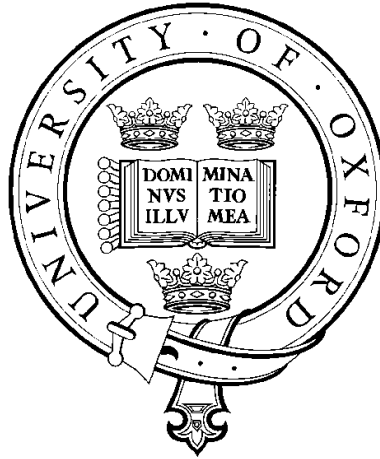




The influence of emotional stimuli on cognitive processing during transient induced mood states

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Abstract

Selective attention is a mechanism used to allocate resources to information processing. Both mood states and emotionally salient stimuli can influence which information is selectively attended. This information is subsequently processed in a more elaborative manner and affects task performance. The experiments presented in this thesis explore the influence of mood and emotional stimuli on selective attention and consequently task performance.

Mood induction procedures were used to induce transient neutral, sad, and happy mood states in healthy volunteers. A systematic review and meta-analysis of 41 studies using sad mood induction procedures showed cognitive impairments in performance in the context of task neutral stimuli. In contrast biases in attention towards mood-congruent negative stimuli led to improved task performance.

A series of three behavioural experiments with 197 participants demonstrated that participants made decisions on the basis of less information when that information was preceded by emotional but not neutral stimuli. Induced mood state did not affect performance.

The behavioural and neural correlates of visual attentional processing to emotional stimuli were explored using magnetoencephalography in 24 healthy participants following sad, happy, and neutral mood induction procedures. The M300, a component associated with selective attention, had greater amplitude following presentation of negative compared with positive stimuli, which was associated with improved task performance. Reduced M300 amplitude and impairments in performance occurred following sad mood induction procedures.

The experiments presented in this thesis demonstrate prioritized processing of emotional information and provide some evidence for impaired performance following sad mood induction procedures.

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Preface

We inhabit an environment in which there is a continuous flow of information. The processing of this information is, however, capacity limited and therefore requires a mechanism for selection. This mechanism, known as selective attention, distinguishes task-relevant or target information from task-irrelevant or non-target information for further processing. Such processing is required for conscious awareness and access to working memory, for example. Selective attention implies competition among information to become a target for further processing. This competition may be biased by physical properties of the stimulus material (e.g. emotionally salient stimuli) and state of the organism (e.g. mood).

One debate concerns the automaticity of the processing of emotional information; that is the question of whether the processing of emotional information occurs under the control of, or independently from, attention mechanisms. The experiments presented in this thesis aim to explore the influence of emotionally salient information on cognitive processing under conditions of limited cognitive capacity. In addition the influence of mood state was examined using Mood Induction Procedures (MIPs) to induce transient neutral, sad, and happy mood states in controlled, laboratory settings. The design of these experiments allows an investigation of the interaction of mood state and emotional stimuli. Traditionally, research has focussed on examining *either* cognitive impairments *or* biases using neutral *or* emotional stimuli, respectively. Here both cognitive impairments and biases were explored.

In addition to behavioural experiments, magnetoencephalography (MEG), a non-invasive method of functional brain imaging, was used to examine the neural activity associated with cognitive processing. The aim of this thesis was to develop and use paradigms to investigate the behavioural dynamics and spatiotemporal patterns of neural activity associated with the influence and interaction of mood state and emotional stimuli with attentional mechanisms and cognitive processing.

Chapter one provides an overview of the theories and models of attention, emotion, and mood. A review of theories of attention is followed by an introduction to the influence of emotionally salient stimuli and mood states as bottom-up (i.e. stimulus-driven) and top-down (i.e. goal-driven) mechanisms of selective attention, respectively.

Chapter two presents a systematic review and meta-analysis that aims to investigate the efficacy of sad MIPs at inducing mood change. This is followed by an exploration of the influence of sad induced mood on cognitive performance and bias in healthy participants. This is intended to enable conclusions about the extent to which changes in performance reflect global impairments or cognitive biases in information processing.

Chapter three describes a series of three experiments designed to assess the influence of emotion on inductive reasoning. 197 participants performed an emotional version of an inductive reasoning task following sad or happy and neutral MIPs.

Chapter four provides a summary of various methods of functional brain imaging techniques, including MEG, and their utility in examining the spatiotemporal patterns of neural activity associated with cognitive processes. This chapter also presents an overview of time-locked, stimulus-evoked components, or event related fields (ERFs), that are measured using MEG and have been associated with various neuropsychological functions.

