. 2015). Anxious apprehension is associated with an enduring tendency to engage in cognitive worry, a form of repetitive negative thinking, and anxious arousal has been characterised by a persistent pattern of hyperarousal of physical anxiety symptoms and hypervigilance (Nitschke et al. 1999). Anxious apprehension or trait worry has been described as a "chain of thoughts and images, negatively affect-laden and relatively uncontrollable" (Borkovec, Robinson, Pruzinsky & DePree, 1983, p.10). State

worry is a common experience and has been found to be associated with an adaptive, problem-focused coping strategy (Davey, Hampton, Farrell & Davidson, 1992). Worry regularly occurring at excessive, seemingly uncontrollable and distressing levels (anxious apprehension) is associated with various forms of psychopathology (Davey & Meeten, 2016) and is a defining feature of generalised anxiety disorder (GAD) (DSM-5, American Psychiatric Association, 2013).

2.1.2 Intolerance of Uncertainty

Intolerance of uncertainty (IU) has been proposed as one model to account for the development and maintenance of worry episodes (Dugas, Letarte, Rhéaume, Freeston, & Ladouceur, 1995; Dugas, Schwartz & Francis, 2004; Koerner & Dugas, 2006; Meeten, Dash, Scarlet & Davey, 2012). It is a transdiagnostic process associated with the tendency to respond to situations involving uncertainty and ambiguity with distress and avoidance irrespective of probability and outcomes (Dugas et al. 2005). This construct has been shown to be present across a range of anxiety conditions including GAD and obsessive-compulsive disorder (Gentes & Ruscio, 2011), social anxiety (Boelen & Reijntjes, 2009), and panic (Carleton et al. 2014). Research has also demonstrated elevated levels of IU in depression (Gentes & Ruscio, 2011), eating disorders (Brown et al. 2017) and psychosis (White & Gumley, 2010) and has been suggested as a core cognitive vulnerability in the development of anxiety and depression (Hong & Cheung, 2015).

IU has been explored in non-clinical samples and has been suggested to play a causal role in the development of worry (Ladouceur, Gosselin & Dugas, 2000). In this study tolerance of uncertainty was manipulated between two groups taking part in a gambling task. They found that the group of participants who were told several times that their chances of winning were unacceptable had significantly higher levels of self-

reported worry regarding the outcome of the gambling task compared to the group who were told their chances of winning were high. Authors concluded that an increase in intolerance of uncertainty was associated with new worries about an outcome which was previously not known to the participants. It is not possible to conclude from this study that IU precedes the appearance of worry, however it does provide some evidence that an increase in IU is associated with an increase in worry. This study had limitations in that level of worry was measured using only three questions adapted from the Penn State Worry Questionnaire (PSWQ; Meyer, Miller, Metzer & Borkovec, 1990) and was therefore not a validated measure of worry. Similarly, IU was measured using six questions adapted from the Intolerance of Uncertainty Scale (IUS; Freeston, Rhéaume, Letarte, Dugas, & Ladouceur, 1994) and so was not a validated measure of IU. Additionally, level of worry and IU was not measured prior to completing the task and therefore it is not known whether the groups had pre-existing differences in their level of worry or IU.

The mechanisms by which IU might increase the risk of these disorders are unclear (Tanovic, Gee & Joorman, 2018). The Uncertainty and Anticipation Model of Anxiety (UAMA) proposed by Grupe and Nitsche (2013) outlines the link between IU and anxiety. This identifies five interacting psychological processes explaining how excessive anxiety may result from uncertainty, with each process resulting from a once adaptive way of responding to potential threat. These include increased attention to threat, deficient safety learning, behavioural and cognitive avoidance, heightened reactivity to threat uncertainty, and an increased estimate of the probability and adversity of an uncertain event. These processes have been argued to have underlying corresponding neurophysiological pathways (Grupe & Nitsche, 2013). The UAMA model has been supported in part by a study by Lieberman, Gorka, Sarapas and Shankman (2016) who

found a relationship between intolerance of uncertainty and deficient safety learning in individuals with panic disorder and found that this relationship was mediated specifically by cognitive flexibility, measured using switching conditions on verbal and design fluency tasks. It has been suggested for future research to aim to further understand the connections between the cognitive correlates that may underpin IU and psychopathology (Shihata, McEvoy, Mullan & Carleton, 2016), of which cognitive flexibility may be one.

2.1.3 Cognitive Models of Anxious Apprehension

Two theories have outlined the link between cognitive processes and pathological worry. Firstly, Hirsch and Matthew's (2012) cognitive model of worry conceptualises the interaction of unconscious emotional processing biases (threat representations) and impairment of voluntary attentional control, including the ability to ignore distracting information and to shift attention from one topic to another, in increasing the likelihood of developing and maintaining pathological worry. It has been argued that the role of attentional control in relation to worry and anxiety has not been investigated as comprehensively as other components of the model such as biased informational processing (Fox, Dutton, Yates, Georgiou & Mouchlianitis, 2015).

The relationship between impairments in attentional control and worry is also a key component of Attentional Control Theory (ACT; Derakshan & Eysenck, 2009; Eysenck et al. 2007; Eysenck & Derakshan, 2011). According to ACT, trait anxiety and worry interrupt 'top-down' goal-directed attentional control and increases the influence of a stimulus driven, 'bottom-up' attentional system. Attentional resources are allocated widely if the individual perceives a threat, impacting on the efficiency of cognitive performance. This model highlights the impact anxiety will have on specific cognitive functions of shifting and inhibition, as these are directly related to executive control

(Eysenck & Derakshan, 2011). One of the commonalities between both cognitive models is the role of cognitive flexibility or shifting/switching of attention, in pathological worry.

2.1.4 Cognitive Flexibility

Cognitive flexibility is a property of executive functioning (EF) and has been described and operationalised in the research literature in a number of different ways (Ionescu, 2012). It has frequently been described in the context of specific cognitive processes, such as attention switching and shifting of mental sets (Dajani & Udin, 2015) and is often used interchangeably with set/task switching abilities (Morris & Mansell, 2018; Sharp, Miller & Heller, 2015). Others have referred to cognitive flexibility in the context of behavioural abilities such as the quick and efficient adaptation of behaviours according to changing environmental demands (e.g., Ionescu, 2012). Research exploring the neural components of cognitive flexibility has identified activation of the executive control and salience networks as being key neural networks underpinning cognitive flexibility (Dajani & Uddin, 2015).

Cognitive flexibility has been operationalised by the tasks that have been used to measure it, such as the Wisconsin Cart Sorting Test (WCST; Berg, 1948; Grant & Berg, 1948; Heaton, Chelune, Talley, Kay & Curtiss, 1993), the Stroop Test and the Alternative Uses Task (Ionescu, 2012). A hierarchy of complexity has been argued to exist within the construct of cognitive flexibility with set-shifting being the lower-level form and task-switching being the most complex form (Bunge & Zelazo, 2006). Cognitive flexibility has also been measured using self-report instruments such as the Cognitive Flexibility Inventory (CFI; Dennis & Vander Wal, 2010) and the Cognitive Flexibility Scale (CFS; Martin & Rubin, 1995). These have been developed to assess different aspects of cognitive flexibility in everyday settings, such as responses to difficult thoughts and emotions and in social communication and decision making (Johnco, Wuthrich & Rapee,

2014). Several studies have found a poor relationship between behavioural and self-report measures of cognitive flexibility suggesting the possibility of different processes being captured by each (Carly, Wuthrich & Rapee, 2014; Lounes, Khan & Tchanturia, 2011; Williams, Rau, Suchy, Thorgusen & Smith, 2017).

Eslinger and Grattan (1993) identified two forms of cognitive flexibility; spontaneous and reactive. According to them, spontaneous flexibility refers to the ability to produce alternative ideas in response to a question or problem. Reactive flexibility relates to the ability to "freely shift cognition and behaviour according to the particular demands and context of a situation" (Eslinger & Grattan, 1993, p18) and the WCST was described as a widely used assessment of this type of reactive cognitive flexibility.

Cognitive flexibility has been suggested to facilitate problem solving through the generation of alternative interpretations of the problem along with possible solutions, as well as adapting and switching responses based on incoming information (Krems, 1995). Reduced cognitive flexibility has been associated with a range of anxiety disorders including GAD (Hazlett-Stevens, 2001; Lee & Orsillo, 2014; Matthews & Macleod, 1985), Obsessive Compulsive Disorder (OCD) (de Lima Muller, Torquato, Manfro & Trentini, 2015), panic (Lieberman, Gorka, Sarapas & Shankman, 2016) and social anxiety (Fujii et al. 2013). In contrast, increased cognitive flexibility has been reported to be associated with higher resilience to negative life events and stress in adulthood (Genet & Siemer, 2011).

2.1.5 Anxious Apprehension and Cognitive Flexibility

Research investigating the relationship between anxious apprehension, worry and cognitive flexibility measured by switching/shifting paradigms, have shown mixed findings. For example, a study looking at the relationship between shifting performance and trait anxiety found higher levels of trait anxiety associated with poorer efficiency on

the WCST, in those reporting that the WCST required higher effort (Edwards, Edwards & Lyvers, 2015). In support, Tempesta et al. (2013) found increased errors on the WCST in those meeting criteria for GAD compared to non-anxious controls. Deficits in set-shifting, as measured by latency scores on a switching task, have also been found to predict future elevated GAD diagnosis 9 years later (Zainal & Newman, 2018a). In contrast, Whitmer and Banich (2007) found no association between severity of worry, as measured by the PSWQ, and performance on a set-switching task. Furthermore, Gulpers, Lugtenburg, Zuidersma, Verhey, and Voshaar (2018) found GAD to be associated with poor executive functioning as measured by the Ruff figural fluency test, however this relationship was fully explained by co-morbid depressive symptoms.

A review by Sharp et al. (2015) reported that anxious apprehension seemed to correlate more with shifting impairments, whereas anxious arousal was more closely associated with deficits in inhibition and updating. These authors hypothesised that executive inflexibility, such as impairment in shifting, could be an important component of anxious apprehension, in addition to a stable pattern of worry, and suggests future research should try and clarify the interactions between anxious apprehension, worry and executive inflexibility. This may help to inform treatment strategies for individuals with different profiles of anxiety dimensions and executive function deficits (Sharp et al. 2015).

2.1.6 The Present Study

In consideration of the aforementioned, the present web-based study aimed to investigate the relationships between different facets of cognitive flexibility, worry and intolerance of uncertainty in an analogue sample. The purpose of this study is to explore the relationships between cognitive flexibility, worry, intolerance of uncertainty and anxiety using measures reflecting trait processes and by using a task which captures these

processes in the moment (state). To date, this is the first study to explore the relationship between cognitive flexibility and intolerance of uncertainty using a combination of a neuropsychological and self-report measure of cognitive flexibility.

2.1.7 Hypotheses

1. We expect to replicate established positive relationships between intolerance of uncertainty, worry and anxiety.

Furthermore, we expect to find:

2. Higher levels of worry will be more strongly associated with a larger number of consequences generated on the negative tree task but not with the positive tree task. This is based on predictions from Hirsch and Matthews (2012) cognitive model of worry which suggests that those with high levels of worry will attend more to situations with potential threat and will have greater difficulty shifting their attention away towards a neutral or positive topic, leading to worry being maintained.

In line with the hypotheses of Attentional Control Theory (ACT) that anxiety is associated with impaired shifting/switching ability and that anxiety will impair processing efficiency to a greater extent than performance accuracy it is predicted that:

3. A higher number of perseverative errors on the WCST will be associated with higher levels of intolerance of uncertainty, worry and generalised anxiety.

4. Higher reported general anxiety symptoms will be related to impaired processing efficiency but not performance effectiveness on the WCST.

5. Lower cognitive flexibility, as indicated by a higher number of perseverative errors on the WCST, will be related to a higher number of consequences generated on the negative tree task. This is based on Hirsch and Matthews (2012) cognitive model of worry which states that impaired attentional control such as shifting ability, maintains worry.

6. Increased cognitive flexibility will be associated with reduced anxiety and uncertainty after generating consequences on the tree tasks.

2.2 Method

2.2.1 Ethics

The Ethics and Research Governance Online (ERGO II) office at the University of Southampton granted ethical approval for the current study (Ergo Number 45863; Appendix I). All participants were given information regarding the content of the study prior to agreeing to take part (Appendix J) and were asked to indicate their consent by ticking an onscreen box. Participants were informed of their right to withdraw at any time during the study and their data could be removed by providing the researchers with their unique study ID. A debrief statement was shown to each participant at the end of the study (Appendix K) and to participants who did not meet inclusion criteria (Appendix L).

2.2.2 Design

This study used a cross-sectional web-based design with each participant taking part in one online study session. Outcome variables were performance on the WCST, self-report questionnaire measures of cognitive flexibility, intolerance of uncertainty, worry, general anxiety and low mood. Numbers of possibilities generated on the positive and negative tree tasks were also used as dependent variables, along with ratings of anxiety upon completion of each tree task, feeling of uncertainty about the event and vividness of the imagined event. Performance variables which were used from the WCST were total number of errors, total number of perseverative errors, percentage perseverative errors, failure to maintain set, processing efficiency, performance effectiveness and switch cost.

2.2.3 Sample Size Calculation

A sample size of n=153 was indicated to be needed to have the power to detect an effect size of r=0.20 (80% power, a=0.05). This was informed by a meta-analysis carried out by Zetsche, Bürkner and Schulze (2018) who found an overall correlation of r=0.20

when looking at the relationship between cognitive control (an indicator of cognitive flexibility) and repetitive negative thinking, including rumination and worry.

2.2.4 Participants

A total of *n*=119 participants signed up to take part in the study. To meet inclusion criteria, participants were required to speak fluent English and to be aged between 18-65 years. Participants completed a suitability check prior to completing the study to screen for inclusion and exclusion criteria. Participants were excluded from taking part in the study if they indicated they were currently taking prescribed medication for a mental health difficulty or accessing mental health services. Participants were also asked to indicate whether they had a history of any neurological disorder or head injury, including concussion, or had consumed an illicit substance in the previous week or 15 units or more of alcohol in the previous 24 hours. Based on this exclusion criteria, *n*=15 participants who signed up to take part in the study were automatically excluded. A further *n*=44 participants signed up to the study but dropped out at the point before completing the WCST. A final *n*=60 participants took part in the study. One participant was unable to complete the WCST and one participant did not complete the tree task.

2.2.4.1 Demographic characteristics of participants.

Demographic characteristics of participants in this study are displayed in Table 4. There were similar numbers of male and female participants who took part in the study with a mean age of 29.53 years (*SD* = 10.82) with a range of 18-64 years. The majority of participants identified themselves as White British (65%). There was a range of educational attainment reported with the most common being an undergraduate degree (30%), a Master's degree (28%) and completion of A-Levels (27%). The majority of participants were in full-time employment (65%) or students (22%).

Table 4
Demographic Characteristics of Study Participants

Demographic		Total	%
Total	*N*	60	-
Age (years)	Mean	29.53	-
	SD	10.82	-
	Median	27	-
	Range	46	-
	Minimum	18	-
	Maximum	64	-
Gender	Male	29	48
	Female	31	52
Ethnicity	White British	39	65
	American	3	5
	Mixed White	3	5
	Any Other White Background	3	5
	Black Caribbean	1	2
	White and Black Caribbean	1	2
	Black African	1	2
	White and Black African	1	2
	White and Asian	2	3
	Indian	4	7
	Any Other	1	2
	Prefer Not to Say	1	2
Educational Attainment	CGSE	4	7
	A Level	16	27
	Higher	4	7
	Undergraduate Degree	18	30
	Masters	17	28
	Doctorate	0	0
	None	1	2
Employment Status	Employed Full-Time	39	65
	Employed Part-Time	7	12
	Student	13	22
	Retired	1	2

Notes: Higher = Tertiary education at non-degree level.

2.2.5 Outcomes

Both a neuropsychological and self-report measure of cognitive flexibility were included in this study based on previous evidence highlighting a poor associationed between self-reported and neuropsychological measures of cognitive flexibility (Carly, Wuthrich & Rapee, 2014; Lounes, Khan & Tchanturia, 2011; Williams, Rau, Suchy, Thorgusen & Smith, 2017). This enabled further exploration of the relationship between these two constructs.

2.2.5.1 Neuropsychological measure.

2.2.5.1.1 Computerised Wisconsin Card Sort Test (WCST; based on Grant and Berg, 1948).

The Wisconsin Card Sorting Test (WCST; Berg, 1948; Grant & Berg, 1948; Heaton, Chelune, Talley, Kay & Curtiss, 1993) is a popular measure used to assess cognitive flexibility (Diamond, 2013; Lange, Seer, Müller-Vahl & Kopp, 2017). A review of factor analytic studies of the standard 128-card version administered manually have shown good construct validity providing evidence supporting a three-factor structure underlying performance on the WCST (Greve, Stickle, Love, Bianchini & Stanford, 2005). These processes have been identified as cognitive flexibility, problem solving and response maintenance, with this three-factor solution explaining 99.1% of the total variance in performance in traumatic brain injury patients (Greve, Love, Sherwin & Mathias, 2002). Research has provided support for the equivalence of the manual and computer versions of the standard 128-card WCST (Fortuny & Heaton 1996; Shan, Chen, Lee & Su, 2008; Wagner & Trentini, 2009).

Participants were asked to complete a computerised version of the WCST using the Inquisit 5 Web platform (Inquisit, 2016). This required participants to download and run Inquisit 5 Web software to the device they were using to take part in the study. The

computerised version of the WCST requires participants to sort a maximum of 128 response cards, presented individually, to one of four decks based upon one of three rules (sort by colour, number of figures, or shape of figures). These four decks have a different design on each; one red triangle, two green stars, three yellow crosses and four blue circles (see Appendix B for schematic). No instructions are provided to participants to indicate the rule for correct categorisation however they are provided with feedback after every response indicating whether the choice was correct or incorrect. Participants can therefore find the correct categorisation rule based on trial and error. Once a participant chooses the correct rule, this sorting principle (set) must be maintained until the rule changes, which happens after every 10 correct consecutive sorts. The task ends when participants have correctly sorted either 6 sets or 128 cards. Outcomes are recorded via Inquisit Web and include latency and accuracy of responses, total number of errors, number and percentage of perseverative errors, number of categories completed, number of failures to maintain set, total number of trials and number of trials needed to complete first category.

The outcomes used in this study include total number of errors, total number of perseverative errors, percentage perseverative errors and failure to maintain set. These outcomes are commonly used in research. Perservative errors reflect a person's inability to shift/switch to a new rule and instead continue using a previous rule. Failure to maintain set is a measure of the number of times a participant makes 5 or more correct consecutive responses but then makes an error before successfully achieving a category (10 consecutive correct sorts) (Heaton et al. 1993) and is argued to reflect distractibility (Figueroa & Youmans, 2013). Processing efficiency, performance effectiveness and switch costs are not included within the standardised WCST manual however have been suggested by Edwards et al. (2015) as useful measures to include. Performance

effectiveness was operationalised as the percentage of responses that were not perseverative and was calculated by Edwards et al. (2015) using the following equation:

Performance Effectiveness =

100% - Percentage of Perseverative Errors

Processing efficiency was put forward as a measure of shifting efficiency that reflected the relationship between accuracy and reaction times (RT) (Edwards et al. 2015). It has been operationalised as the inverse of shifting inefficiency, which was calculated using the following equation:

Processing Efficiency =

$$\left(1 - \left(\frac{\textit{Number of Perseverative Errors}}{\textit{Mean RT on Perseverative Error Trials}}\right)\right) \times 1000$$

Switch cost was operationalised as the mean difference in RT between switching trials and repeat trials (Soveri, Waris & Laine, 2013). A repetition block was identified as 6 or more correct consecutive trials. A switch block was identified as the trials immediately following a rule switch until (and including) the first correct sort at the start of a repetition block. Mean RT were calculated for both repeat and switch blocks. Switch cost was calculated as follows:

Switch Cost =

Repeat block mean RT – Switch Block mean RT

2.2.5.2 Self-report measures.

2.2.5.2.1 Cognitive Flexibility Inventory (CFI; Dennis & Vander Wal, 2010; Copyright).

The Cognitive Flexibility Inventory (CFI) is a brief, 20-item self-report measure designed to assess cognitive flexibility in the context of maladaptive thinking styles when facing difficult experiences (Dennis & Vander Wal, 2010). It has an underlying two-factor structure related to the ability to generate multiple, alternative explanations and solutions in the face of difficult life events (Alternatives subscale), and the propensity to view difficult circumstances as controllable (Control subscale). Both subscales have been shown to have good to excellent internal consistency (α = 0.84 to 0.91). The CFI demonstrates high test-retest reliability for both the total score and subscales (r = 0.75–0.81; $p < 0.001$) and has been shown to have good construct validity based on associations with other measures of cognitive flexibility such as the Cognitive Flexibility Scale (CFS; Martin & Rubin, 1995) and the Attributional Style Questionnaire (ASQ; Peterson, Semmel, Von Baeyer, Abramson, Metalsky & Seligman, 1982).