Chapter five presents a study that investigates the behavioural and neural correlates of visual attentional processing in 24 healthy participants. An emotional version of the Rapid Serial Visual Presentation (RSVP) paradigm was designed and performed by participants in the MEG scanner following sad or happy and neutral MIPs.

Chapter six presents a summary and conclusions of the main findings of this thesis as well as suggestions for future research.

Abbreviations

2AFC	Two Alternative Forced Choice
AB	Attentional Blink
ANOVA	Analysis of Variance
BDI	Beck Depression Inventory
DSM	Diagnostic and Statistical Manual of Mental Disorders
EEG	Electroencephalography
ERF	Event Related Field
ERP	Event Related Potential
fMRI	functional Magnetic Resonance Imaging
M	Mean
MD	Major Depression
MEG	Magnetoencephalography
MIP	Mood Induction Procedure
POMS	Profile of Mood States
RMS	Root Mean Square
RSVP	Rapid Serial Visual Presentation
SCID	Structured Clinical Interview for DSM-IV-TR Axis 1 Disorders
SD	Standard Deviation
SOA	Stimulus Onset Asynchrony
SQUID	Superconducting Quantum Interference Device
STAI	State-Trait Anxiety Inventory
T1	First target (word)
T2	Second target (word)
TMD	Total Mood Disturbance
UMACL	UWIST Mood Adjective Checklist
VAS	Visual Analogue Scale

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Publications

Published work

Le Masurier, M., Hermann, L. L., **Coulson, L. K.**, and Ebmeier, K. P.
Physical Treatments in Bipolar Disorder.
Chapter in Alan Young, Erin Michalak and Nicol Ferrier (eds.) *“Practical Management of Bipolar Disorder: A Guide for Clinicians”*, Cambridge University Press.

Papers in submission

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Emotional valence, not arousal modulates the attentional blink and resource allocation: Behavioural evidence and electrophysiological markers

Papers in preparation

Coulson, L.K., Kalu, U.G., and Ebmeier, K.P.
A systematic review and meta-analysis of the effectiveness of depressive mood induction procedures.

Coulson, L.K., Ebmeier, K.P., and Lau, J.Y.F.
The influence of emotion on reasoning: results from a novel variation of the Beads Task.

Abstracts

Poster abstracts

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The use of mood induction procedures to investigate reasoning biases in depression: The beads task.
Department Scientific Day, University of Oxford, January 2009

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The attentional blink and mood induction.
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Oral abstracts

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The attentional blink phenomenon and mood induction.
MEG UK, Cardiff, January 2010

Chapter 1 General Introduction

“Everyone knows what attention is. It is the taking possession by the mind, in clear and vivid form, of one out of what seem several simultaneously possible objects or trains of thought. Focalization, concentration of consciousness are of its essence. It implies withdrawal from some things in order to deal effectively with others, and is a condition which has a real opposite in the confused, dazed, scatterbrained state...”

William James, 1890; pp. 403-404

1.1 Attention

Inherent in James’ definition of attention is the notion that only a subset of the continuous flow of information is selected and prioritised for further, more elaborative processing. This is achieved by a mechanism known as selective attention (Desimone & Duncan, 1995; James, 1890). That only a subset of information is selectively attended to suggests the existence of capacity limitations in the information processing system. Various theories of attention have been proposed to describe and explain the nature and magnitude of information processing that occurs before the capacity-limited ‘bottleneck’ of selective attention (for a comprehensive review of the theories see Näätänen, 1992).

1.1.1 Theories of attention

Proponents of filter theories argue that there is a single attentional bottleneck which occurs either at an early or a late stage of processing. Broadbent’s (1958) classical bottleneck theory of attention suggests that the physical properties of multiple incoming information are processed in parallel until they reach a filter (selective attention). At this stage only a single item may proceed (i.e. serial processing) into capacity-limited higher-level processing (short term memory); see Figure 1.1 A. Information that did not pass through the filter will not be processed beyond the initial pre-attentive stage. Although revolutionary in reviving the

interest of psychologists in exploring attention, this theory has since been criticised. It was not able to account for situations when non-attended, salient information (e.g. a person's own name) broke through this selective attentional filter in a 'bottom-up' (stimulus-driven) manner; for example in the 'cocktail party phenomenon' (Cherry, 1953; Moray, 1959). Two prominent and alternative models attempted to account for such findings: the filter attenuation theory (Treisman, 1960, 1964) and a late selection model (Deutsch & Deutsch, 1963). According to the filter attenuation theory, selective attention attenuates rather than blocks a stimulus in the unattended channel. When this stimulus is important or relevant to the individual (e.g. a person's own name), it has a lower threshold for activation and is more readily available for conscious report (Treisman, 1960, 1964); see Figure 1.1 C. The notion of attenuation contradicted Broadbent's 'all-or-nothing' approach to the filter mechanism. In contrast to the early selection models, it has been proposed that the attentional bottleneck or filter occurs at a later stage of processing. This late selection theory argues that all sensory stimuli are perceptually processed to the highest level (i.e. semantic processing) before the attentional bottleneck or filter (Deutsch & Deutsch, 1963); see Figure 1.1 B. The filter thus occurs at a late stage of perceptual processing and involves the matching of stimuli with some pre-specified criteria of interest/importance to the individual. The most important stimulus is selected for further processing (e.g. into short term memory), but this also allows for any subsequent important stimulus to break through and displace processing of the previously most important stimulus.

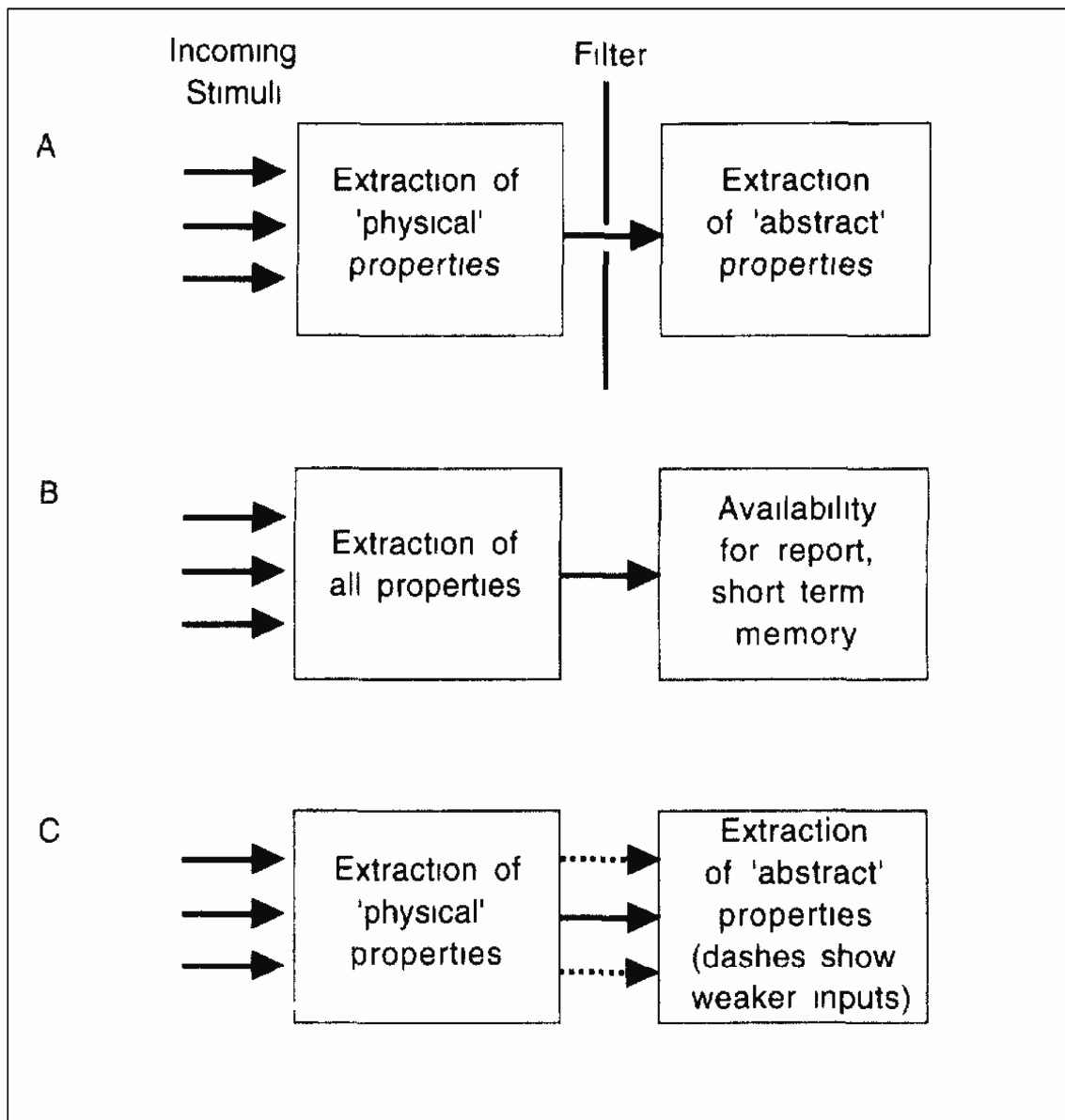


Figure 1.1: Schematic depiction of three theories of selective attention. A = early-selection theory (Broadbent, 1958); B = late-selection theory (Deutsch & Deutsch, 1963); C = attenuation theory (Treisman, 1960, 1964)