2.2.5.2.2 The Intolerance of Uncertainty Scale – Short Form (IUS-12; Carleton, Norton & Asmundson, 2007).

The IUS-12 is a 12-item short form of the original 27-item Intolerance of Uncertainty Scale (IUS; Freeston, Rhéaume, Letarte, Dugas, & Ladouceur, 1994). This scale was designed to measure responses towards uncertainty, ambiguous situations and future events (Carleton, Norton et al. 2007). The IUS-12 has been shown to correlate highly with the original IUS (r = 0.94 – 0.96; Carleton, Norton et al, 2007; Khawaja & Yu, 2010). The IUS-12 has an underlying two factor structure consisting of prospective IU (cognitive dimension) and inhibitory IU (behavioural dimension), both demonstrating high internal consistencies (α = 0.85; Carleton et al. 2007). The IUS-12 has excellent internal consistency and convergent validity with the original (Carleton, Norton et al. 2007; Carleton, Sharpe & Asmundson, 2007).

2.2.5.2.3 The Penn State Worry Questionnaire (PSWQ; Meyer, Miller, Metzger & Borkovec, 1990; Appendix M).

The PSWQ is a widely used 16-item self-report measure of trait worry. Worry-related statements are rated on a Likert scale ranging from 1 ("not at all typical of me") to 5 ("very typical of me") with higher scores reflecting greater levels of pathological worry. It has been shown to have very good internal consistency (α = 0.86 to 0.93; Brown, Antony & Barlow, 1992) and good test-retest reliability (r's = 0.74 to 0.93; Meyer et al. 1990).

2.2.5.2.4 The Generalised Anxiety Disorder Questionnaire (GAD-7; Spitzer, Kroenke, Williams & Löwe, 2006).

The GAD-7 is a brief 7-item self-report anxiety scale commonly used as a screening tool to assess for symptoms of GAD with higher scores indicating greater severity of GAD symptoms. Items are scored on a Likert scale indicating presence of symptoms over the past two weeks ranging from 0 ("not at all") to 3 ("nearly every day"). Total scores range from 0 to 21. The GAD-7 has been shown to have excellent internal consistency (α = 0.92) and good test-retest reliability (intraclass correlation = 0.83) (Spitzer et al. 2006). It has also demonstrated good convergent validity with other anxiety measures such as the Beck Anxiety Inventory (r = 0.72) and the anxiety subscale of the Symptom Checklist-90 (r = 0.74) (Spitzer et al. 2006).

2.2.5.2.5 The Patient Health Questionnaire (PHQ-9; Spitzer, Williams & Kroenke, 1999).

The PHQ-9 is a 9-item self-report screening tool for the presence and severity of depression symptoms. Items are scored on a Likert scale indicating presence of symptoms over the past two weeks ranging from 0 ("not at all") to 3 ("nearly every day"). Total scores range from 0 to 20 with higher scores indicating greater severity of

depression symptoms. The PHQ-9 has been shown to have excellent internal reliability (α = 0.86 to 0.89) and test-retest reliability (*r* = 0.84) (Kroenke, Spitzer & Williams, 2001).

Low mood was measured in order to control for the possible impact of depressive symptoms on worry and uncertainty. This was informed by previous research indicating a strong overlap between anxiety and depressive symptoms particularly cognitive processes of repetitive negative thinking (Madian, Bredemeier, Heller, Miller & Warren, 2018).

2.2.5.3 Demographic information.

Demographic information was collected from participants regarding their age, identified gender and ethnicity, employment status and highest education achieved at the point of taking part in the study.

2.2.5.4 Tree task.

This study used a modified version of the Vertical Arrow Technique (VAT) Procedure used by Mosca, Lauriola and Carleton (2016) (see Appendix N). In the current study, the self-administered 'tree task' was used to capture an individual's thought process while they considered both a negative and positive idiosyncratic life event that might occur in the future (Tree Task; Appendix O). Participants were required to generate potential consequences that could occur from each event in turn in a 'downward arrow' style. This task could be argued to capture state spontaneous flexibility along with worry cognitions and state uncertainty surrounding both positively and negatively valanced cognitions.

2.2.6 Procedure

Participants were a self-selected sample from the general population and were informed of how to opt in to take part in the study via advertising notices placed on social

networking platforms of Facebook, Instagram, and FindParticipants.com. Participants were also recruited via The University of Southampton's online research dashboard (eFolio) and through advertising notices were placed around university campus.

The study was hosted on LifeGuide Online, a web-based platform developed by The University of Southampton (Yardley et al. 2009). Prior to taking part, participants were asked to generate their own unique 5-character study ID by using the first letter of their middle name, first letter of their street name, and last three digits of their phone number. This was to ensure participants' data were kept anonymous and that response data held in LifeGuide and Inquisit could be matched together. Participants were given information regarding the purpose of the study prior to indicating consent to take part (see Appendix J). The study was estimated to take no longer than 1.5 hours to complete and participants were informed that they should be in a quiet area with minimal distractions while completing the study.

Participants were first asked to complete a computerised version of the WCST via Inquisit 5 Web before being directed back to LifeGuide to complete the CFI, IUS-12, PSWQ, GAD-7 and PHQ-9 questionnaires. Participants were then asked to take part in the tree tasks which asked participants to generate possible outcomes related to two future events thought up by each participant. Participants were asked to imagine two idiosyncratic future events or scenarios, one positive and one negative, and to describe any possible outcomes that could happen from these. The order in which either the negative or positive event was presented first was counterbalanced to control for possible influences of one scenario on the other. There was no time limit to complete the task (instructions given to participants are shown in Appendix P). Participants' imagined event was kept written at the top of each page whilst generating consequences, to help keep responses focused to that event. After each possible consequence was written, participants

were asked consecutively whether any further possibilities could occur or not. If they indicated a further consequence could happen, they were asked to briefly describe this and to continue stating whether further possibilities until they indicated that no further consequences could happen, at which point the task would end. Upon completion of each task, participants were presented with a series of Visual Analogue Scales (VAS) from 0-10 (0 = least, 10 = highest), and were asked to provide ratings for the vividness of their imagined event, their feeling of uncertainty around the event and their current feeling of anxiety (see Appendix Q).

Participants were guided through a brief grounding exercise script after completing each tree task and rating scales to reduce the possible impact the first task might have had on the second. This was accompanied by a re-rating of participants' current state anxiety on an additional VAS from 0-10 (Appendix R). After participants had completed each tree task, rating scales, grounding scripts and had re-rated their state anxiety for both the positive and negative tree tasks they were presented with a debriefing statement outlining the purpose of the study and providing information for how to access support (see Appendix K). Instructions on how to remove the Inquisit 5 Web software from their devices were then shown (Appendix S).

Instructions for how to sign up to a prize draw to win one of three cash vouchers was included in the debrief statement. To sign up for the prize draw, participants were given a numerical code generated by LifeGuide on the debrief page along with a link to an iSurvey questionnaire. Participants were asked in the iSurvey questionnaire to provide an email address and to state whether they were a University of Southampton Psychology undergraduate study to claim 12 course credits. The code generated in LifeGuide was to ensure only participants who had completed the study were included in the prize draw.

2.3 Results

2.3.1 Key Findings in Relation to Hypotheses

1. Established positive relationships between IU, worry and anxiety were replicated as expected.
2. Higher general anxiety, rather than worry as predicted, was associated with more consequences generated on the negative tree task but not with the positive tree task.
3. A higher number of perseverative errors made on the WCST (an indicator of reduced cognitive flexibility), was associated with higher intolerance of uncertainty, but not worry or general anxiety as predicted.
4. Higher intolerance of uncertainty, rather than general anxiety which was predicted, was associated with reduced processing efficiency on the WCST. General anxiety was unrelated to performance effectiveness (an indicator of accuracy).
5. Cognitive flexibility, as indicated by performance on the WCST, was not associated with the number of consequences generated from future uncertain events.
6. Higher self-reported cognitive flexibility, rather than cognitive flexibility as indicated by the WCST as expected, was associated with lower anxiety after generating consequences from uncertain future events. Both measures of cognitive flexibility were unrelated to the uncertainty felt about these future events.

2.3.2 Characteristics of Outcome Measures

2.3.2.1 Characteristics of self-report questionnaires.

Table 5 reports the outcomes from the questionnaire measures used. Scores of self-reported cognitive flexibility (*M* = 109.38, *SD* = 15.36; CFI) and intolerance of uncertainty (*M* = 26.38, *SD* = 7.73; IUS-12) were comparable to those reported in non-clinical samples (Carleton, Norton & Asmundson, 2007; Dennis & Vander Wal, 2010). Scores for worry (*M* = 40.40, *SD* = 7.74; PSWQ) were slightly lower than those reported

in other non-clinical samples (*M* = 48.8, *SD* = 13.8; Meyer et al. 1990) and the overall mean fell just within the 'moderate' range for worry ('moderate' worry = 40-59/80; Meyer et al. 1990). Mean scores for anxiety (*M* = 4.07, *SD* = 3.21; GAD-7) and low mood (*M* = 4.87, *SD* = 4.54; PHQ-9) both fell within the 'non-clinical' range (Spitzer et al. 1999).

Table. 5
Characteristics of Self-Report Questionnaires

Measure	Subscale	Mean	SD	Median	IQR	Min-Max	α	K-S Test	*p*
CFI	*Alternatives*	73.77	10.04	76.50	13.00	48-90	.904	.126	.018
	Control	35.62	8.21	36.50	13.00	15-48	.900	.087	.200
	Total	109.38	15.36	110.00	26.00	74-137	.909	.092	.200
IUS-12	*Prospective*	17.13	5.25	16.50	8.00	8-28	.805	.091	.200
	Inhibition	9.25	3.50	9.00	5.00	5-18	.813	.123	.024
	Total	26.38	7.73	25.50	13.00	15-42	.857	.107	.085
PSWQ*	*Total*	40.40	7.74	38.50	10.75	24-58	.718	.122	.027
GAD7	*Total*	4.07	3.21	4.00	5.00	0-13	.732	.170	.000
PHQ9	*Total*	4.87	4.54	3.50	4.00	0-20	.840	.226	.000

Notes: N=59. *PSWQ – deletion of item 10 improved internal consistency from .594 to .718
Abbreviations: K-S = Kolmogorov-Smirnov Test; CFI = Cognitive Flexibility Inventory; IUS-12 = Intolerance of Uncertainty Scale Short Form; PSWQ = Penn State Worry Questionnaire; GAD7 = Generalised Anxiety Disorder Assessment-7; PHQ9 = Patient Health Questionnaire-9.

An independent samples t-test was run to determine if there were gender differences in outcomes on self-reported measures. No significant differences ($p > .05$) were found between men and women on scores of self-reported cognitive flexibility, intolerance of uncertainty, worry, general anxiety and low mood (not reported).

2.3.2.1.1 Data diagnostics and assumption checking.

The PSWQ was initially shown to have 'poor' internal consistency, determined by a Cronbach's alpha of 0.594. Deletion of item 10 from the measure improved internal consistency to $\alpha = 0.718$. All other questionnaires used were shown to have good internal

consistency (see Table 2). Subscales of the IUS-12 and CFI, along with the PSWQ, GAD-7 and PHQ-9 appeared to be non-normally distributed, as assessed by Kolmogorov-Smirnov's test, and visual inspection of histograms and boxplots (Appendix T.1). This indicated the more appropriate use of non-parametric tests within the analysis. The self-report measures generally had a skewed distribution however this was expected due to the use of a non-clinical sample. Visual inspection of boxplots showed one extreme outlier on the PHQ-9 with a z score of 3.33, falling above the recommended cut-off z = 3.20 (Tabachnik & Fidell, 2007), and therefore this was excluded from analysis.

2.3.2.2 Characteristics of tree task.

Fifty-nine participants completed both the positive and negative tree tasks. Table 6 outlines the characteristics of outcomes on these tasks. Participants tended to generate a higher number of consequences from a positive scenario (*Mdn* = 5, IQR = 4) compared to a negative one (*Mdn* = 3, IQR = 3). A Wilcoxon Signed-Ranks Test indicated that the number of consequences on the positive scenario was significantly higher than the number of consequences in the negative scenario ($Z = -4.14$, $p < .000$). Participants also rated the vividness of the imagined positive event as slightly more vivid (*Mdn* = 8, IQR = 2) compared to the negative image (*Mdn* = 7, IOR = 3) (see Table 6). A Wilcoxon Signed-Ranks Test indicated that the level of vividness was significantly higher for the positive event than the negative event ($Z = -2.83$, $p = .005$). After completing the negative tree task, participants generally rated their feeling of anxiety (*Mdn* = 5, IQR = 5) and feeling of uncertainty about the event (*Mdn* = 7, IQR = 3) as higher compared to the positive tree task. A Wilcoxon Signed-Ranks Test indicated that the level of anxiety was significantly higher for the negative event than the positive event ($Z = -4.59$, $p < .000$). A Sign Test indicated that level of uncertainty was significantly higher in the negative tree task than the positive tree task ($Z = -3.92$, $p < .000$).

2.3.2.2.1 Data diagnostics and assumption checking.

Outcomes from both tasks appeared to be non-normally distributed, as assessed by Kolmogorov-Smirnov's test, and visual inspection of histograms and boxplots (Appendix T.2). Data tended to be positively skewed and logarithmic transformation did not result in a more normal distribution. This indicated the more appropriate use of non-parametric tests within the analysis.

Table 6
Descriptive Characteristics of Outcomes on Tree Tasks

VAS		Negative Tree			Positive Tree		
Vividness	Median	7			8		
	Min-Max	1-10			1-10		
	IQR	3			2		
Uncertainty	Median	7			4		
	Min-Max	1-10			1-10		
	IQR	3			5		
Anxiety	Median	5			2		
	Min-Max	1-10			1-9		
	IQR	5			3		
Consequence Type		Negative Tree			Positive Tree		
		Negative	Neutral	Positive	Negative	Neutral	Positive
Number of Consequences Generated	Median	3	0	0	0	0	5
	Min-Max	0-14	0-2	0	0-1	0-4	1-14

Notes: N = 59; VAS=Visual Analogue Scale rated from 0-10 (0=lowest, 10=highest)

2.3.2.2.2 Grounding exercise.

A Wilcoxon signed-rank test was conducted to determine the effect of the grounding exercise on level of state anxiety after completing both the positive and negative tree tasks. The difference scores were approximately symmetrically distributed, as assessed by a histogram with a superimposed normal curve. Of the 59 participants who took part in the negative tree task, the grounding exercise elicited a decrease in anxiety in 44 participants, whereas 2 participants reported an increase in anxiety. There was a statistically significant decrease in anxiety after completing the grounding exercise for the negative tree task (*Mdn* = 1 point) with higher anxiety reported before the grounding

exercise (*Mdn* = 5/10) compared to after (*Mdn* = 2/10), z = -4.97, p < .001. Of the 59 participants who completed the positive tree task, 27 reported a decrease in anxiety after being guided through a brief grounding exercise, with 28 reporting no change and 4 reporting an increase in anxiety. There was a statistically significant decrease in anxiety upon completion of the grounding exercise after the positive tree task (*Mdn* = 0 points) with slightly higher anxiety reported before the grounding exercise (*Mdn* = 2/10) compared to after (*Mdn* = 1/10), z = -3.62, p < .001.

2.3.2.3 Characteristics of The Wisconsin Card Sorting Test (WCST).

Fifty-nine participants took part in the web-based WCST. This sample performed comparably with reported normative samples on total number of errors, number and percentage of perseverative errors and failure to maintain set (Heaton et al. 1993) (see Table 7). This sample also performed comparably on processing efficiency and performance effectiveness measures with a non-clinical sample reported by Edwards, Edwards and Lyvers (2015).

Table 7
Descriptive Characteristics of Wisconsin Card Sorting Test (WCST)

Variables	Mean	*SD*	Median	IQR	Min	Max	K-S Test	*p*
Total Error	30.27	20.69	24.00	33.00	8.00	82.00	.181	.000
No. Perseverative Errors	7.03	3.60	6.00	3.00	1.00	21.00	.250	.000
% Perseverative Errors	35.15	21.86	34.21	39.14	1.23	94.44	.117	.043
Failure to Maintain Set	0.83	1.07	.00	2.00	0.00	4.00	.324	.000
Processing Efficiency	995.08	2.75	995.62	4.07	984.93	998.57	.133	.011
Performance Effectiveness	64.85	21.86	65.79	39.14	5.56	98.77	.117	.043
Switch Cost (ms)	697.24	580.38	632.46	606.92	-241.30	2819.54	.147	.003

Notes: N=59; WCST: Wisconsin Card Sorting Test.

2.3.2.3.1 Data diagnostics and assumption checking.

Prior to main analyses, variables were screened for outliers and normality. Univariate outliers were considered significant with *z* scores >3.50. One outlier for number of perseverative errors were identified using this criterion. Visual inspection of the values in box plots confirmed the outlier as realistic for this sample. Analyses were run with this outlier included and excluded and as the pattern of results remained similar, the case was retained. All variables were non-normally distributed and were skewed, as assessed by Kolmogorov-Smirnov's test (see Table 7), and from visual inspection of histograms and boxplots (Appendix T.3). Logarithmic transformation did not result in a more normal distribution therefore non-parametric analyses on untransformed variables, using the full data set was indicated to be appropriate. Total perseverative error and mean RT data were uncorrelated, discounting the possibility of a speed-accuracy confound, $r(59) = -.073$, $p = .581$, *ns*.

2.3.2 Main Analyses

The strength of the relationships reported are interpreted using a rule of thumb outlined by Dancey and Reidy (2007). Correlations between 0.1 and 0.3 are classified as 'weak'; 0.4 and 0.6 as 'moderate'; and 0.7 – 0.9 as 'strong' associations.

2.3.2.1 Associations between self-report measures.

We expected to replicate established positive relationships between intolerance of uncertainty, worry and anxiety.

2.3.2.1.1 Self-Reported cognitive flexibility.

Two-tailed Spearman's rank-order correlations were run to assess the association between self-report measures (see Table 8). Lower self-reported cognitive flexibility was moderately associated with higher worry, and weakly associated with increased generalised anxiety and low mood (see Table 8). There was no evidence of an association

between self-reported cognitive flexibility and intolerance of uncertainty. The tendency to view difficult situations as uncontrollable ('the control' subscale of CFI) was weakly associated with avoidance-orientated responses to uncertainty ('inhibition' subscale of IUS) and moderately associated with worry (see Table 8). There was evidence to show the control subscale of the CFI was weakly associated with higher general anxiety and lower mood.

There was no evidence of an association between viewing situations as uncontrollable and seeking information to reduce uncertainty ('prospective' subscale of IUS) (see Table 8) nor a relationship between the ability to generate multiple solutions to problems (the 'alternatives' subscale of the CFI) and intolerance of uncertainty, worry, general anxiety or low mood (see Table 8).

Table 8
Spearman's Rho Correlations between Self-Report Measures

Measure	1. CFI Control	2. CFI Alt	3. CFI Total	4. IUS Prosp	5. IUS Inhib	6. IUS Total	7. PSWQ	8. GAD7
1. CFI Control	-							
2. CFI Alt	.503**	-						
3. CFI Total	.827**	.886**	-					
4. IUS Prosp	-.088	-.057	-.061	-				
5. IUS Inhib	-.275**	-.176	-.237	.607**	-			
6. IUS Total	-.202	-.128	-.164	.934**	.825**	-		
7. PSWQ	-.569**	-.238	-.419**	.387**	.440**	.476**	-	
8. GAD7	-.396**	-.100	-.261*	.350**	.337**	.382**	.599**	-
9. PHQ9	-.293*	-.185	-.278*	.023	.161	.097	.255*	.456**

Notes: N=59. CFI: Cognitive Flexibility Inventory; IUS: Intolerance of Uncertainty Scale; Prosp: Prospective subscale; Inhib: Inhibitory subscale; PSWQ: Penn State Worry Questionnaire; GAD7: Generalised Anxiety Disorder Assessment-7; PHQ9: Patient Health Questionnaire-9.
*p<0.05; **p<0.01.

2.3.2.1.2 Intolerance of uncertainty.

There was evidence to show intolerance of uncertainty was moderately positively related to worry and weakly associated with general anxiety (see Table 8). The tendency to seek information to reduce uncertainty (the 'prospective' subscale on IUS) was weakly associated with higher worry and general anxiety. Avoidance-orientated responses to uncertainty (the 'inhibition' subscale of IUS) was moderately associated with higher worry and weakly associated with higher general anxiety (see Table 8). There was no evidence of a relationship between intolerance of uncertainty and low mood.

2.3.2.1.3 Worry.

There was evidence of a moderate positive relationship between worry and general anxiety, but level of worry was weakly associated with low mood (see Table 8).

2.3.2.1.4 Generalised anxiety.

There was a moderate positive relationship between general anxiety and low mood (see Table 8).

2.3.2.2 Associations between outcomes on tree tasks.

2.3.2.2.1 Negative tree.

Two-tailed Spearman's rank-order correlations were run to assess the association between outcomes on the positive and negative tree tasks (see Table 9). The total number of negative consequences generated on the tree task was moderately associated with increased uncertainty felt about the event described but not with level of anxiety felt after generating consequences nor vividness of the imagined negative event (see Table 9). The vividness of the imagined negative event was moderately associated with higher anxiety after generating negative consequences, and weakly associated with a higher level of uncertainty felt about the event (see Table 9).