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These early and late theories of selective attention suggest that the bottleneck or filtering must occur at a particular stage of processing, due to the capacity-limited nature of information processing at (or beyond) that stage of processing (see Figure 1.1). In contrast

resource theories propose that the bottleneck may occur at any stage but depends upon the amount of processing resources available. Such theories assume that attention is shareable, flexible, and freely allocated (Näätänen, 1992). One particular resource theory proposes that when there is competition among stimuli to be processed, resources (which are capacity-limited) may be shared or divided between the concurrent stimuli (Wickens, 1980). The availability of limited resources has implications for task performance: the more difficult a (primary) task, the more resources are required. Therefore fewer are available for another (secondary) task, resulting in poorer performance of the secondary task if both tasks share common resources (Norman & Bobrow, 1975). Such theories assume that resources are somewhat heterogeneous, such that task performance does not deteriorate when multiple tasks require different information processing mechanisms.

In summary, proponents of these theories argue that information processing resources are capacity-limited and that the allocation of resources (by a filter or selective attention mechanism) leads to further, more elaborative processing of only a subset of the continuous flow of information and subsequently impacts upon task performance.

1.1.2 Voluntary and involuntary attention

That only a subset of information can be selected implies competition among items of information to become a target for further processing. William James (1890) proposed two types of attention: active voluntary and passive involuntary, which are now known as top-down and bottom-up, respectively (Desimone & Duncan, 1995). Top-down attention occurs when one actively and voluntarily attends to a stimulus, therefore the stimulus is chosen as the object of attention. Bottom-up or passive involuntary attention is initiated by the stimulus itself and can be caused by the physical (e.g. intensity or suddenness) or semantic properties of the stimulus. The ideas of top-down, active voluntary and bottom-up, passive involuntary attention may be considered in the context of the influence of mood state and salient stimuli

on information processing. It has been noted that *“selection is not completely random...[it is influenced by] certain properties of the events and by certain states of the organism”* (pp. 297; Broadbent, 1958). Another description of attention is that it can *“scan or focus on different objects depending on our momentary or permanent interests and goals [mood] as well as on the properties of the stimuli involved [emotional].”* (pp. 4; Näätänen, 1992). Bottom-up, Involuntary passive attention may be consistent with the idea that information processing might occur independently of capacity limitations and selective attention; also described as automatic processing. Posner & Snyder (1975) hypothesised three criteria that must be met in order for a process to be described as automatic:

- Without intention, involuntary,
- Without giving rise to conscious awareness, and
- Without producing interference with current mental activity, thus implying that automatic processing is independent of capacity limitations.

Although there has been debate about the meaning of the term ‘automatic’ (cf. Moors & De Houwer, 2006), researchers largely agree that such processing is rapid, occurs in parallel, and below the level of conscious awareness, and requires no or minimal processing resources. For the purposes of this thesis, the above definition of automaticity given by Posner & Snyder (1975) was adopted.

The aim of the next section is to provide an overview of the theories of emotion and mood and their interaction with (top-down active and bottom-up passive) attention mechanisms and information processing, and cognition.

1.2 Cognition, emotion, and mood

Mood and emotion were traditionally considered as anatomically and functionally separate entities from cognition and were, therefore, studied independently. Over the past few decades, however, there has been a surge of studies investigating the influence of mood states and emotional stimuli on attention and cognitive processing.

Affect is an overarching term that encompasses specific forms including emotion and mood (Rosenberg, 1998). In this thesis, emotion will be used to describe transient responses (i.e. lasting a few seconds) to an object or event (Ekman, 1984). Whereas mood describes an objectless state lasting for several minutes or hours (Oatley & Johnson-laird, 1987).

1.2.1 What is emotion?

There are two main ideologies that conceptualise emotions as best described by discreet categories or as (bipolar) dimensions.

It has been argued that to describe emotions adequately requires *“the identification of those dimensions that are both necessary and sufficient to define all emotional states”* (pp. 273; Russell & Mehrabian, 1977). Early theorists argued that emotions could be described by three dimensions: pleasantness-unpleasantness, excitation-inhibition, and strain-relaxation. Later, Russell (1980) proposed, and provided further justification for (Russell & Carroll, 1999) a two dimensional model of affect: pleasure-displeasure (or happy-sad) and arousal (aroused, tense, or excited-relaxed or sleepy); see Figure 1.2.

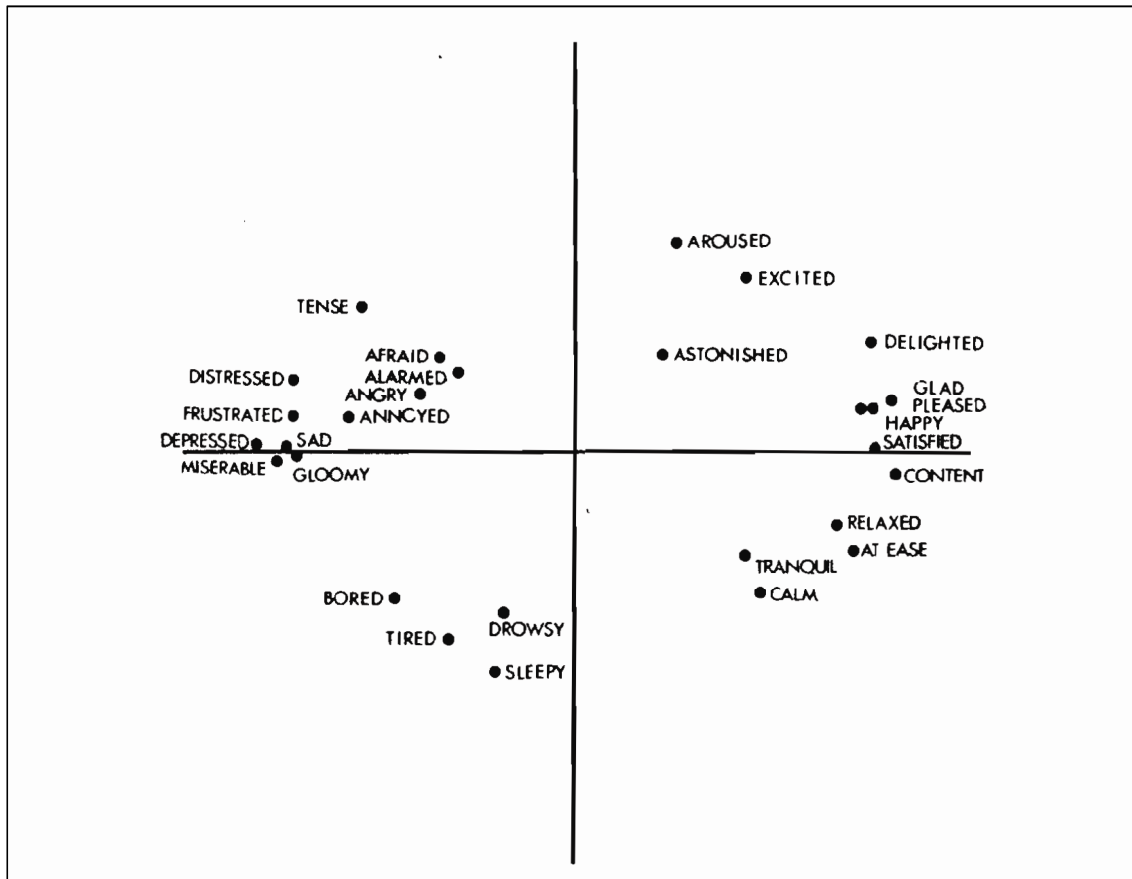


Figure 1.2: Regression weights for 28 affect words as a function of pleasure-displeasure (horizontal axis) and degree of arousal (vertical axis)

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This view of emotion as dimensional constructs is in contrast to those advocating discrete categories of, for example, positive and negative affect (Watson, Clark, & Tellegen, 1988). Consistent with latter is the idea that there are a set of universal, basic emotion concepts such as happiness, sadness, anger, fear, disgust, and surprise (Ekman, 1994).¹ Negative emotions have been categorised by their distinctive qualities into, for example, anger, disgust, fear, and sadness. It has been suggested that positive emotions are studied less because they are a

¹ Facial expressions associated with these emotion concepts have been shown to be universal i.e. across cultures and independent of learning (Ekman & Friesen, 1971). Accordingly facial expressions are considered important non-verbal signals that convey emotional information. For example, facial expressions of happiness and anger signal joy and threat and thus elicit approach and avoidance behaviour, respectively (Lang, Bradley, & Cuthbert, 1997; Tomkins, 1962).

more difficult concept to define, being called “*vague*” (pp. 3; Eysenck, 1990), “*obscure and mysterious*” (pp. 1; Argyle, 2001). However one researcher has categorised positive emotions as joy, interest, contentment, and love (Fredrickson, 1998).

The aim of this thesis is not to determine whether emotions are best described as dimensional or categorical, rather to investigate the influence of emotional stimuli (and mood states) on attention and cognitive processing. Indeed, the importance of integrating the dimensional and categorical perspectives has since been acknowledged (Russell, 2003).