Table 9
Spearman's Rho Correlations within Tree Task

		Negative Tree Task				Positive Tree Task			
	Outcomes	Total	Anx	Uncert	Vivid	Total	Anx	Uncert	Vivid
Negative Tree Task	Total	-							
	Anxiety	.152	-						
	Uncertain	.480**	.142	-					
	Vivid	.124	.528**	.309*	-				
Positive Tree Task	Total	.509**	-.045	.389**	.019	-			
	Anxiety	.083	.334**	.039	.132	.036	-		
	Uncertain	.289*	.283**	.466**	.287*	.158	.424**	-	
	Vivid	-.287*	-.045	-.169	.044	.135	-.082	-.375**	-

Notes: Anx: Anxiety; Uncert: Uncertainty; Vivid: Vividness
*p<0.05; **p<0.01.

2.3.2.2.2 Positive tree.

After generating consequences from an imagined positive event, there was evidence of a moderate positive relationship between the level of uncertainty about the event and anxiety felt after generating consequences. There was a weak association between the uncertainty participants felt about their positive event and the vividness of their event (see Table 9).

2.3.2.2.3 Associations between negative and positive tree tasks.

There was a moderate positive association between number of consequences generated for both negative and positive imagined events. The level of uncertainty felt about both imagined events were moderately related to each other (see Table 9). Higher anxiety after generating negative consequences was weakly associated with higher anxiety and higher uncertainty after generating positive consequences (see Table 9).

2.3.2.3 Associations between questionnaire measures and outcomes on tree tasks.

We hypothesised that increased worry would be associated with more consequences generated on the negative tree task but not with the positive tree task.

2.3.2.3.1 Self-reported cognitive flexibility.

Two-tailed Spearman's rank-order correlations were run to assess the association between self-report measures and outcomes on the tree tasks (see Table 10). An increased tendency to view difficult situations as controllable ('control' CFI subscale) was associated with lower anxiety after generating consequences from both a negative and positive event (see Table 10). Higher overall self-reported cognitive flexibility was also related to lower anxiety after completing both tree tasks (see Table 10). There was no evidence of a relationship between a self-reported ability to generate multiple solutions to problems ('alternatives' CFI subscale), nor reported cognitive flexibility, and the number of consequences generated on both tree tasks.

Table 10
Spearman's Rho Correlations with Tree Task and Self-Report Questionnaires

	Negative Tree Task				Positive Tree Task			
	Total	Anxiety	Uncertainty	Vividness	Total	Anxiety	Uncertainty	Vividness
CFI Control	-.184	-.346**	-.009	.026	.043	-.553**	-.189	.268*
CFI Alt	-.010	-.134	.099	.040	.190	-.213	-.208	.224
CFI Total	-.105	-.276*	.047	.030	.111	-.429**	-.208	.239
IUS Prosp	.147	.248	.163	.206	.206	.280*	.479**	-.071
IUS Inhib	.008	.221	.119	.110	.082	.202	.340**	-.130
IUS Total	.109	.271*	.190	.210	.203	.301*	.497**	-.108
PSWQ	.249	.199	.082	-.072	.090	.317*	.255	-.340**
GAD7	.403**	.381**	.349**	.173	.215	.433**	.332*	-.223
PHQ9	.313*	.434**	.305*	.414**	.025	.335**	.205	-.192

Notes: N=59. CFI: Cognitive Flexibility Inventory; IUS: Intolerance of Uncertainty Scale; Prosp: Prospective subscale; Inhib: Inhibitory subscale; PSWQ: Penn State Worry Questionnaire; GAD7: Generalised Anxiety Disorder Assessment-7; PHQ9: Patient Health Questionnaire-9.
*p<0.05; **p<0.01.

2.3.2.3.2 Intolerance of uncertainty.

Higher intolerance of uncertainty was moderately associated with higher reported uncertainty about an imagined positive event but not for a negative event (see Table 10).

A weak positive relationship was also found between intolerance of uncertainty and anxiety felt about both events (see Table 10).

2.3.2.3.3 Worry.

Decreased worry was weakly related to both lower anxiety after generating consequences from a positive event and to higher vividness of the imagined positive event (see Table 10). There was no evidence of a relationship between worry and the number of consequences generated on both tasks.

2.3.2.3.4 Generalised anxiety.

Higher general anxiety was moderately associated with more consequences produced from an imagined future negative event but not for a positive event (see Table 10). Higher general anxiety was weakly related to increased anxiety and uncertainty after completing both tasks (see Table 10).

2.3.2.3.5 Low mood.

Low mood was moderately positively associated with anxiety and vividness of an imagined future negative event and weakly associated with the number of consequences generated from negative scenarios and uncertainty felt after completing this task. Low mood was weakly related to anxiety felt after imagining consequences from a positive event but there was no evidence of a relationship between low mood and uncertainty, vividness or number of consequences generated from a positive event (see Table 10).

2.3.2.4 Associations between the WCST and questionnaire measures.

We hypothesised that a higher number of perseverative errors would be associated with increased intolerance of uncertainty, worry and general anxiety. It was also thought that higher anxiety would be related to reduced processing efficiency but not performance effectiveness on the WCST.

Two-tailed Spearman's rank-order correlations were run to assess the relationship between performance on the WCST and self-report measures of cognitive flexibility, intolerance of uncertainty, worry, general anxiety and low mood (Table 11). Preliminary analysis showed the relationships to be monotonic, as assessed by visual inspection of scatterplots (Appendix T.4). These patterns of results remained the same when low mood was included as a control variable (Appendix T.5).

Table 11
Spearman's Rho Correlations between Wisconsin Card Sorting Test (WCST) and Self-Report Measures

Variable	CFI Control	CFI Alt	CFI Total	IUS Prosp	IUS Inhib	IUS Total	PSWQ	GAD7	PHQ9
Total Errors	.105	-.157	-.039	.073	.043	.058	.216	.025	-.264*
Total Perseverative Errors	.012	.016	.023	.425**	.187	.383**	.052	-.120	-.080
% Perseverative Errors	-.044	.177	.090	.110	.067	.117	-.159	-.047	.260*
Failure to Maintain Set	-.013	-.090	-.036	.060	.065	.035	.123	.106	-.155
Processing Efficiency	.003	-.116	-.071	-.362**	-.213	-.340**	-.005	.072	-.038
Performance Effectiveness	.044	-.177	-.090	-.110	-.067	-.117	.159	.047	-.260*
Switch Cost	.093	.068	.092	.011	-.077	-.031	-.171	.007	.207

Notes: N=59. WCST: Wisconsin Card Sorting Task; CFI: Cognitive Flexibility Inventory; IUS: Intolerance of Uncertainty Scale; Prosp: Prospective subscale; Inhib: Inhibitory subscale; PSWQ: Penn State Worry Questionnaire; GAD7: Generalised Anxiety Disorder Assessment-7; PHQ9: Patient Health Questionnaire-9.
*p<0.05; **p<0.01.

2.3.2.4.1 Self-reported cognitive flexibility.

Performance indicators reflecting cognitive flexibility on the WCST were unrelated to self-reported cognitive flexibility (see Table 11).

2.3.2.4.2 Intolerance of uncertainty.

Lower cognitive flexibility (indicated by more perseverative errors made on the WCST and reduced processing efficiency) was weakly associated with higher intolerance of uncertainty (Fig.2). In particular, with a higher tendency to seek information to reduce

uncertainty (‘prospective’ IUS subscale) (Fig 3). There was a negligible relationship between cognitive flexibility and avoidance-orientated responses to uncertainty (the ‘inhibition’ IUS subscale). There was no evidence that performance effectiveness or switch cost was associated with intolerance of uncertainty (see Table 11).

Figure 2.
Relationship between the Number of Perseverative Errors made on the Wisconsin Card Sorting Test (WCST) and the Intolerance of Uncertainty Scale (IUS-12)

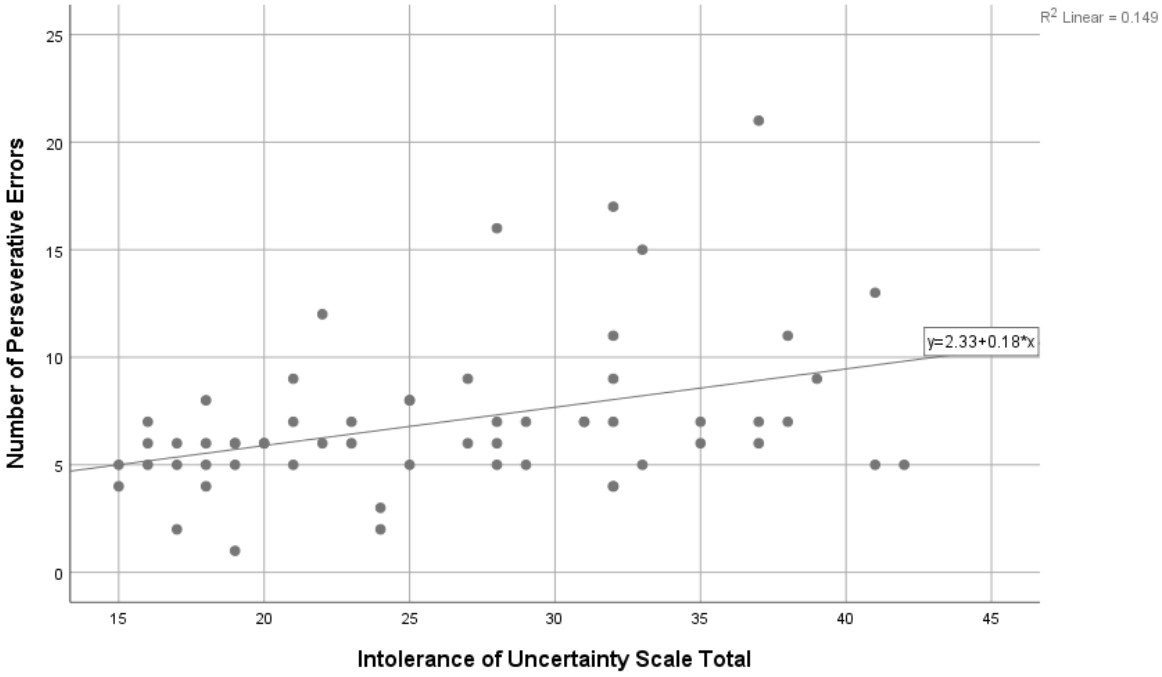
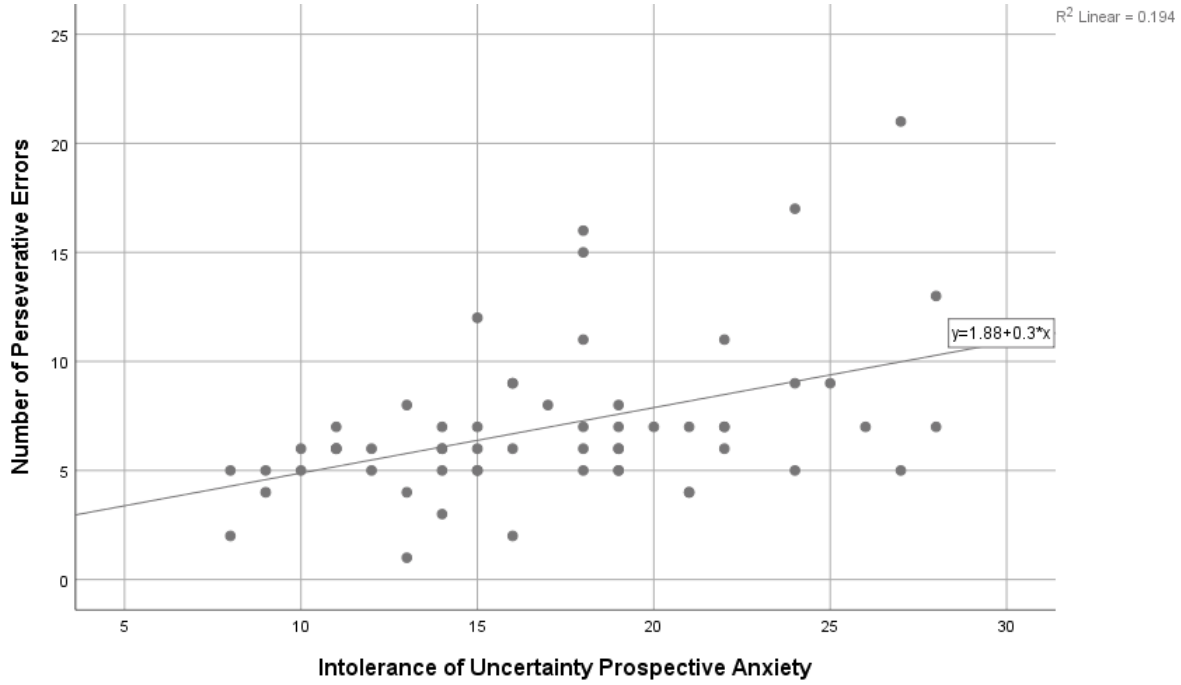


Figure 3.
Relationship between the Number of Perseverative Errors made on the Wisconsin Card Sorting Test (WCST) and the Prospective Anxiety Subscale of the Intolerance of Uncertainty Scale (IUS-12).



2.3.2.4.3 Worry.

There was no evidence of a relationship between cognitive flexibility, as indicated by performance on the WCST, and worry (see Table 11).

2.3.2.4.4 Generalised Anxiety.

There was no evidence of a relationship between cognitive flexibility and general anxiety (see Table 11). In particular, general anxiety was not related to performance effectiveness or processing efficiency on the WCST (see Table 11).

2.3.2.4.5 Low Mood.

Decreased mood was weakly associated with a higher percentage of perseverative errors (an indicator of cognitive inflexibility), and lower performance accuracy (reflected by a higher number of errors and reduced performance effectiveness) (see Table 11).

2.3.2.5 Associations between the WCST and outcomes on tree tasks.

It was hypothesised that a higher number of perseverative errors (reflecting reduced cognitive flexibility), would be related to more consequences being generated from a negative future scenario and higher anxiety and uncertainty felt after completing this task. Two-tailed Spearman's rank-order correlations were run to assess the relationship between performance indicators on the WCST and outcomes from the tree tasks (see Table 12).

2.3.2.5.1 Failure to maintain set.

A higher number of failures to maintain set (an indicator of distractibility) was weakly associated with lower rated anxiety after generating consequences from a negative future event and a lower rated vividness of this negative event (see Table 12). There was no evidence that behavioural cognitive flexibility was associated with the number of consequences generated when thinking of uncertain future events (see Table 12).

Table 12
Associations with Wisconsin Card Sorting Test (WCST) and Tree Tasks

	Negative Tree Task				Positive Tree Task			
	Total	Anx	Uncert	Vivid	Total	Anx	Uncert	Vivid
Total Errors	-.181	-.217	-.183	-.213	-.077	-.169	-.160	.056
No. Perseverative Errors	.047	.002	-.007	-.171	.066	.166	.209	-.172
% Perseverative Errors	.144	.169	.171	.165	.070	.251	.249	-.130
Failure to Maintain Set	.020	-.302*	.115	-.328*	.004	-.103	-.099	.028
Processing Efficiency	-.182	-.148	-.078	.024	-.096	-.234	-.211	.091
Performance Effectiveness	-.144	-.169	-.171	-.165	-.070	-.251	-.249	.130
Switch Cost	.013	-.044	.063	.071	.134	.009	-.034	.051

Notes: N=59. Anx: Anxiety; Uncert: Uncertainty; Vivid: Vividness. WCST: Wisconsin Card Sorting Task.
*p<0.05

2.4 Discussion

This study aimed to explore the relationship between cognitive flexibility, worry, intolerance of uncertainty and anxiety with the aim of contributing towards a growing evidence base looking at transdiagnostic constructs integrating cognitive and emotional processes underlying psychopathologies (e.g. Fox et al. 2015; Zetsche et al. 2018).

2.4.1 Summary of Findings

Established positive relationships between IU, worry and anxiety were replicated as expected. It was found that higher general anxiety, rather than worry as was predicted, was associated with more consequences generated on the negative tree task and not with the positive tree task. Reduced cognitive flexibility (indicated by a larger number of perseverative errors and lower processing efficiency) was found to only be associated with higher intolerance of uncertainty, but not with worry or general anxiety, which was unexpected. General anxiety was unrelated to performance effectiveness on the WCST (an indicator of accuracy), which was expected.

Both the self-report, and behavioural measure, of cognitive flexibility were unrelated to the number of consequences participants generated when thinking of uncertain future events, which was unexpected. Higher self-reported cognitive flexibility, rather than cognitive flexibility as indicated by the WCST as hypothesised, was associated with lower anxiety after generating consequences from uncertain future events. Both measures of cognitive flexibility were unrelated to the uncertainty felt about these future events.

Self-reported cognitive flexibility was unrelated to performance on the WCST, a widely used neuropsychological measure of cognitive flexibility.

2.4.2 Cognitive Flexibility and Intolerance of Uncertainty

A key finding from this study was reduced cognitive flexibility (reflected by the number of perseverative errors made and reduced processing efficiency on the WCST) was associated with higher intolerance of uncertainty, in particular, with the tendency seek information to try and reduce uncertainty. Avoidance-orientated responses to uncertainty were found to be unrelated to cognitive flexibility. These relationships persisted after controlling for depressive symptoms.

The WCST has been widely used as a measure of a person's ability to shift cognition and behaviour in response to unexpected rule changes and is in line with Eslinger and Grattan's (1993) description of 'reactive' cognitive flexibility, referring to the ability to "freely shift cognition and behaviour according to the particular demands and context of a situation" (Eslinger & Grattan, 1993, p18). 'Spontaneous' flexibility refers to the ability to produce alternative ideas in response to a question or problem and is in line with the 'alternatives' subscale of the CFI, reflecting the ability to generate multiple solutions to problems.

These findings suggest that a diminished ability to shift cognitions in response to changing demands of a situation, rather than an inability to generate multiple solutions to problems, is linked to increased intolerance of uncertainty, and in particular, with a propensity to seek more information to try and reduce uncertainty, rather than avoiding uncertain situations.

This finding may have implications for Attentional Control Theory (ACT; Derakshan & Eysenck, 2009; Eysenck et al. 2007; Eysenck & Derakshan, 2011), which predicts that anxiety will impact cognitive processes such as shifting ability. Findings from this study suggest intolerance of uncertainty could be an important component to consider for this

model, and further work is needed to explore the links between intolerance of uncertainty and cognitive shifting, using multiple executive functioning tasks.

This may also have implications for the uncertainty and anticipatory model of anxiety (UAMA; Grupe & Nitschke, 2013), by suggesting that cognitive flexibility may be a cognitive mechanism underlying the psychological processes involved in maladaptive responses to uncertainty. This is supported by research from Lieberman et al. (2018) who found that cognitive flexibility mediated the relationship between intolerance of uncertainty and deficient safety learning in participants with panic disorder.

2.4.3 Cognitive Flexibility, Worry and Anxiety

Higher self-reported cognitive flexibility, but not shifting ability, was found to be related to decreased worry and general anxiety. In particular, those with a tendency to perceive difficult situations as more controllable, rather than being able to generate multiple solutions to problems, reported lower worry and general anxiety. This supports a hypothesis from Dennis and Vander Wal (2010) who suggested that the control subscale of the Cognitive Flexibility Inventory (CFI) may be indicative of a coping style whereby individuals have a belief in their capacity to exert control over difficult situations and therefore utilise problem solving strategies to overcome difficulties rather than cognitive avoidance strategies such as "wishful thinking or ruminative self-blame" (Dennis & Vander Wal 2010, p.249).

The finding that cognitive shifting was unrelated to worry or anxiety was unexpected, however previous research looking at the links between cognitive flexibility, worry and anxiety has also shown mixed findings. Some have reported an association between higher trait anxiety and decreased performance on the WCST (Edwards et al, 2015; Tempesta et al. 2013). Others have found no evidence of a relationship between worry or anxiety and performance on cognitive shifting tasks (Gulpers et al. 2018; Whitmer &

Banich, 2007). The average level of reported worry by participants in this study fell on the lower boundary of 'moderate' worry and average general anxiety was low, falling within the 'non-clinical' range. Therefore, the level of worry and anxiety in this study may have been too low to detect a relationship between cognitive flexibility and worry or anxiety. This is in line with Hirsch and Matthews (2012) cognitive model of worry suggesting a decreased ability to shift attention increases the likelihood of the development of pathological worry. In this study, the level of reported worry was not at a level high enough to be considered pathological.

2.4.4 Tree Tasks

Level of worry and cognitive flexibility were both unrelated to the number of consequences generated by participants when considering outcomes from possible future events. Higher reported general anxiety was associated with an increased number of consequences resulting from a negative event but not from a positive. This suggests those with higher reported general anxiety generate more consequences when thinking about potential negative events but not when considering positive events. This was contrary to what was expected; it was predicted that increased worry would instead be associated with more consequences generated due to the nature of worry itself being a chain of thoughts and images. The measure of general anxiety used however captures worry processes as well as general physical symptoms of anxiety, implying that the physical symptoms of anxiety may be related to the production of worry thoughts.

Higher self-reported cognitive flexibility, but not WCST performance, was associated with decreased state anxiety upon completion of both the negative and positive tree tasks, with this relationship strongest for the 'control' subscale of the CFI, but not the 'alternatives' subscale. This suggests that those with a tendency view difficult situations

as controllable report lower levels of state anxiety after considering consequences surrounding uncertain future events.

2.4.5 Wisconsin Card Sorting Test (WCST)

General anxiety, as measured by the GAD 7, was unrelated to processing efficiency or performance effectiveness on the WCST. This is in line with previous findings showing no relationship between symptoms of GAD and processing efficiency or performance effectiveness on an object-switching task (Airaksinen et al. 2005), or between generalised anxiety symptoms and performance effectiveness on a rule-switching task (Zainal & Newman, 2018b). Other research, however has found that increased generalised anxiety symptoms impacted on performance effectiveness on an object-switching task (Gulpers et al. 2018; Tempesta et al. 2013) and on processing efficiency in a rule-switching task (Zainal & Newman, 2018b).

Findings from this study contradict assumptions of Attentional Control Theory (ACT; Derakshan & Eysenck, 2009; Eysenck et al. 2007; Eysenck & Derakshan, 2011), which state that anxiety will impact processing efficiency on tasks requiring attentional control and will specifically impact set-shifting ability (such as the WCST). The average level of anxiety reported in this study however, fell within the 'non-clinical' range and therefore may not have been at a level high enough to impact cognitive performance.

Self-reported cognitive flexibility was not related to any performance measure on the WCST, a neuropsychological measure of cognitive flexibility. This supports previous findings reporting no evidence of associations between neuropsychological and self-report measures of cognitive flexibility (e.g. Johnco, Wuthrich & Rapee, 2014; Lounes, Khan & Tchanturia, 2011; Williams, Rau, Suchy, Thorgusen & Smith, 2017). These authors advise for self-report measures of cognitive flexibility to not be used in place of

neuropsychological measures and suggest future research is needed to understand which processes are being captured by self-reported flexibility measures.

2.4.2 Clinical Implications

This present study adds to the growing literature looking to understand the links between cognitive flexibility, intolerance of uncertainty, worry and anxiety. The finding that cognitive flexibility/shifting ability was related to intolerance of uncertainty may inform the development of treatment strategies targeting the process of cognitive flexibility in those reporting high intolerance of uncertainty. Cognitive flexibility may help facilitate the use of certain cognitive techniques during psychological interventions, for example generating alternative predictions for worries (Stevens et al. 2018). The findings presented within this study suggest that increasing perception of controllability of difficult events could also impact worry.

The ability to shift one's thoughts and behaviour according to changing situations may also help facilitate behavioural techniques such as behavioural experiments and exposure procedures. This is in line with findings from Lieberman et al. (2016) who found cognitive flexibility mediated the relationship between intolerance of uncertainty and deficient safety learning in participants with panic disorder.

2.4.2.1 Neuropsychology settings.

Assessment of anxiety and depression is widely recommended when carrying out neuropsychological assessment to aid interpretation of results (Mayo, Scarapicchia, Robinson & Gawryluk, 2018). The findings presented in this study suggest the use of more transdiagnostic measures such as intolerance of uncertainty and worry may be indicated. This could help with interpretation of performance on cognitive assessments, particularly when executive function measures including shifting/switching assessments are used.

The finding that performance on the web-based WCST were comparable to that of manually administered WCST provides support for the use of equivalent web-based neuropsychological assessments and is in line with previous research showing similar findings (Fortuny & Heaton 1996; Shan, Chen, Lee & Su, 2008; Wagner & Trentini, 2009). Web-based administration of the WCST has advantages in decreasing variability in administration and errors in recording responses, as well as enabling the assessment of a wider pool of participants not limited to the ability to attend a research base. The programme used to record performance in this study allowed the fast measurement of multiple variables that allowed additional outcomes such as processing efficiency to be calculated. These outcomes would have been difficult and time consuming to record manually. Disadvantages of web-based cognitive testing however include the inability to observe participants to control for distractibility and effort.

2.4.3 Methodological Limitations and Strengths

There were various methodological limitations to the present study. The WCST has commonly been used in studies as a measure of cognitive flexibility and shifting ability (Diamond, 2013; Ionescu, 2012), however the WCST has been argued to tap in to broad cognitive domains such as general executive functioning, rather than specific processes such as shifting (Kessels, 2019; Lezak, 2012). This may affect the interpretation of the results of this study as there may be additional cognitive processes, such as inhibition and updating, or more broad executive functioning, that could be associated with intolerance of uncertainty rather than specifically shifting. This means that these findings may not be generalisable to other shifting-specific or cognitive flexibility measures. Researchers have argued for the use of more than one cognitive paradigm assessing different aspects of executive functioning to uncover difference sources of

variance rather than relying on the use of one specific task (Gustavson et al. 2019; Morris & Mansell, 2018).

The tree task used in this study was included as a means of capturing worry processes surrounding uncertain future events in the moment. This task had limitations in that it was self-paced, therefore it is unknown how much effort or motivation participants had to complete this task to truly reflect their thought processes and therefore may have low validity. From viewing responses qualitatively, some participants generated consequences that appeared to follow a downward arrow path that became more catastrophic, whereas others generated consequences which did not follow one theme. Future research may consider using this design to group participants by response type to explore these relationships with intolerance of uncertainty and worry further. Another limitation of this method was that baseline anxiety was not measured at the start of completing the first tree task. As this task was not known to participants, and therefore contained uncertainties, this may have increased state anxiety prior to taking part in the task which may have affected how participants engaged with the task. As baseline anxiety was not measured this could not therefore be controlled for.

This study had a smaller sample size than the n=153 identified to have 80% power to detect a correlation of $r = 0.2$ as reported by Zetsche, Bürkner and Schulze (2018). A post hoc power analysis of the results of this study was calculated using G*Power 3.1 (Faul, Erdfelder, Buchner & Lang, 2009). This showed that the sample size of this study (n=60) was underpowered to detect relationship with 34% power (1-ß = 0.34) to detect a correlation of $r = 0.2$ ($\alpha = .05$, two-tailed). A larger sample may also have been able to capture a wider spectrum of worry and anxiety severity which could increase the generalisability of findings.

A limitation of this research is the use of multiple correlations inflating the chance of finding false positive results (Type I errors) due to random variability (Feise, 2002). A correction for multiple testing could have been applied to help overcome this however these methods have been criticised for being too conservative, reducing statistical power and increasing the rate of false negative findings (Type 2 errors) (Rothman, 1990). The strength of the relationships between variables have therefore been focused on in the reporting of this study as a means of evaluating the importance of the results rather than an overemphasis on statistical significance (Nakagawa, 2004).

The majority of participants reported a high level of educational attainment (58% reporting a degree or Master's) and therefore findings may also not be generalised to the wider population. There was a relatively high number of participants who signed up to take part in the study but dropped out before completing the WCST (the first task of the study). Participation in the WCST required a download of Inquisit player and participants may have found this complicated or unacceptable and may explain their withdrawal from the study.

This study was the first to the authors knowledge to explore the relationship between cognitive flexibility and intolerance of uncertainty using both a neuropsychological and self-report measure of cognitive flexibility. Previous research has tended to use one or two measures of a specific affect construct, such as trait anxiety or worry (Gustavson et al. 2019), therefore a strength of this study was using measures which reflected transdiagnostic processes of intolerance of uncertainty and worry. Using a web-based design enabled a wider participation pool that was not restricted by location or a student only population.

2.4.4 Future Directions

Future research should explore the relationships between cognitive flexibility, intolerance of uncertainty and worry in clinical populations reporting higher levels of anxiety from across the anxiety disorders spectrum (e.g., OCD, social anxiety). This may help to further understand the potential cognitive mechanisms underlying the link between intolerance of uncertainty and the various classifications of anxiety. These studies should aim to use multiple tasks of executive functioning to try to separate different cognitive process. Furthermore, it is important to conduct studies exploring the differences between tasks of flexibility and self-reported cognitive flexibility to try to understand which processes are being captured by each measure. Future research may also use a longitudinal design to explore whether reduced cognitive flexibility predicts the emergence of subsequent chronic worry and anxiety and whether this is preceded by the effects of generating consequences and working through multiple uncertainties in daily life.

2.4.5 Conclusion

This study explored the relationships between cognitive flexibility, worry, intolerance of uncertainty and anxiety using a web-based design. Cognitive inflexibility, as indicated by perseveration on the WCST, was most strongly associated with intolerance of uncertainty, specifically with the tendency to seek information to try and reduce uncertainty. Self-reported cognitive flexibility was instead more associated with decreased worry and general anxiety but not with intolerance of uncertainty. A strength of this study was the use of measures of transdiagnostic processes of intolerance of uncertainty and worry along with a self-report and neuropsychological measure of cognitive flexibility. Limitations include the use of only one neuropsychological measure of cognitive flexibility, reducing the ability to determine whether the specific process of

shifting ability is being captured or general executive functioning. The small sample size and low reported anxiety may reduce the generalisability of these findings to the wider population. Future research should aim to explore these relationships within a population reporting higher levels of worry and anxiety to further explore cognitive mechanisms underlying the link between intolerance of uncertainty and anxiety using multiple measures of executive functioning. The results of this study highlight the possibility of incorporating therapeutic approaches that target cognitive flexibility in those reporting high intolerance of uncertainty. Findings may also have important implications for ACT and the UAMA.

Appendices

Appendix A – Search Strategy

1. Research topic

Cognitive flexibility and anxiety/worry

2. Key concepts to formulate clear clinical question

Population or problem	Intervention or exposure	Comparison	Outcome
Adults Children and young people	Measured level of **cognitive flexibility** Self-report psychometric tools or neurocognitive tasks	Correlation	Level of **anxiety/worry** symptoms Self-report psychometric tool
Alternative Words			
Excluding animals 5+ years old	Cognitive (in)flexibility Setshifting / Set-shifting Shifting Switching Task switching / task-switching Shifting-attention/ shifting attention Flexible categori?ation Flexible language use Flexible response* Flexible cognition Inhibition failure Attentional inertia selective attention Flexible object sorting Executive function Inhibition Shifting Working memory Cognitive rigidity Cognitive control	Relationship Comparison Correlation Association	Generali?ed anxiety disorder GAD Worry Panic Anxi* Anxiety disorder* Fear Distress Emotion* regulat* Wellbeing Resilien*

	Flexible processing Adaptive updating Conflict monitoring Flexible behaviour Flexible problem solving Inductive reasoning Divergent thinking tasks Verbal fluency Category generating		

3. Research question

What is the relationship between level of cognitive flexibility and anxiety symptoms?

4. Search Limits

Study type:	Correlational, group comparisons, cross-sectional survey
Age range:	5+
Publication date:	1970 - 2018
Language:	English
Other:	

5. Possible Search Strategy

(flexib* N1 (cognitive OR psychological* OR attention*)) OR (attention* N1 (switch* OR shift* OR select*)) OR (task N1 (switch* OR shift*)) OR (cognitive N1 (control* OR rigid*)) OR (set N1 (shift* OR switch*)) OR "executive function*" OR (flexib* N1 (cognition OR respons* OR categori?ation OR language OR sort* OR behavio?r OR "problem solving"))
("generali?ed anxiety disorder*" OR GAD OR worr* OR panic OR anxi* OR "anxiety disorder*" OR fear OR distress* OR "emotion* regulat*" OR wellbeing OR resilien*)

Title Search results:

111 (Web of Science)
200 (PsychINFO ProQuest)
310 (PsychINFO EBSCO)
87 (CINAHL)
3,242 (MEDLINE – Abstract search)

PROSPERO

Bartholomay et al. (review ongoing) A meta-analysis of the association between cognitive control deficits and internalising and externalising psychopathology. http://www.crd.york.ac.uk/PROSPERO/display_record.php?ID=CRD42018092645
Miles et al. (review ongoing) Systematic review of cognitive flexibility in Anorexia Nervosa and after recovery from Anorexia Nervosa. http://www.crd.york.ac.uk/PROSPERO/display_record.php?ID=CRD42018107157

9th November 2018

Refined search strategy to target specific GAD and worry literature
(flexib* N1 (cognitive OR psychological* OR attention*)) OR (attention* N1 (switch* OR shift* OR select*)) OR (task N1 (switch* OR shift*)) OR (cognitive N1 (control* OR rigid*)) OR (set N1 (shift* OR switch*)) OR "executive function*" OR (flexib* N1 (cognition OR respons* OR categori?ation OR language OR sort* OR behavio?r OR "problem solving"))
AND
("generali?ed anxiety disorder*" OR GAD OR worr* OR "generali?ed anxiety")

Scoping Search Results of Abstracts
194 (Web of Science)
179 (PsychINFO ProQuest)
256 (PsychINFO EBSCO)
67 (CINAHL)
182 (MEDLINE)

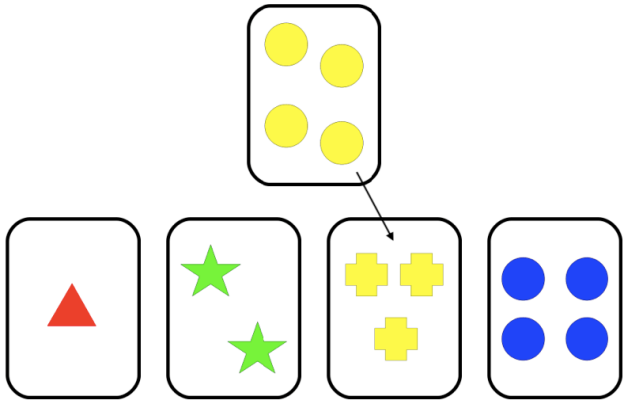
27th November 2018

Inclusion and exclusion criteria developed after scoping literature

Inclusion criteria:
Adult population 18-65
Anxiety symptoms – self-report symptoms of generalised anxiety and worry
Shifting/switching cognitive assessment
Case control, cross-sectional and cohort study designs

Exclusion criteria:
Other anxety disorders – OCD, panic, depression, bipolar disorder
Psychiatric conditions – psychosis, schizophrenia,
Physical health conditions – cancer, MS, acquired and traumatic brain injury, hepatitis, headache, diabetes, epilepsy
Neurodevelopmental disorders – ASD, ADHD
Medication trials
Alcohol consumpton
Psychological intervention trial e.g. CBT, mindfulness, meditation, relaxation
Cognitive training e.g. executive function training
Self-report measure of cognitive flexibility

Appendix B – Schematic of the Wisconsin Card Sorting Test (WCST)



correct

Appendix C – Schematic of a Rule Switching Paradigm

Brief Test of Adult Cognition by telephone (BTAC) used by Zainal and Newman (2018a)

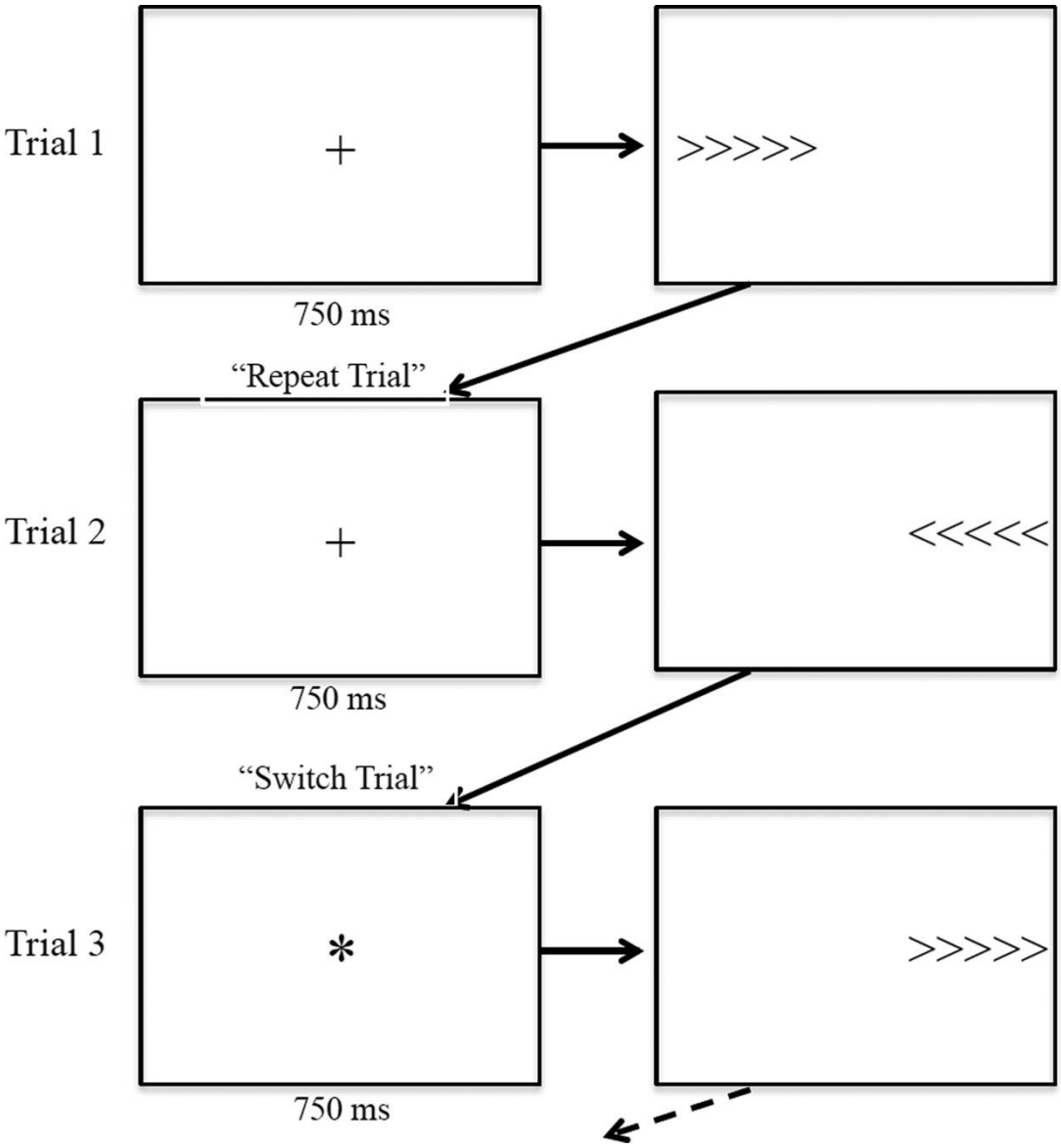
Stop and Go Switch Task:

Speeded two-choice reaction time tests, either:
1. Single-task baseline (blocked tests of Normal and Reverse response modes), or
2. Mixed-task task switching test (requires switching response mode between Normal and Reverse when cued)

Normal condition:
Every time I say RED you will say STOP, and every time I say GREEN you will say GO
Reverse condition:
Every time I say RED you will say GO, and every time I say GREEN you will say STOP.