One current and relatively long-standing topic of controversy is if emotional information is processed automatically: that is whether the processing of emotional information occurs under the control of or independently from attention. This debate will be introduced in the next section and addressed in the experiments presented in this thesis.

1.2.2 Attention and emotional stimuli

There are, broadly, two main schools of thought on the automatic (or ‘bottom up’) processing of emotional information. The proponents of one suggest that the mechanism performing the evaluation (computation) of the affective significance of a stimulus occurs outside of conscious awareness, very rapidly, automatically, and therefore independently of capacity limitations (LeDoux, 1989, 1998; Öhman, Flykt, & Lundqvist, 2000; Vuilleumier, Armony, & Dolan, 2003; Winkielman & Berridge, 2004; Winkielman, Berridge, & Wilbarger, 2005). Conversely, proponents of the other, namely Pessoa (2008), suggest that emotion processing may be prioritised but is dependent upon the available processing resources.

Based on the assumption that information processing is capacity-limited, techniques for measuring the automaticity of (emotional) information processing include manipulating the amount of resources available. There are four main methods that have been used for this purpose:

- Stimulus presentation time (e.g. supraliminal versus subliminal),
- Backward masking (e.g. presenting a stimulus immediately after the target stimulus),
- Task difficulty/demands, and
- Dual/divided attention tasks.²

Posner & Snyder's (1975) three criteria for an automatic process are that it occurs without intention, involuntarily; without giving rise to conscious awareness; and without interfering with current mental activity. Accordingly, it would be expected that subliminally presented and backward masked emotional stimuli would not give rise to conscious awareness; and would not interfere with current mental activity under conditions of dual/divided attention or increased task difficulty/demands when those stimuli are task-irrelevant, but may facilitate performance when task-relevant because, once processed, attention may be oriented towards those stimuli.

Researchers have shown that rapidly presented and backward masked emotional stimuli can be perceived without awareness (Merikle, Smilek, & Eastwood, 2001), and may influence and bias perception of - and participants approach and avoidance behaviour towards - subsequently presented, unrelated stimuli (Murphy & Zajonc, 1993; Winkielman, et al., 2005). Such findings support the affective priming hypothesis which states that emotional reactions to stimuli can occur even when those stimuli are presented extremely rapidly and under degraded visual conditions (Zajonc, 1980). However, researchers have demonstrated that the processing of task-irrelevant stimuli is dependent upon attention and working memory, such that under conditions of high task difficulty, task-irrelevant stimuli do not impair task performance (Doallo, Rodriguez-Hoiguin, & Cadaveira, 2006). This finding has also been shown for task-irrelevant emotional stimuli (Erthal et al., 2005; Okon-Singer, Tzelgov, & Henik, 2007; Pessoa, McKenna, Gutierrez, & Ungerleider, 2002), and negative compared with positive

² The influence of emotional stimuli on task performance in dual task paradigms will be addressed in Chapter 5: The Attentional Blink.

stimuli (Van Dillen & Koole, 2009).³ These findings demonstrate modulation of the influence of emotional stimuli on cognitive processing under conditions of low cognitive load, i.e. when there is working memory capacity available. This argues against the notion of the automatic processing of emotional stimuli. Accordingly, it has been suggested that researchers should focus not on whether or not perception of emotional stimuli occurs without attention, but rather on the conditions (e.g. task demands) that mediate the relationship between attention, awareness, and perception of emotional stimuli (Pessoa, 2008).

Prioritization of the processing of emotional information demonstrates bottom-up (or stimulus driven) mechanisms. However evidence to suggest the influence of top-down (or attentional control) mechanisms on this processing indicates an interaction between bottom-up and top-down (or goal-directed) mechanisms. The next section aims to introduce the influence of a different top-down mechanism on attentional control of processing: mood state.

1.2.3 Mood states

Mood states such as sadness and happiness are object-free and relatively enduring emotional states lasting for several minutes or hours (Oatley & Johnson-laird, 1987). In the framework of the two-dimensional model of affect (Russell, 1980), sadness (or depression) and happiness are at bipolar opposites of the dimension pleasure-displeasure but are similar on the dimension of arousal (moderate); see Figure 1.2.

Major Depression (MD) is a complex, heterogeneous disorder characterised by affective symptoms including a persistent negative mood state (depressed mood) and anhedonia (the loss of pleasure and interest in previously enjoyed and rewarding activities): American Psychiatric Association Diagnostic and statistical manual of mental disorders (4th ed.; DSM-IV; American Psychiatric Association, 1994). These symptoms coexist with cognitive (and physical)

³ Individuals demonstrating an asymmetry in their processing of negative compared with positive or neutral information, such that negative stimuli are prioritised, are said to show a negativity bias (for a review see Baumeister, Bratslavsky, Finkenauer, & Vohs, 2001).

symptoms including a diminished ability to think and concentrate, recurrent thoughts of death and suicidal ideation, and a profound sense of worthlessness.

The components of happiness include a positive emotional state such as joy, satisfaction or subjective well-being, and the absence of negative emotional states such as depression and anxiety (Argyle, 2001; Eysenck, 1990).

1.2.4 Mood and cognition

Researchers are interested in exploring the influence of mood states on cognitive processing, however the focus of many investigations has been on negative mood. This is most likely because negative mood is associated with the psychopathology of problems such as depression and anxiety. Although extremes of positive mood are implicated in the psychopathology of various disorders (such as mania in Bipolar Disorder, and addiction), it is only more recently that researchers have begun to investigate positive mood per se. The aim of this section is to present a summary of the influences of both negative and positive mood on attention. Derryberry & Tucker (1994) suggested that there are two ways in which mood influences attention:

- It can broaden or narrow the focus of attention (a general influence), and
- It directs attention towards particular information that is of importance to the individual's current state (a specific influence).

With regard to the *general* influence, negative mood is associated with impairment in various measures of cognitive processing including attention, memory, and psychomotor skills (Austin, Mitchell, & Goodwin, 2001; Castaneda, Tuulio-Henriksson, Marttunen, Suvisaari, & Lönnqvist, 2008; Herrmann, Goodwin, & Ebmeier, 2007; Rogers et al., 2004). In contrast, a plethora of work by Isen and colleagues (for reviews see Fredrickson, 2001; Isen, 2000) showed that positive mood increases cognitive elaboration and flexibility, alongside more creative, variable,

and flexible thinking, as well as thorough and efficient problem solving. The Broaden and Build model of positive mood (Fredrickson, 1998, 2001) suggests that happy mood states *broaden* the focus of attention, cognition and behaviour, and repeated experience of these happy mood states *builds* resources that produce lasting effects on health and well-being.

The aim of the next section is to briefly review the theories and evidence of the *specific* influence of mood state on directing attention towards emotional information, which has implications for cognitive processing.

1.2.5 The interaction of emotional stimuli and mood states

Similar to Derryberry & Tucker (1994), Desimone & Duncan's (1995) biased competition model of selective attention postulates that competition between incoming information to become a target for further processing is biased by the relevance of that information to an individual's current state (e.g. goal-oriented or top-down mechanisms). The relevance of the information may be determined by features of the stimuli, therefore selective attention proceeds via an interaction between bottom-up and top-down mechanisms.

Mood-congruent attention (or cognitive) biases occur when individuals in a particular mood state preferentially attend to emotional stimuli that match their mood state. Multiple theories of depression predict cognitive biases across all domains of information processing including perception, attention, and memory (Beck, 1989; Bower, 1981).⁴ In contrast, however, it has been argued that cognitive biases in depression occur when there is elaboration of the stimulus. Therefore they only occur when the stimuli are presented in such way that they are not processed automatically (Williams, Watts, MacLeod, & Mathews, 1997). Although there is some evidence to suggest that negative attention biases in depression are associated with

⁴ Beck's cognitive model of depression (Beck, 1989) predicts that the negative schemas that characterise depression dominate information processing in the form of negative automatic thoughts, constructs and perspectives. Bower's network theory (1981) predicts that an individual's current mood state increases the salience of congruent emotional information which has implications for perception, attention, memory, and learning.

conscious awareness of the stimuli (Bradley, Mogg, & Lee, 1997; Koster, De Raedt, Goeleven, Franck, & Crombez, 2005; Mogg, Bradley, & Williams, 1995), this remains a current topic of debate (cf. Peckham, McHugh, & Otto, 2010). Various paradigms will be used to contribute experimental findings to this debate in Chapter 3: Inductive Reasoning and Chapter 5: The Attentional Blink.

One recent, comprehensive review explored the interaction of attention and emotion in studies including populations of individuals with naturally varying and transient induced mood states (Yiend, 2010). Mood induction procedures (MIPs) are used to induce transient mood states in healthy participants. Methods of mood induction and a review of their effectiveness as well as their influence on multiple domains of cognition will be provided in Chapter 2: Sad Mood Induction: A Systematic Review.

1.3 Aims

The work presented in this thesis aims to provide a systematic review and meta-analysis of the effectiveness of MIPs at inducing sad and happy mood states and the influence of mood on cognitive processing and biases across a range of tasks probing multiple domains of information processing (see Chapter 2: Sad Mood Induction: A Systematic Review).