Appendix D – Schematic of a Task Switching Paradigm

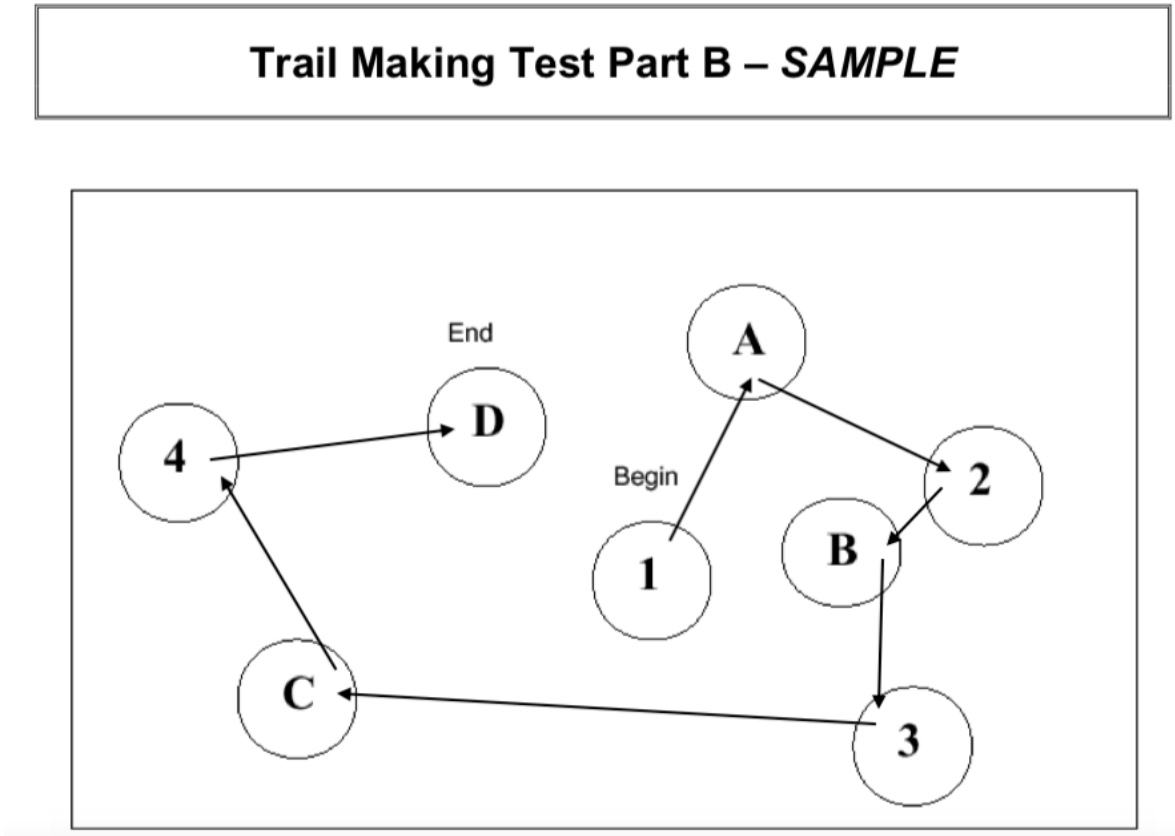
Asymmetric Switching Paradigm used by Gustavson et al. (2017)



*A cue (+ or *) appeared in the middle of the screen for 750 ms, indicating the dimension (location or direction) of the arrow stimulus (>>>>> or <<<<<) to which participants should attend. The + cue meant to respond with the location of the arrow, and the * cue meant to respond with the arrow's direction.*

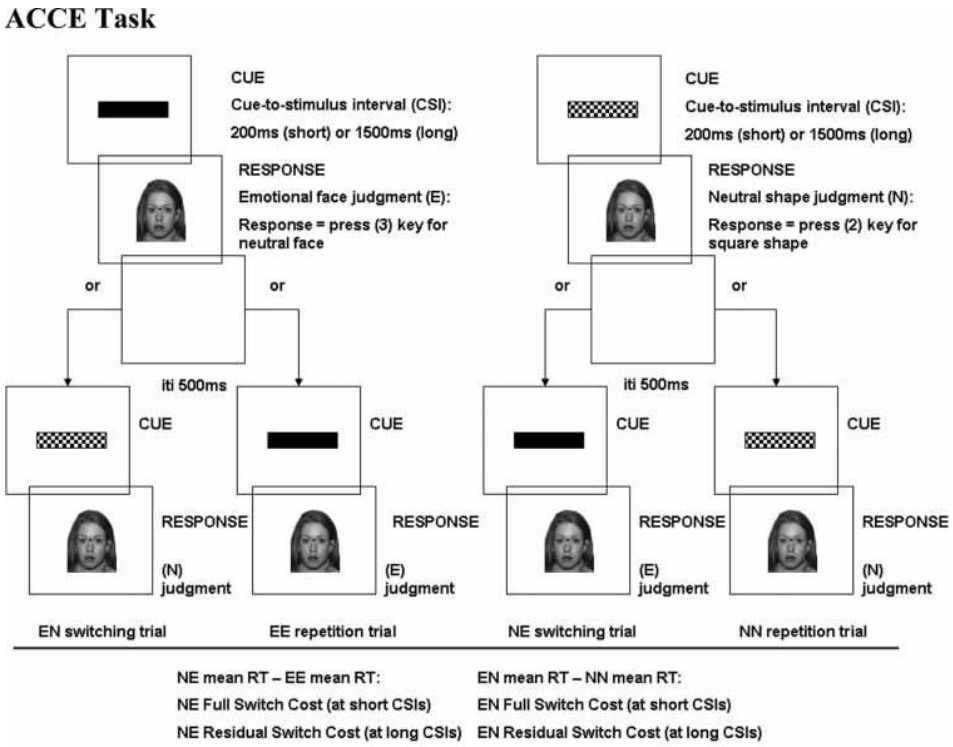
Appendix E - Schematic of an Object Switching Paradigm

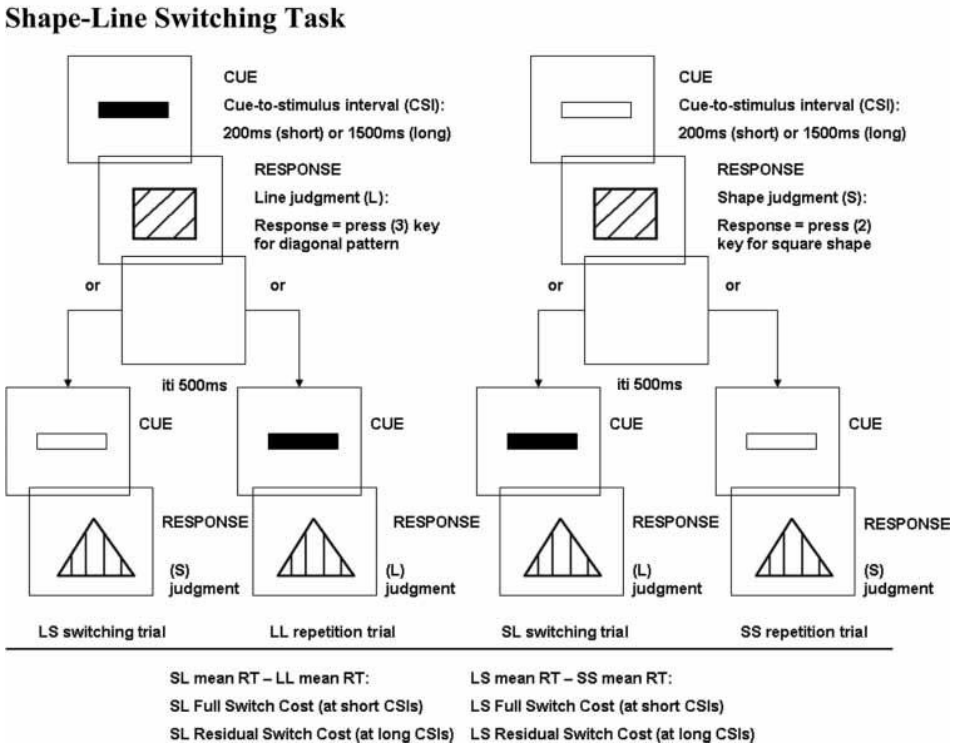
Trail Making Test –Part B (TMT-B) used by Airaksinen et al. (2005)



Appendix F – Schematic of an Object Switching Paradigm

Attentional Control Capacity for Emotion (ACCE) Task and Shape-line Switching Task developed by Johnson (2009)





Appendix G - Schematic of a Location Switching Paradigm

Ansari et al. (2008) Anti- and Pro-saccade Task

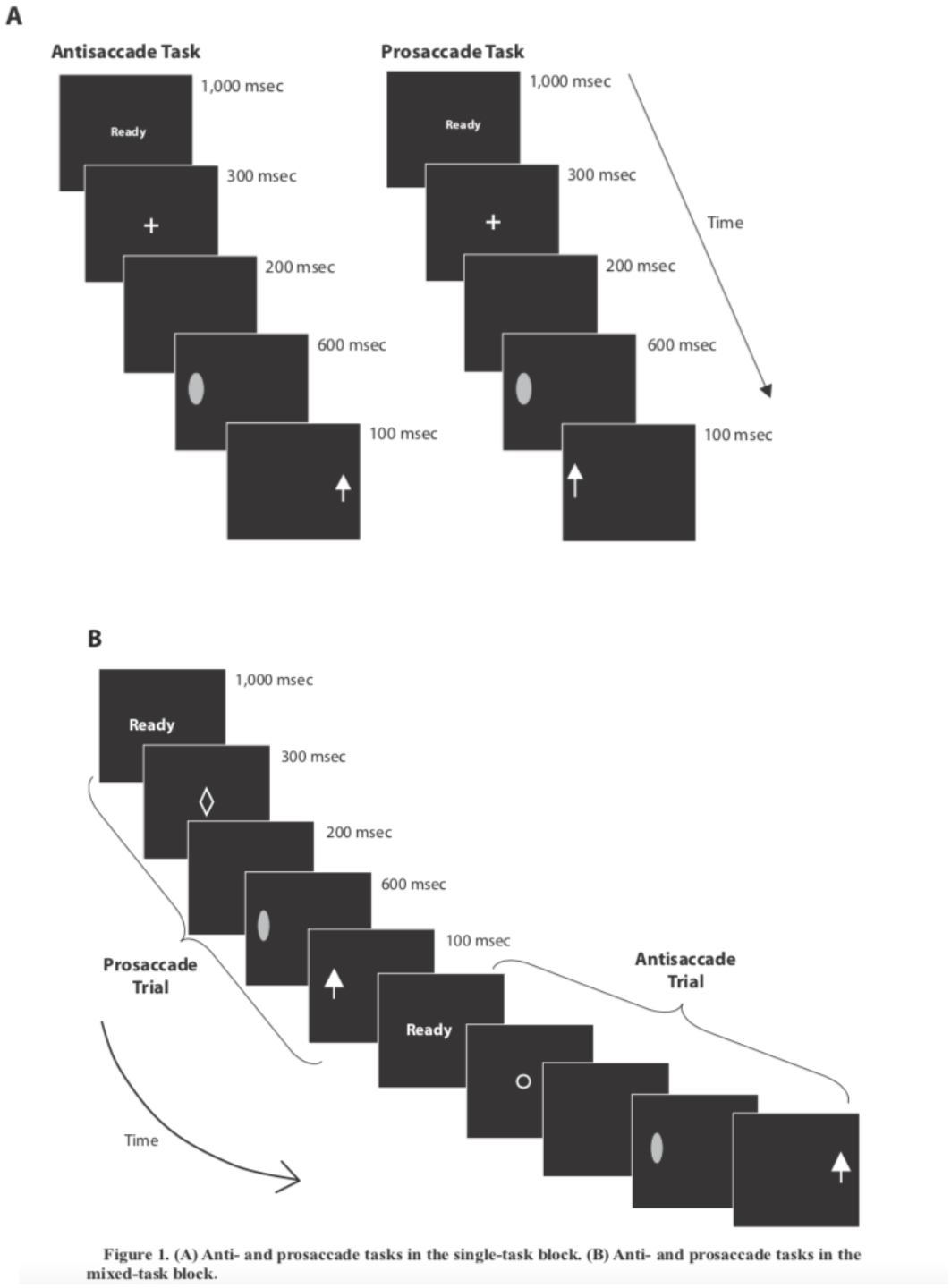


Figure 1. (A) Anti- and prosaccade tasks in the single-task block. (B) Anti- and prosaccade tasks in the mixed-task block.

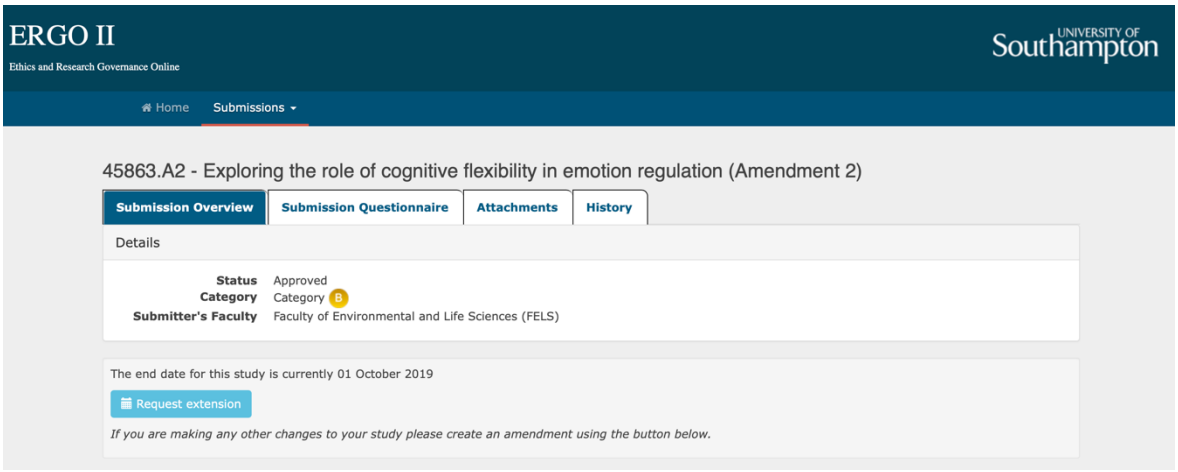
Appendix H – Quality Assessment Check

Quality Assessment Check Using The EPHPP Quality Assessment Tool for Quantitative Studies – rated by GG and CC Jan 19

Author and Title	Selection Bias	Study Design	Confounders	Blinding	Data Collection Method	Withdrawals and Drop-outs	Final Score
1. Airaksinen, Larsson & Forsell (2005) Neuropsychological functions in anxiety disorders in population-based samples: evidence of episodic memory dysfunction	Weak	Weak	Moderate	Weak	Strong	N/A	Weak
2. Ansari, Derakshan and Richards (2008) Effects of anxiety on task switching: Evidence from the mixed anti-saccade task.	Weak	Moderate	Weak	Weak	Strong	N/A	Weak
3. Ansari and Derakshan (2011) The neural correlates of cognitive effort in anxiety: Effects on processing efficiency	Weak	Moderate	Weak	Weak	Strong	N/A	Weak
4. Beckwe et al. (2014) Worrying and rumination are both associated with reduced cognitive control	Weak	Moderate	Strong	Weak	Strong	N/A	Weak
5. Caselli et al. (2004) A distinctive interaction between chronic anxiety and problem solving in asymptomatic APOE e4 homozygotes	Weak	Weak	Strong	Weak	Strong	N/A	Weak
6. Derakshan, Smyth and Eysenck (2009) Effects of state anxiety on performance using a task-switching paradigm: an investigation of attentional control theory	Weak	Moderate	Weak	Weak	Strong	N/A	Weak
7. Edwards, Edwards and Lyvers (2015) Cognitive trait anxiety, situational stress, and mental effort predict shifting efficiency: Implications for attentional control theory	Weak	Moderate	Strong	Weak	Strong	N/A	Weak
8. Edwards, Moore et al. (2015) Effects of trait anxiety and situational stress on attentional shifting are buffered by working memory capacity	Weak	Moderate	Strong	Weak	Strong	N/A	Weak
9. Gershuny et al. (1995) Compulsive checking and anxiety in a nonclinical sample: Differences in cognition, behaviour, personality, and affect.	Weak	Weak	Strong	Weak	Strong	N/A	Weak
10. Goodwin and Sher (1992) Deficits in Set-Shifting Ability in Nonclinical Compulsive checkers	Weak	Moderate	Strong	Weak	Strong	N/A	Weak

11. Gulpers et al. (2018) Anxiety disorders and figural fluency: a measure of executive function	Weak	Weak	Strong	Weak	Strong	N/A	Weak
12. Gustavson et al. (2017) Is set shifting really impaired in trait anxiety? Only when switching away from an effortfully established task.	Weak	Moderate	Weak	Weak	Strong	N/A	Weak
13. Johnson (2009) Attentional control capacity for emotion: an individual difference measure of internal controlled attention	Weak	Moderate	Weak	Weak	Weak	N/A	Weak
14. Muraven (2005) Self-focused attention and self-regulation of attention: implications for personality and pathology	Weak	Moderate	Weak	Weak	Strong	N/A	Weak
15. Robinson et al. (2011) Regulated and unregulated forms of cortisol reactivity: a dual vulnerability model	Weak	Moderate	Weak	Weak	Weak	Weak	Weak
16. Salters-Pednault et al. (2008) An experimental investigation of the effect of worry on responses to a discrimination learning task	Weak	Moderate	Weak	Weak	Strong	Strong	Weak
17. Tempesta et al. (2013) Neuropsychological functioning in young subjects with generalised anxiety disorder with and without psychopharmacology	Moderate	Weak	Strong	Moderate	Strong	N/A	Moderate
18. Visu-Petra et al. (2013) Individual differences in anxiety and executive functioning: a multidimensional view	Weak	Weak	Weak	Weak	Strong	N/A	Weak
19. Whitmer & Banich (2007) Inhibition versus switching deficits in different forms of rumination	Weak	Weak	Weak	Weak	Strong	N/A	Weak
20. Zainal & Newman (2018a) Executive function and other cognitive deficits are distal risk factors of generalised anxiety disorder 9 years later	Moderate	Moderate	Strong	Weak	Strong	N/A	Moderate
21. Zainal & Newman (2018b) Worry amplifies theory of mind reasoning for negatively valenced social stimuli in generalised anxiety disorder	Weak	Moderate	Strong	Weak	Strong	N/A	Weak

Appendix I - Ethical Approval



Appendix J - Information Sheet

Participant Information Sheet

Study title: Exploring the role of cognitive flexibility in emotion regulation.

Researcher name: Genevieve Warriner-Gallyer

ERGO number: 45863 Version 2. 12.10.18

Please read this information carefully before deciding to take part in this research. It is up to you to decide whether or not to take part. If you are happy to participate you will be asked to sign a consent form.

What is the research about?

This project is being completed as part of a Doctorate in Clinical Psychology at The University of Southampton. I am a Trainee Clinical Psychologist and am interested in the role of cognitive flexibility in emotion regulation. Studies have shown that being faced with situations of uncertainty can cause feelings of anxiety in some people. Cognitive flexibility is the ability to switch attention between different things to help respond appropriately to the task(s) at hand. We are interested to see what how cognitive flexibility helps regulate emotion during a series of tasks.

Who can participate?

I am looking for participants aged between 18-65 and fluent in English to take part in this study.

Given the nature of this study we advise that if you are currently taking medication for a mental health difficulty, are currently accessing mental health services, have a history of any neurological disorder or brain injury (including concussion), have taken/currently are taking illicit drugs in the past week, or have a current alcohol consumption above 15 units in the past 24 hours, to not take part in this study.

What will happen to me if I take part?

This study will last approximately 1.5 hours. You will first be asked to complete a brief (7 minute) card sorting task. Then you will be invited to complete 5 questionnaires asking about your mood. You will then be invited to complete two tasks that ask you to process information related to a variety of future events (each task should last approximately 25 minutes). At the end of the second task you will be debriefed and will be provided an email address for it you have any questions.

Are there any benefits in my taking part?

Your name will be entered in to a prize draw for the chance to win either a £75, £50 or £25 Amazon voucher. This database will not be linked to the study data and will be stored separately.

We aim to recruit 92 participants, and estimate the chance of winning a voucher = 1/30.

If you are a psychology undergraduate at the University of Southampton you will be eligible to receive 12 credits for taking part.

Are there any risks involved?

Throughout the study you will be asked some questions about your current mood and wellbeing. Information about local support services will be available to any participant that is concerned about their emotional wellbeing.

Will my participation be confidential?

Your participation and the information we collect about you during the course of the research will be kept strictly confidential.

Only members of the research team and responsible members of the University of Southampton may be given access to data about you for monitoring purposes and/or to carry out an audit of the study to ensure that the research is complying with applicable

regulations. Individuals from regulatory authorities (people who check that we are carrying out the study correctly) may require access to your data. All of these people have a duty to keep your information, as a research participant, strictly confidential.

All data is anonymized and confidential. You will be assigned a unique participant number that will be used to identify your data – your name will not be linked with or stored with any of your data unless you specify that you would like to be contacted to take part in a follow up of this study and provide your email address and consent. Any information and research study documentation taken for this research study will remain confidential and will be available only to the principal investigator and members of the research team directly involved in the project.

What happens if I change my mind?

You have the right to change your mind and withdraw your involvement at any time without giving a reason and without your participant rights being affected. You can request this by contacting the research team (email below). You can also request the withdrawal of your data from the study and any unpublished reports by contacting the research team.

What will happen to the results of the research?

Your personal details will remain strictly confidential. Research findings made available in any reports or publications will not include information that can directly identify you without your specific consent.

When the study has been completed, the research team will analyse the data and report the findings. The results will be included in research reports written by members of the research team, including research student projects and papers for publication/presentation at scientific conferences. You would not be identified in any way and if you would like a copy of the final paper, you may request this.

Where can I get more information?

If you have any questions about this study please do not hesitate to contact either Genevieve Warriner-Gallyer (gwg1n16@soton.ac.uk), Prof Matt Garner (M.J.Garner@soton.ac.uk) or Dr Margo Ononaiye (M.S.Ononaiye@soton.ac.uk).

What happens if there is a problem?

If you have a concern about any aspect of this study, you should speak to the researchers who will do their best to answer your questions.

If you remain unhappy or have a complaint about any aspect of this study, please contact the Chair of the Ethics Committee, Psychology, University of Southampton, Southampton, SO17 1BJ. Phone: +44 (0)23 8059 3856, email fshs-rso@soton.ac.uk.

Data Protection Privacy Notice

The University of Southampton conducts research to the highest standards of research integrity. As a publicly-funded organisation, the University has to ensure that it is in the public interest when we use personally-identifiable information about people who have agreed to take part in research. This means that when you agree to take part in a research study, we will use information about you in the ways needed, and for the purposes specified, to conduct and complete the research project. Under data protection law, 'Personal data' means any information that relates to and is capable of identifying a living individual. The University's data protection policy governing the use of personal data by the University can be found on its website (https://www.southampton.ac.uk/legalservices/what-we-do/data-protection-and-foi.page).

This Participant Information Sheet tells you what data will be collected for this project and whether this includes any personal data. Please ask the research team via email if you have any questions or are unclear what data is being collected about you.

Our privacy notice for research participants provides more information on how the University of Southampton collects and uses your personal data when you take part in one of our research projects and can be found at:

http://www.southampton.ac.uk/assets/sharepoint/intranet/ls/Public/Research%20and%20Integrity%20Privacy%20Notice/Privacy%20Notice%20for%20Research%20Participants.pdf

Any personal data we collect in this study will be used only for the purposes of carrying out our research and will be handled according to the University's policies in line with data protection law. If any personal data is used from which you can be identified directly, it will not be disclosed to anyone else without your consent unless the University of Southampton is required by law to disclose it.

Data protection law requires us to have a valid legal reason ('lawful basis') to process and use your Personal data. The lawful basis for processing personal information in this research study is for the performance of a task carried out in the public interest. Personal data collected for research will not be used for any other purpose.

For the purposes of data protection law, the University of Southampton is the 'Data Controller' for this study, which means that we are responsible for looking after your information and using it properly. The University of Southampton will store participant

for 10 years after the study has finished after which time any link between you and your information will be removed.

To safeguard your rights, we will use the minimum personal data necessary to achieve our research study objectives. Your data protection rights – such as to access, change, or transfer such information - may be limited, however, in order for the research output to be reliable and accurate. The University will not do anything with your personal data that you would not reasonably expect.

If you have any questions about how your personal data is used, or wish to exercise any of your rights, please consult the University's data protection webpage (https://www.southampton.ac.uk/legalservices/what-we-do/data-protection-and-foi.page) where you can make a request using our online form. If you need further assistance, please contact the University's Data Protection Officer (data.protection@soton.ac.uk).

Thank you.

Appendix K - Debriefing Statement

Debriefing Statement (V2, 12.10.18) Ethics ID: 45863

You have now completed this study. Thank you for your time in taking part.

To enter in to our **prize draw** and to claim **course credit** (if you are a University of Southampton undergraduate psychology student) please **click continue** at the end of this page.

What this study was about: The aim of this research was explore the role of cognitive flexibility in uncertainty and anxiety. It is expected that those with higher levels of cognitive flexibility will experience less anxiety during uncertain situations. It is not clear what role cognitive flexibility might have in people who already do not like uncertainty and find it difficult to tolerate. Your participation in this study is greatly appreciated and your data will help our understanding of this area, which so far there has been little.

Once again results of this study will not include your name or any other identifying characteristics. The research did not use deception. If you wish to be contacted with the results of this study or to be entered in to our prize draw, please provide your email address on the next page to be stored on a separate database.

Over the course of the screening interview we asked you to discuss certain aspects of your mental health and well-being. If you found any of these questions have caused you concern, there are several sources of advice which are available and which may prove helpful in dealing with your concerns. These include your **GP**, **NHS direct**, and also **Student Services** or your **personal tutor**.

If you are a **University of Southampton student**, you can contact the **Counselling Service** (http://www.southampton.ac.uk/edusupport/counselling) or the **24-hour Listening Service** (http://nline.susu.org).

If you are interested in this research area and would like to find out more:

Grupe, D. W., & Nitschke, J. B. (2013). Uncertainty and anticipation in anxiety: an integrated neurobiological and psychological perspective. Nature Reviews Neuroscience, 14(7), 488.

If you have any questions about this study please do not hesitate to contact either me: **Genevieve Warriner-Gallyer (gwg1n16@soton.ac.uk)**, Prof Matt Garner (M.J.Garner@soton.ac.uk) or Dr Margo Ononaiye (M.S.Ononaiye@soton.ac.uk) and we would be happy to answer any queries you might have.

If you have questions about your rights as a participant in this research, or if you feel that you have been placed at risk, you may contact the University of Southampton Research Integrity and Governance Manager (023 8059 5058, rgoinfo@soton.ac.uk).

- ○ Yes, I would like to enter the prize draw only
- ○ Yes, I would like to enter the prize draw and receive my course credit
- ○ Yes, I would like to receive course credit only
- ○ None of the above

CONTINUE

Appendix L - Statement for participants not eligible to take part in study

Thank you for your interest in taking part in this study. Unfortunately, due to the nature of this study, the information you have provided indicates you are not eligible to take part.

To assess eligibility to take part in this study we asked you questions relating to certain aspects of your mental health and well-being. If you found any of these questions have caused you concern, there are several sources of advice which are available and which may prove helpful in addressing any concerns. These include your **GP**, **NHS Direct**, **Student Services** or your **personal tutor**.

If you are a **University of Southampton student**, you can contact the **Counselling Service** (http://www.southampton.ac.uk/edusupport/counselling) or the **24-hour Listening Service** (http://nline.susu.org).

The information you have provided remains confidential and will subsequently be removed from our database.

Thank you again for your interest in taking part in this study. If you have any questions about this study please do not hesitate to contact a member of our study team: **Genevieve Warriner-Gallyer (gwg1n16@soton.ac.uk)** ; Prof Matt Garner (M.J.Garner@soton.ac.uk) or Dr Margo Ononaiye (M.S.Ononaiye@soton.ac.uk).

If you have any questions about your rights as a participant in this research, or if you feel you have been placed at risk, you may contact the University of Southampton Research Integrity and Governance Manager (02380 595 058, rgoinfo@soton.ac.uk).

Appendix M - Copy of the Penn State Worry Questionnaire and Scoring Instructions

(PSWQ; Meyer, Miller, Metzger and Borkovec, 1990)

Study Title: Exploring the role of cognitive flexibility in emotion regulation

The Penn State Worry Questionnaire (PSWQ)

Instructions: Rate each of the following statements on a scale of 1 ("not at all typical of me") to 5 ("very typical of me"). Please do not leave any items blank.

	Not at all typical of me				Very typical of me
1. If I do not have enough time to do everything, I do not worry about it.	1	2	3	4	5
2. My worries overwhelm me.	1	2	3	4	5
3. I do not tend to worry about things.	1	2	3	4	5
4. Many situations make me worry.	1	2	3	4	5
5. I know I should not worry about things, but I just cannot help it.	1	2	3	4	5
6. When I am under pressure I worry a lot.	1	2	3	4	5
7. I am always worrying about something.	1	2	3	4	5
8. I find it easy to dismiss worrisome thoughts.	1	2	3	4	5
9. As soon as I finish one task, I start to worry about everything else I have to do.	1	2	3	4	5
10. I never worry about anything.	1	2	3	4	5
11. When there is nothing more I can do about a concern, I do not worry about it any more.	1	2	3	4	5
12. I have been a worrier all my life.	1	2	3	4	5
13. I notice that I have been worrying about things.	1	2	3	4	5
14. Once I start worrying, I cannot stop.	1	2	3	4	5
15. I worry all the time.	1	2	3	4	5
16. I worry about projects until they are all done.	1	2	3	4	5

21.09.18 V1 [ERGO No. 45863]

Scoring the PSWQ

In scoring the PSWQ, a value of 1, 2, 3, 4, and 5 is assigned to a response depending upon whether the item is worded positively or negatively. The total score of the scale ranges from 16 to 80.

Items 1, 3, 8, 10, 11 are reverse scored as follows:

- Very typical of me = 1 (circled 5 on the sheet)
- Circled 4 on the sheet = 2
- Circled 3 on the sheet = 3
- Circled 2 on the sheet = 4
- Not at all typical of me = 5 (circled 1 on the sheet)

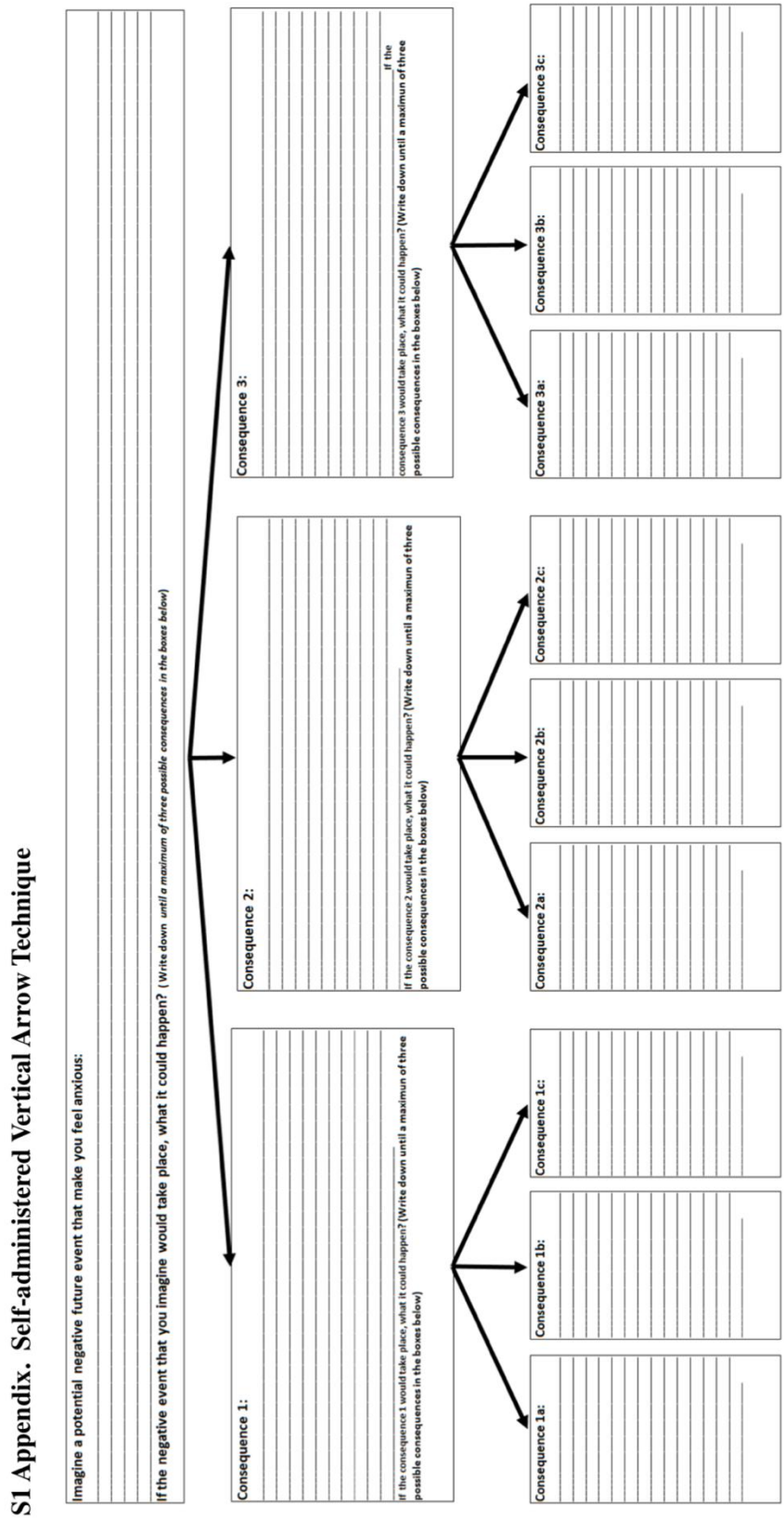
For items 2, 4, 5, 6, 7, 9, 12, 13, 14, 15, 16 the scoring is:

- Not at all typical of me = 1
- Ratings of 2, 3, and 4 are not transformed
- Very typical of me = 5

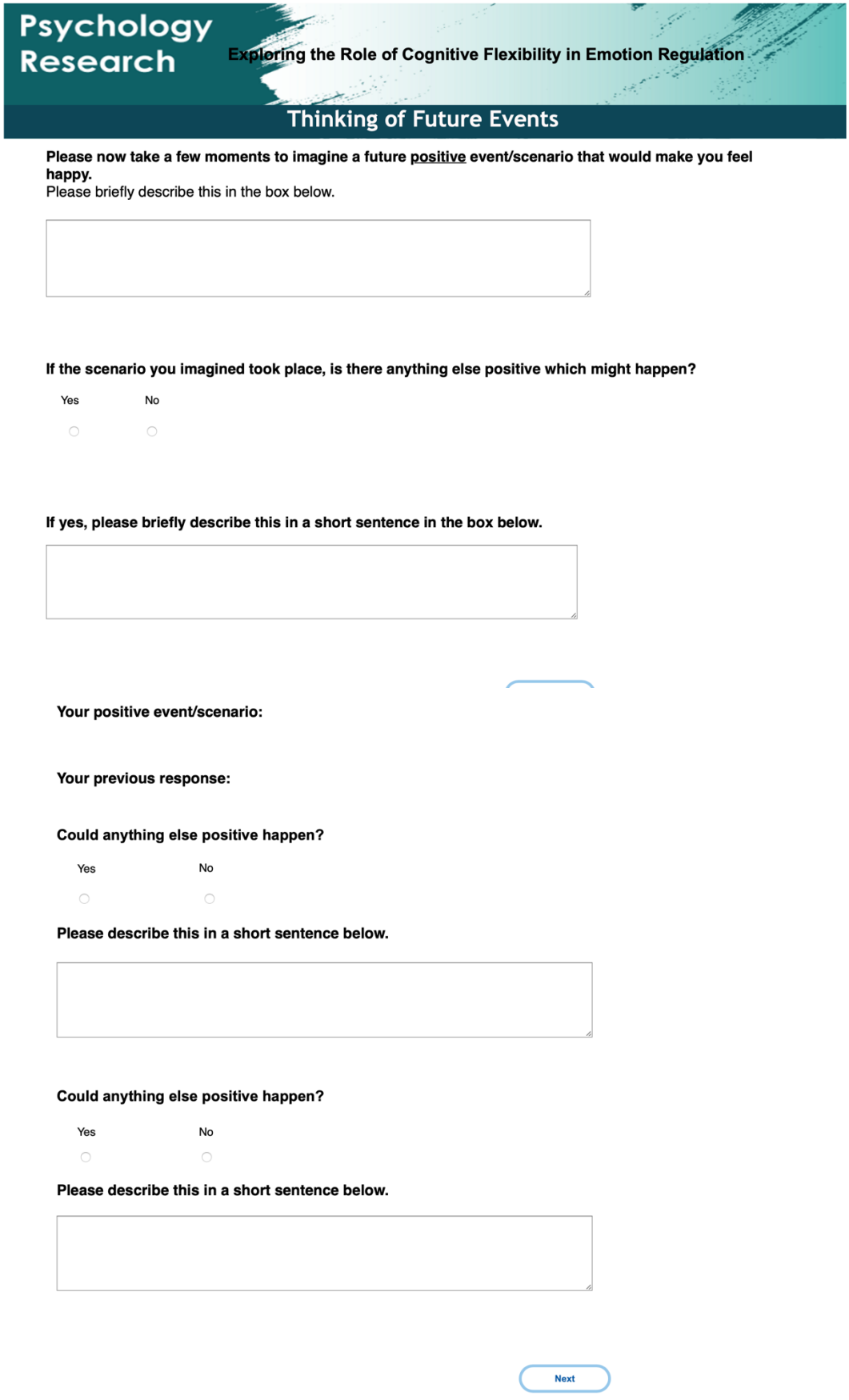
Citation: Meyer TJ, Miller ML, Metzger RL, Borkovec TD: Development and Validation of the Penn State Worry Questionnaire. Behaviour Research and Therapy 28:487-495,1990

Appendix N – Schematic of the Vertical Arrow Technique (VAT)

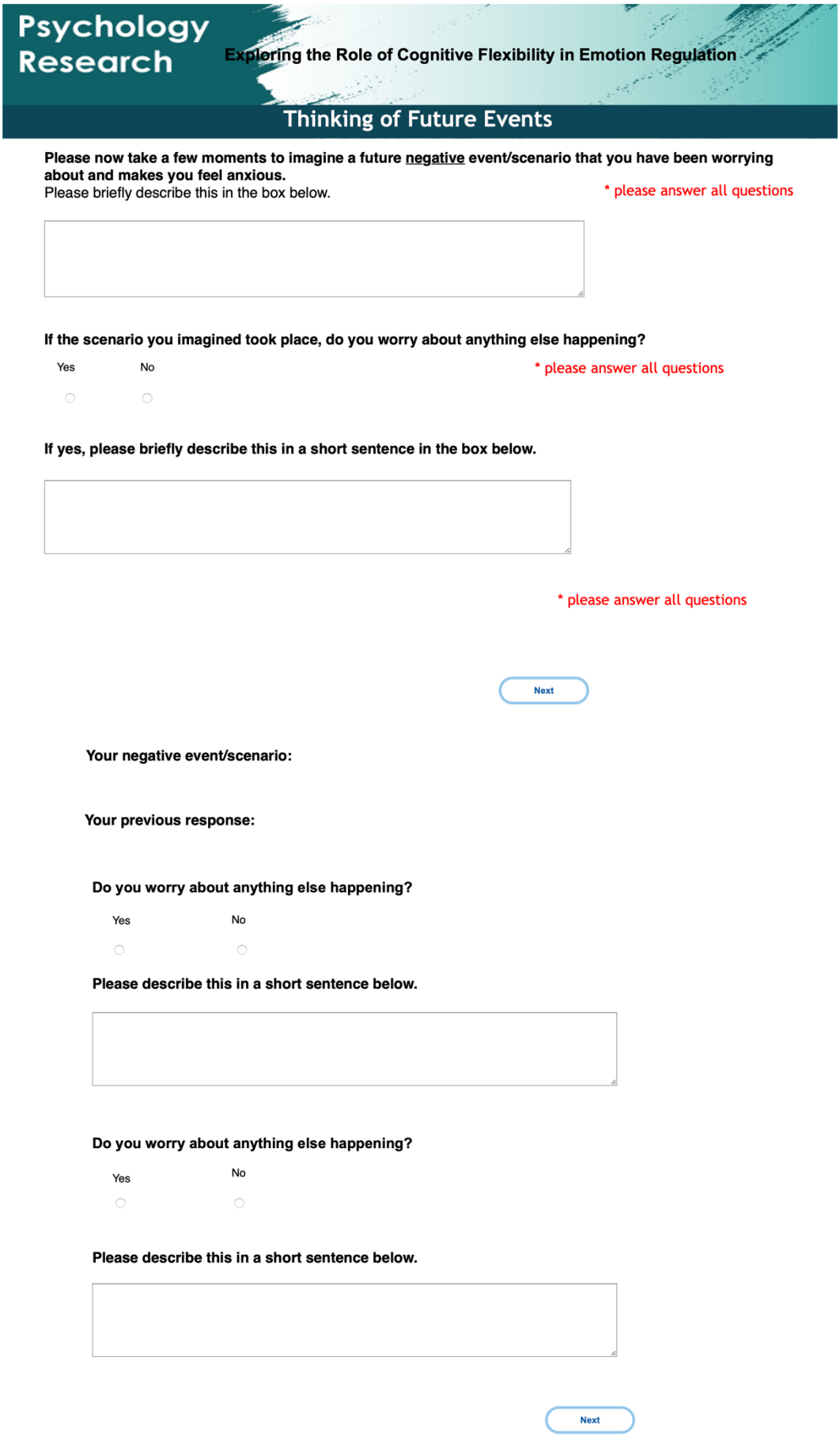
Taken from Mosca, Lauriola & Carleton (2016)



Appendix O – Schematic of Positive Tree Task



Schematic of Negative Tree Task



Appendix P - Instructions to Complete Tree Tasks

Thank you. For the final part of this study you will be asked to complete two tasks.

For the first task you will be asked imagine a future event or scenario, and to describe any possible outcomes that could happen from this.

There is no time limit to complete this task.

At the end, you will be asked to give three ratings and guided through a 30-second exercise to help bring your attention back to the present moment, before moving on to the second task.

Click to begin

Appendix Q - Visual Analogue Scales (VAS) provided after each Tree Task

Vividness check

1. Please indicate how **vividly** you could imagine the event describedfrom 1 (not at all vivid) to 10 (extremely vivid)

Not at all vivid — Extremely vivid

1 2 3 4 5 6 7 8 9 10

Uncertainty check

2. Please indicate how **uncertain** you feel about the event you describedfrom 1 (extremely certain) to 10 (extremely uncertain)

Extremely certain — Extremely uncertain

1 2 3 4 5 6 7 8 9 10

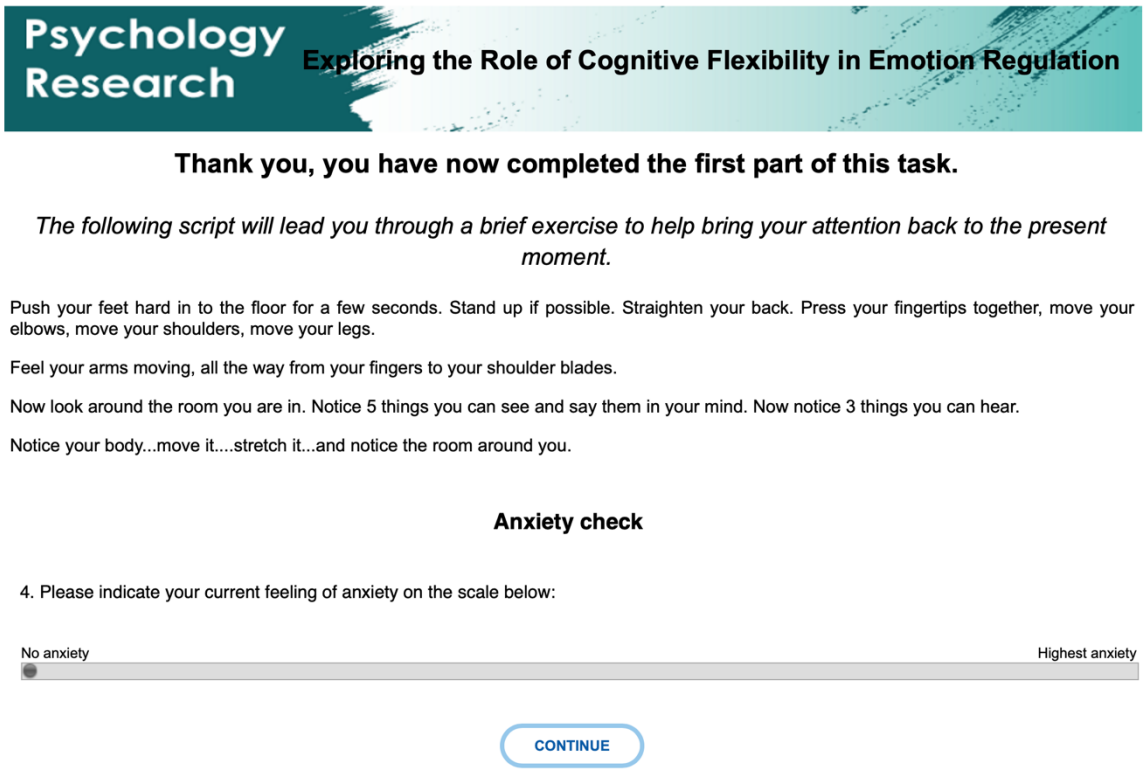
Anxiety check

3. Please indicate your currentfeeling of **anxiety** on the scale below:

No anxiety — Highest anxiety

Next

Appendix R - Grounding Exercise and Anxiety Re-Rating



Appendix S - Instructions for how to Remove Inquisit 5 Web Software

Thank you for participating!

If you wish to uninstall **Inquisit Player**, please follow the instructions below.

Instructions for **Windows** :
1. Open the "Programs and Features" applet in Windows Control Panel (called "Add/Remove Programs" in Windows XP).
2. Search for the entry with "Inquisit 5 Web" in the programs list. If you find it, double click to uninstall.

Instructions for **Mac** :
1. Close your browser
2. Delete the "/Applications/InquisitPlayer.app" file.
3. Or delete the "/Users/(your username)/Applications/InquisitPlayer.app" file.

Instructions for **iOS** :
1. Press and hold the **Inquisit Player** icon for a few seconds until the icon starts "wiggling".
2. Press the black X on the **Inquisit Player** icon to delete it.

If you have any difficulties, information and support can be found at
https://www.millisecond.com/products/faq.aspx.

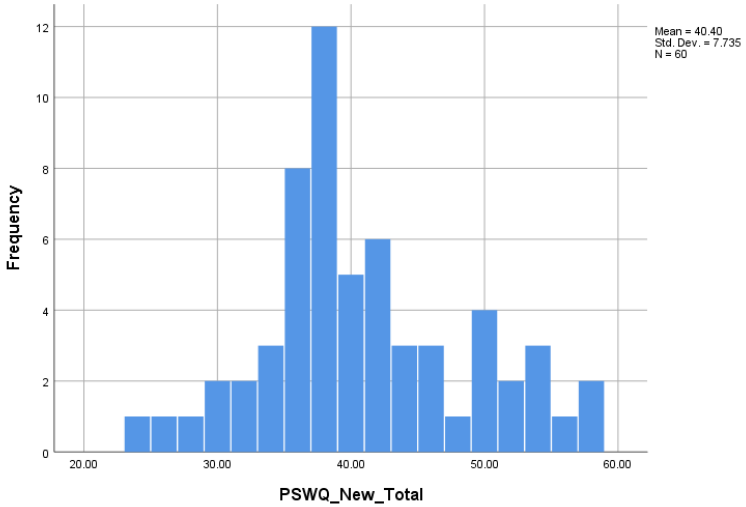
If you have any questions about this study please do not hesitate to contact a member of the research team, we would be happy to answer any queries you might have: **Genevieve Warriner-Gallyer (gwg1n16@soton.ac.uk)** ; Prof Matt Garner (M.J.Garner@soton.ac.uk) and Dr Margo Ononaiye (M.S.Ononaiye@soton.ac.uk).

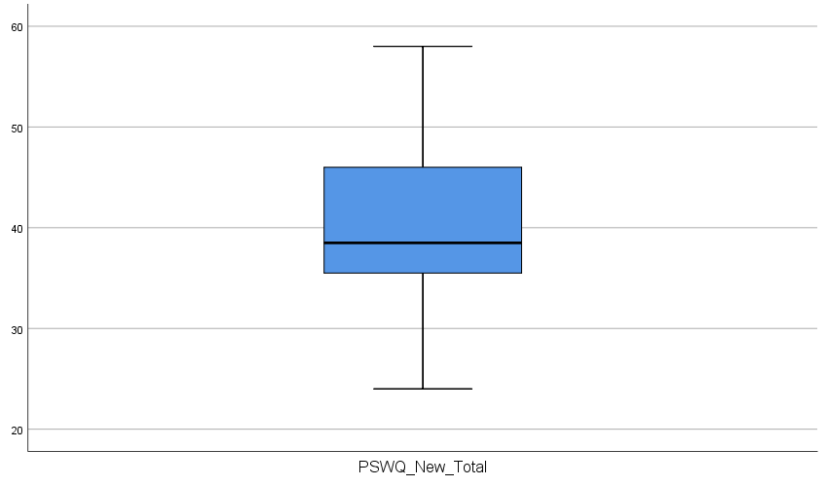
Thank you!

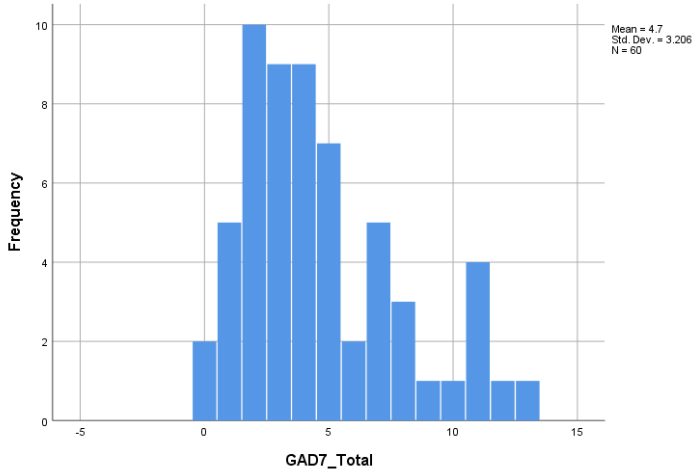
You may now close your web browser. If you are using a shared/public device please restart or shut down your device.

Appendix T – Data Diagnostic and Assumption Checking

T.1) Distribution of self-report Questionnaires



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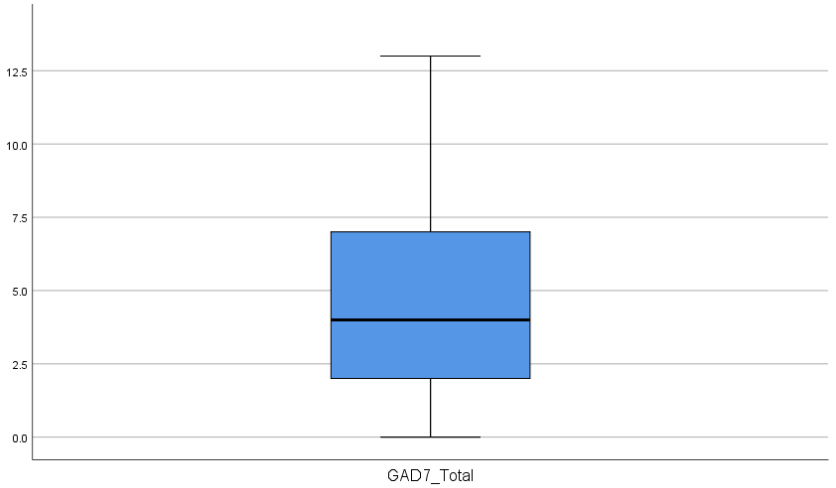
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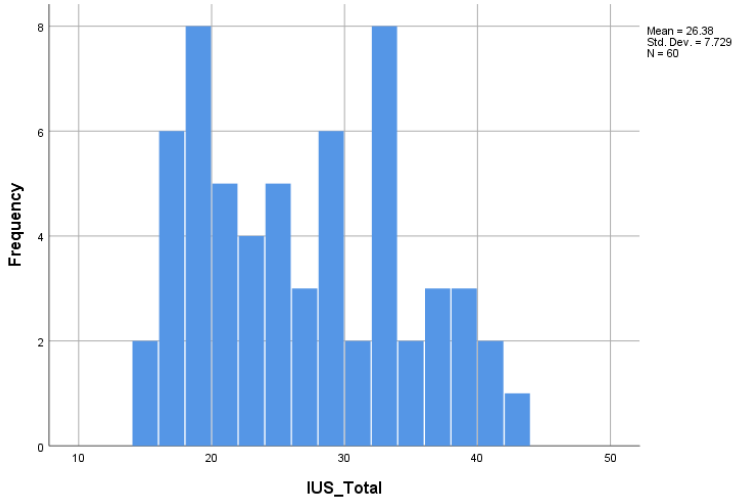
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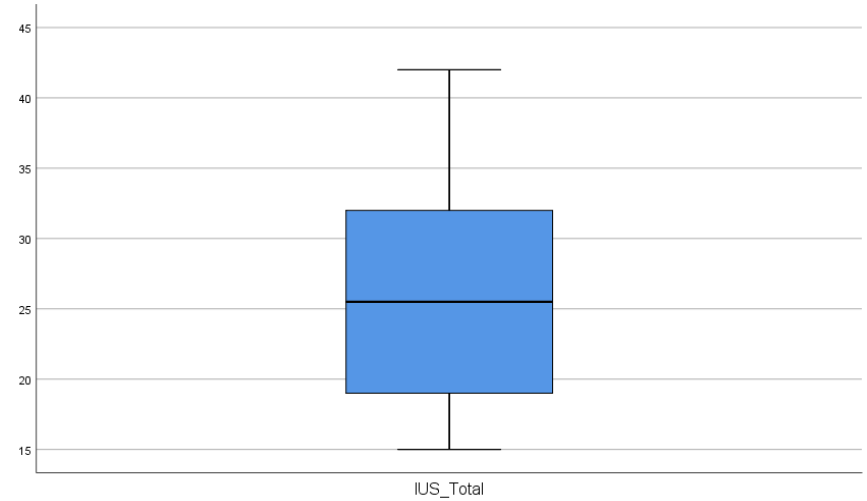
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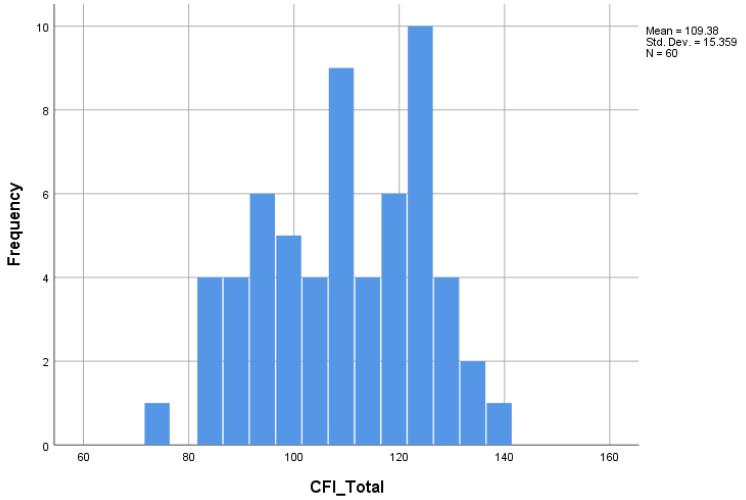
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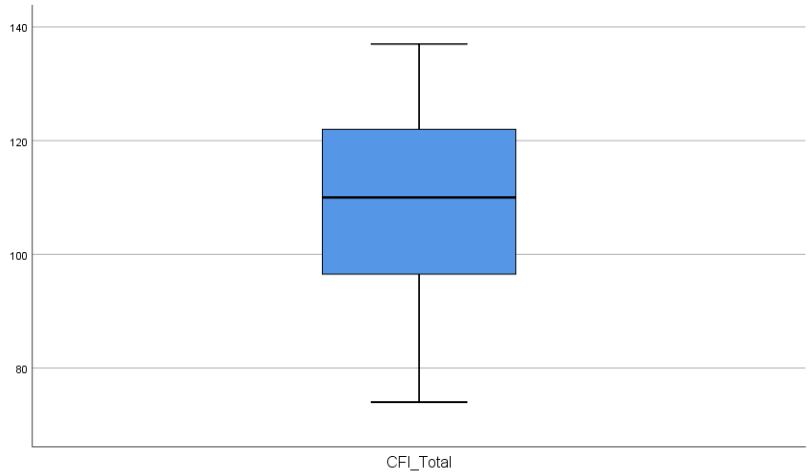
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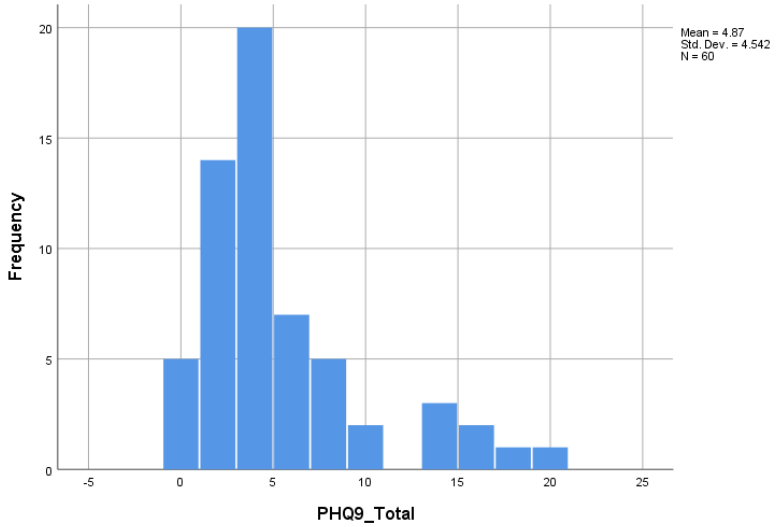
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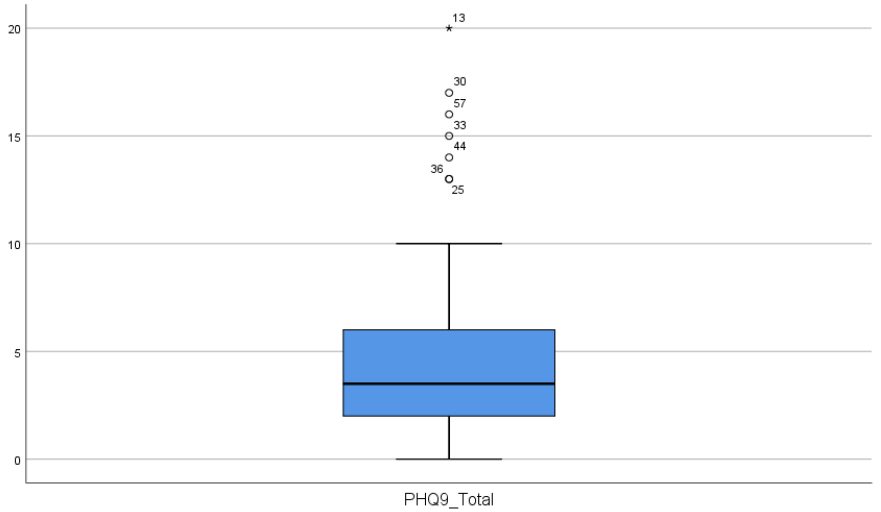
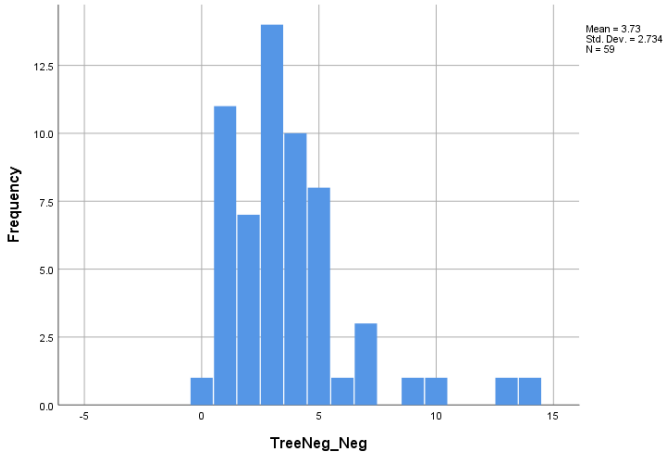
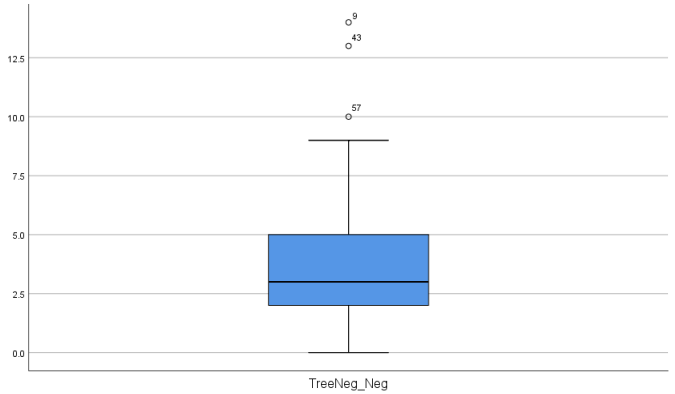
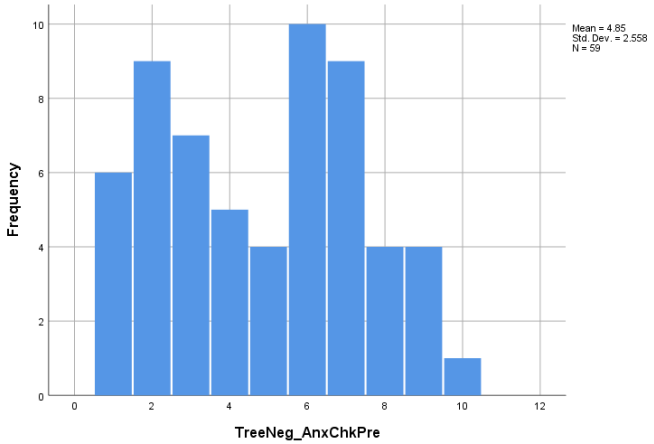
Std. Dev. = 4.542
N = 60
Frequency
PHQ9_Total

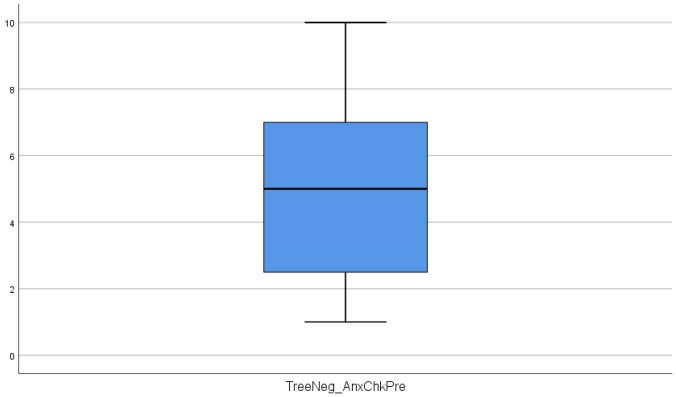

PHQ9_Total

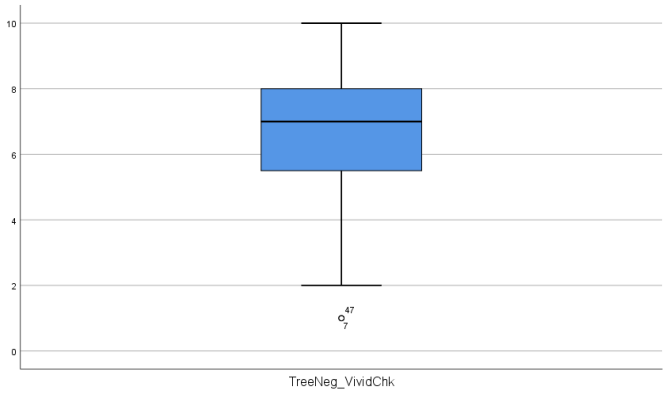
T.2) Distribution of Negative and Positive Tree Tasks







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8
6
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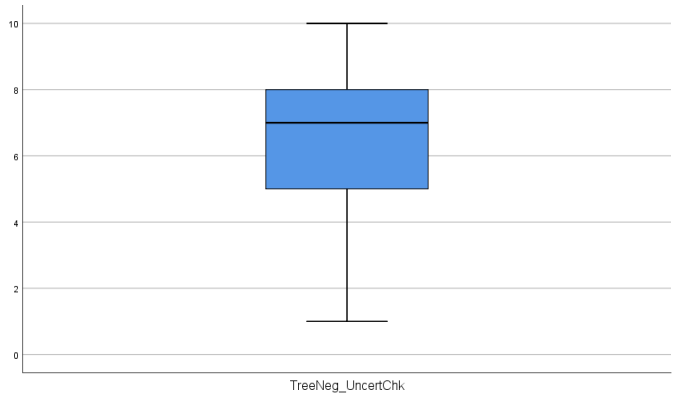
2
0
47
7
TreeNeg_VividChk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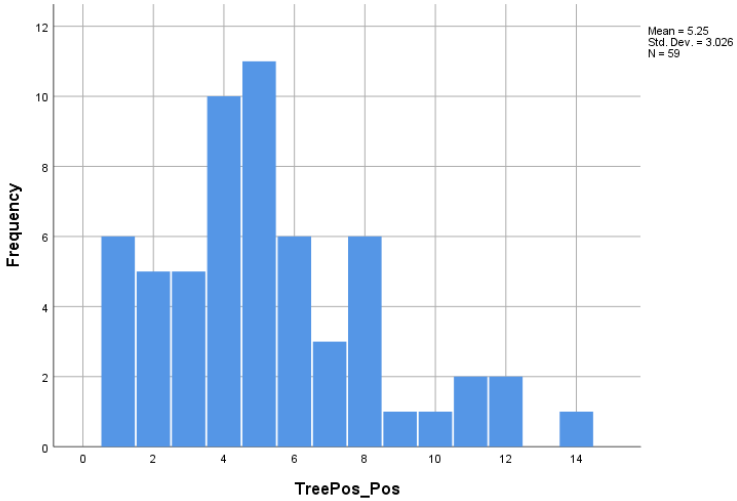
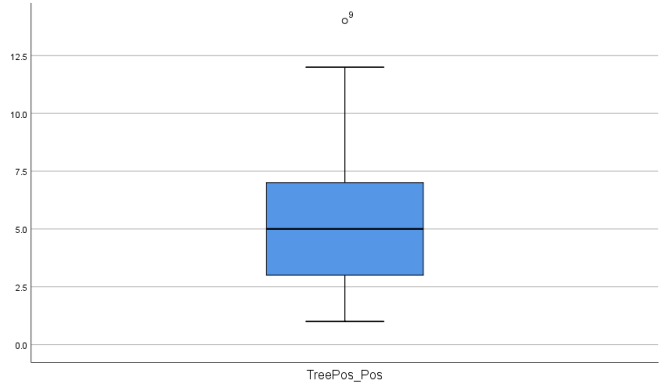
TreeNeg_UncertChk


Mean = 5.25
Std. Dev. = 3.026
N = 59
Frequency
TreePos_Pos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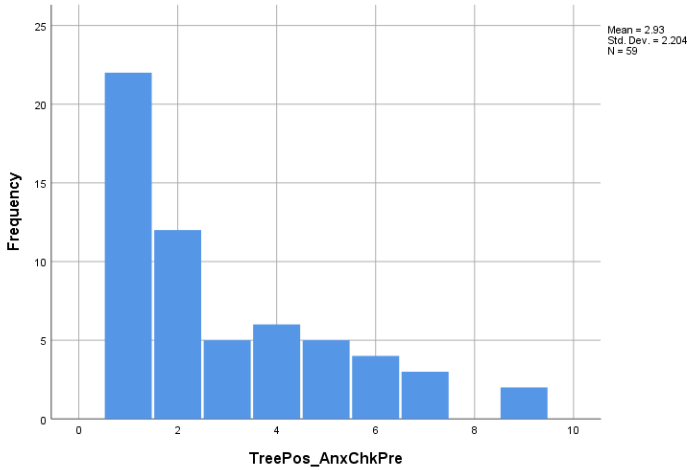
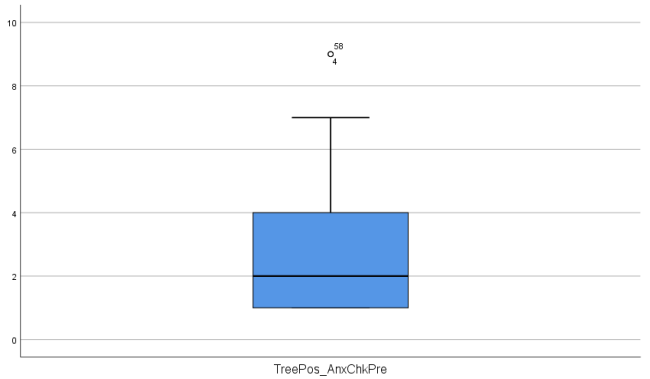
TreePos_Pos


Mean = 2.93
Std. Dev. = 2.204
N = 59
Frequency
TreePos_AnxChkPre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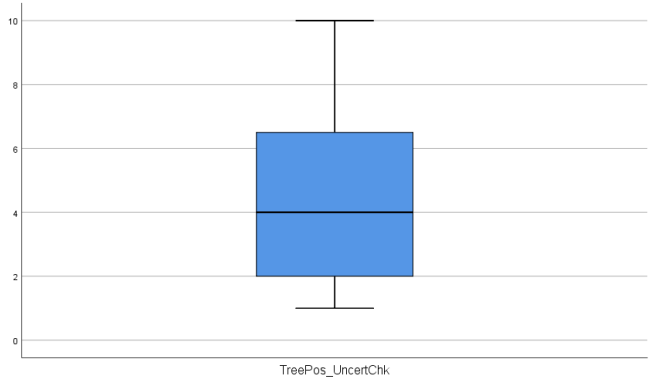
4
TreePos_AnxChkPre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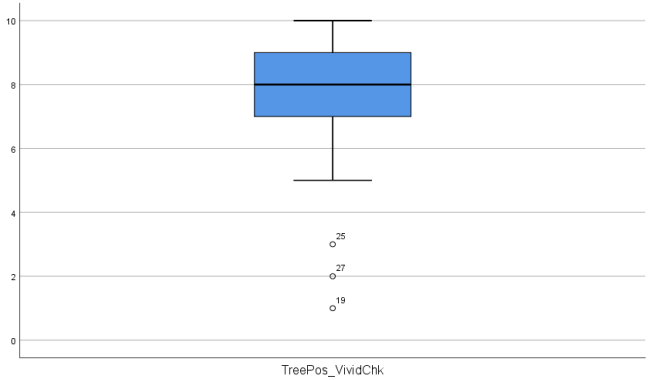
TreePos_UncertChk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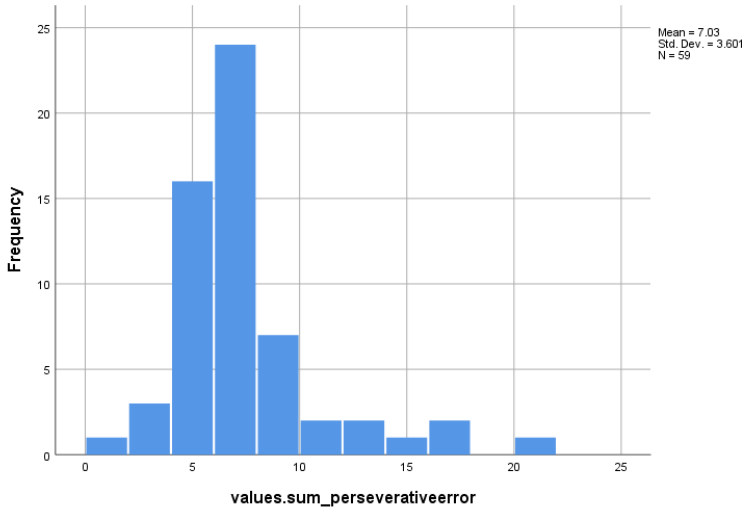
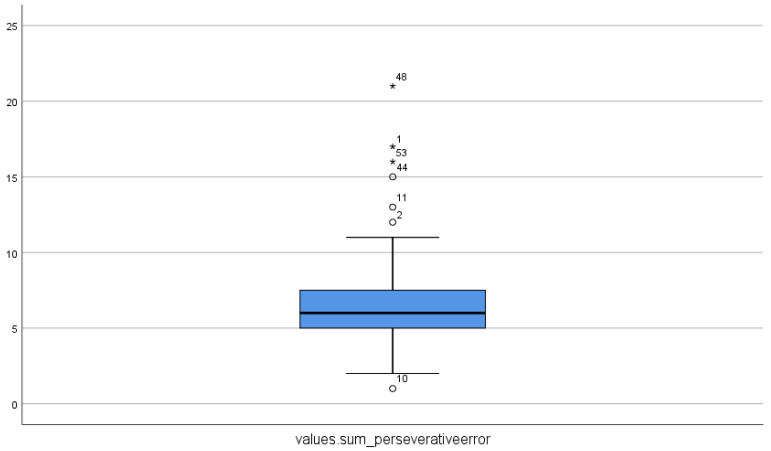
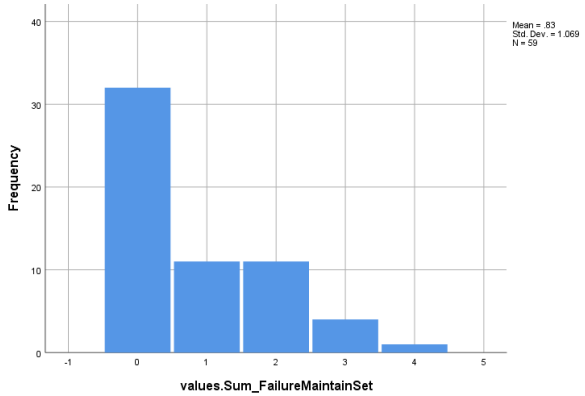
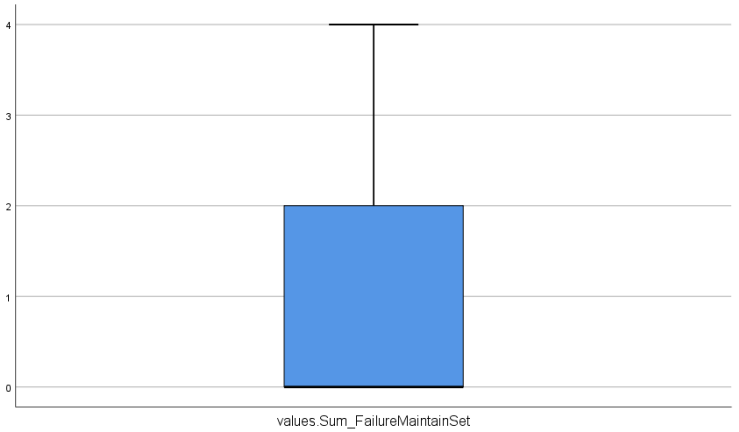
25
27
19
TreePos_VividChk

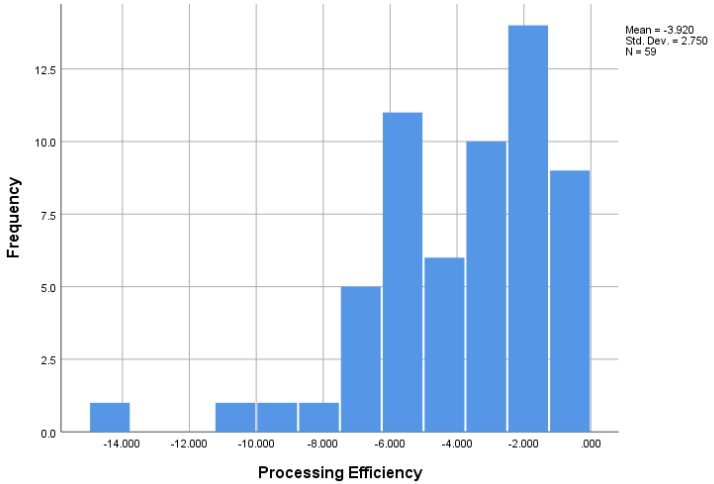
T.3) Distribution of Wisconsin Card Sorting Test (WCST)

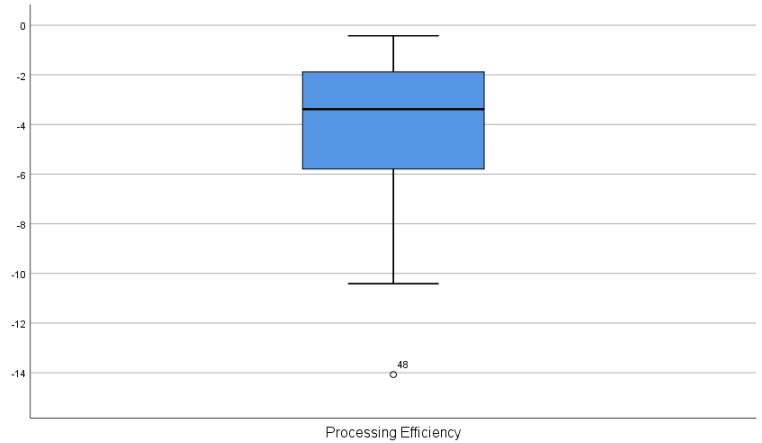


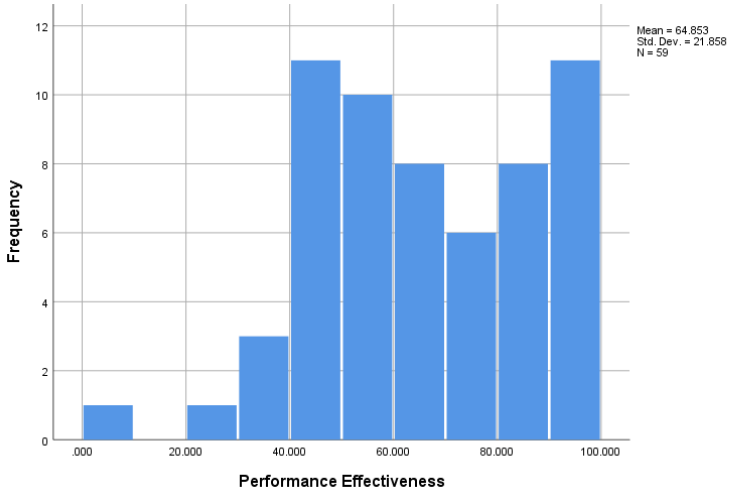


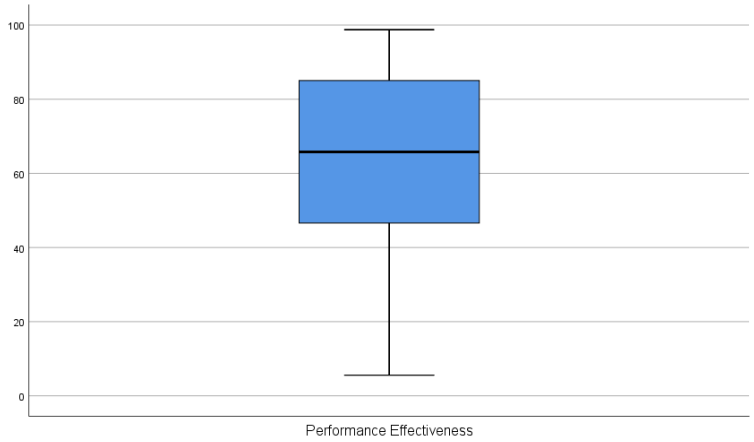




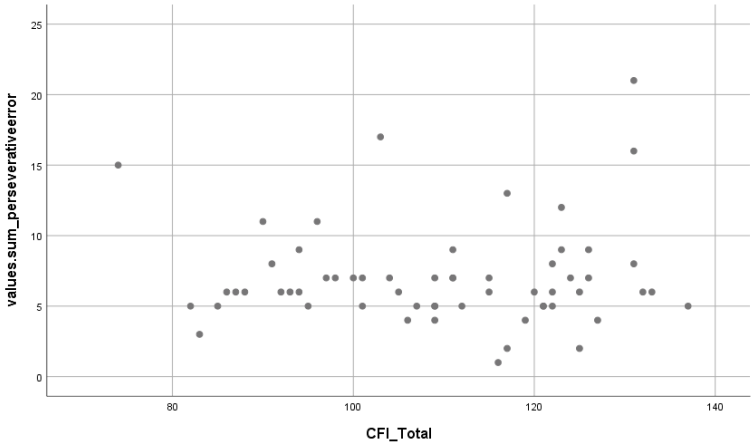

Mean = -3.920
Std. Dev. = 2.750
N = 59
Frequency
Processing Efficiency

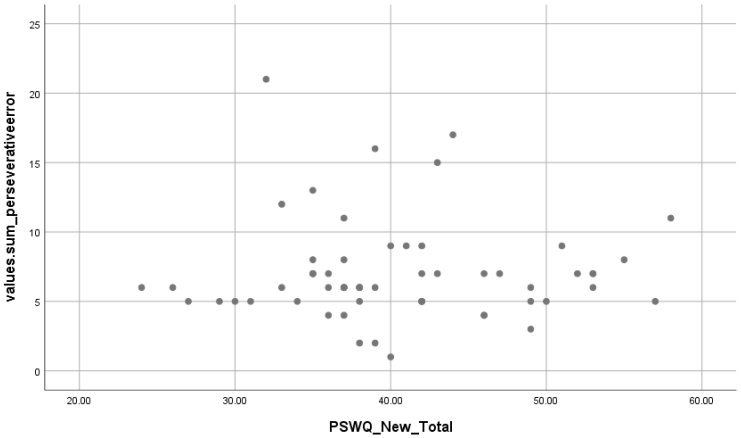

48
Processing Efficiency

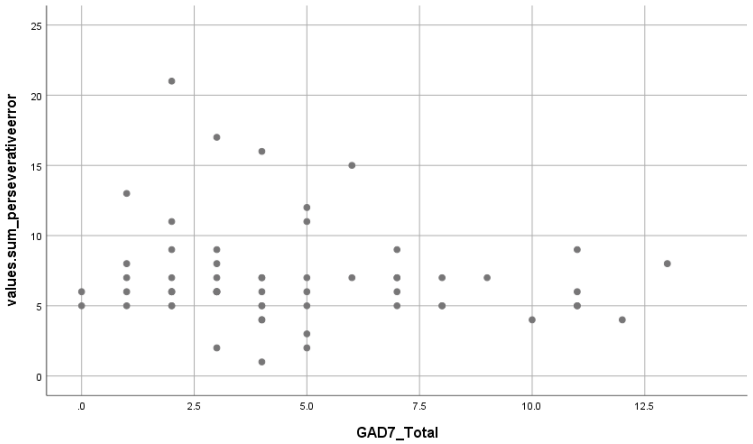

Mean = 64.853
Std. Dev. = 21.858
N = 59
Frequency
Performance Effectiveness

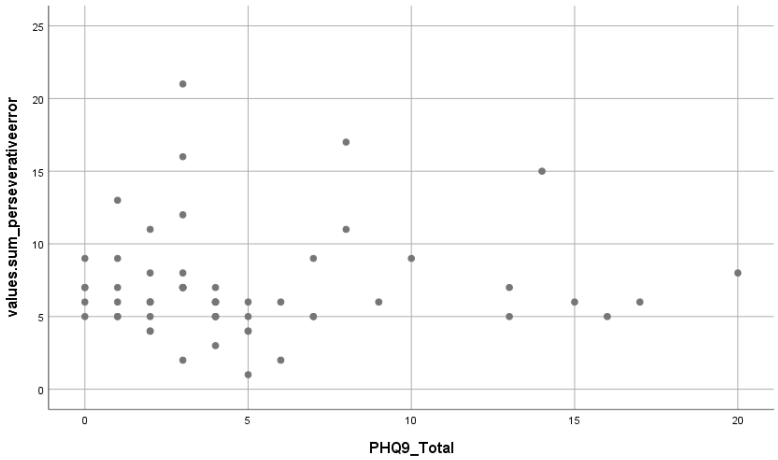

Performance Effectiveness

T.4) Monotonic Relationships between Performance on Wisconsin Card Sorting Test (WCST) and Self-Report Measures









T.5) Spearman's Rho Correlations between Performance on Wisconsin Card Sorting Test (WCST) and Self-Report Measures Controlling for Low Mood

Table T.5.
Spearman's Rho Correlations between WCST and Self-Report Measures controlling for low mood (PHQ9)

Variable	CFI Control	CFI Alt	CFI Total	IUS Prosp	IUS Inhib	IUS Total	PSWQ	GAD7
Total Errors	.001	-.128	-.085	.027	.044	.038	.227	.128
Total Perseverative Errors	.084	.007	.049	.429**	.190	.384**	-.023	-.198
% Perseverative Errors	.061	.155	.136	.104	.003	.072	-.235	-.241
Failure to Maintain Set	-.041	-.059	-.061	.015	.029	.024	.184	.252
Processing Efficiency	-.082	-.132	-.131	-.375**	-.151	-.323*	.029	.208
Performance Effectiveness	-.061	-.155	-.136	-.104	-.003	-.072	.235	.241
Switch Cost	.140	-.018	.062	-.030	-.087	-.060	-.219	-.053

Notes: N=59. CFI: Cognitive Flexibility Inventory; IUS: Intolerance of Uncertainty Scale; Prosp: Prospective subscale; Inhib: Inhibitory subscale; PSWQ: Penn State Worry Questionnaire; GAD7: Generalised Anxiety Disorder Assessment-7; PHQ9: Patient Health Questionnaire-9.
*p<0.05; **p<0.01.

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