Following this, experimental studies are presented which were designed to examine the influence of emotional stimuli, mood state, and their interaction with attention and cognitive processing under conditions of rapid stimulus presentation, backward masking, and varying task load (see Chapter 3: Inductive Reasoning) as well as dual/divided attention tasks (see Chapter 5: The Attentional Blink).

Chapter 2 Sad Mood Induction: A Systematic Review

“very little is known about the degree to which cognitive biases may be related to the occurrence of cognitive deficits, and vice versa”

Stephen Ilardi et al., 2007; pp.176

2.1 Abstract

Over the past few decades there has been a surge of studies investigating the influence of mood on cognitive processing. Mood induction procedures have been extensively used in healthy participants as a preclinical model of depression to investigate the relationship between cognition and affect. Some models of depression and some researchers emphasise cognitive impairments. Others highlight cognitive biases wherein individuals in a particular mood state preferentially process emotional information matching that mood state.

The aim of this chapter is to review the methods used to induce mood and conduct a meta-analysis to investigate the effectiveness of sad mood induction procedures to induce mood change. After establishing the efficacy of mood induction procedures, a systematic review was conducted to examine the influence of induced sad mood on both cognitive performance and bias in healthy participants. This qualitative review was supplemented by quantitative meta-analyses of these effects in a subset of studies with the appropriate data available.

2.2 Introduction

Major Depression (MD) is a complex, heterogeneous disorder characterised by affective, cognitive, and physical symptoms. As outlined in Chapter 1: General Introduction, previous reviews report that patients with depression demonstrate *impairments* in various measures of cognitive processing including executive functioning (selective attention, working memory, cognitive flexibility, set shifting and planning/problem solving), processing speed and episodic memory (immediate and delayed recall, learning and recognition) (Austin, Mitchell, & Goodwin, 2001; Castaneda, Tuulio-Henriksson, Marttunen, Suvisaari, & Lönnqvist, 2008; Herrmann, Goodwin, & Ebmeier, 2007; Rogers et al., 2004), which worsen with increasing severity of depression (McDermott & Ebmeier, 2009). In addition to general impairments, patients with depression show cognitive biases across multiple domains of information processing including perception, attention (Peckham, McHugh, & Otto, 2010; Yiend, 2010), and memory (Williams, Watts, MacLeod, & Mathews, 1997). These findings are in keeping with the predictions of various models of depression (A.T. Beck, 1989; Bower, 1981).

Researchers have developed and used a variety of laboratory techniques, including Mood Induction Procedures (MIPs), to induce transient depressed mood states in healthy participants as an analogue of clinical depression to investigate depression-related impairments and biases. Following depressive mood induction both patients with MD and healthy volunteers demonstrate a *negative (or mood-congruent) cognitive bias* which affects performance on a wide range of tasks (for reviews see Blanchette & Richards, 2010; Bower, Sahgal, & Routh, 1983; Goodwin & Williams, 1982; Yiend, 2010).

Studies using MIPs in healthy volunteers do not suffer from the confounding effects of comorbid diagnoses, medication, psychological therapy, and physical illness, which may lead to variability of results both within and between studies investigating patients with clinical

depression (Rose & Ebmeier, 2006). Furthermore, because mood is induced experimentally, researchers can examine multiple mood states (e.g. sad, happy, and neutral) in a within-subjects design. Such a design would be restricted in patients with depression by the time course of natural variations in mood state, and confounded by potential treatment side effects. Alternatively, researchers might investigate natural variations in mood state in a non-clinical population (for example, dysphoric and non-dysphoric participants); however it may be difficult to attribute any effects to state versus trait aspects of mood.

The Velten MIP was one of the first and most widely used methods in which participants were presented with a set of 60 self-referential statements that gradually progressed from neutral to sad or happy (Velten, 1968). Researchers have subsequently varied this method by the number and duration of presentation of these statements (Seibert & Ellis, 1991). A review of 46 studies using the Velten MIP to induce sad, happy, and neutral mood states concluded that successful mood induction using self-report measures occurred in 67% of studies (Kenealy, 1986). Furthermore a review of almost 250 studies using a variety of MIPs demonstrated that 80% of studies using the Velten MIP were $\geq 75\%$ effective at inducing a sad or happy mood state (Gerrards-Hesse, Spies, & Hesse, 1994). In a follow-up of this review, a meta-analysis confirmed that Velten MIPs demonstrated medium effect sizes (Cohen's $d = 0.5$ to 0.8 ; Cohen, 1977) for inducing sad and happy mood states (Westermann, Spies, Stahl, & Hesse, 1996). Despite early evidence for the effectiveness of the Velten MIPs (Hale & Strickland, 1976; Strickland, Hale, & Anderson, 1975), some studies reported that a proportion of participants were unresponsive to the procedure (for example Sutherland, Newman, & Rachman, 1982; Teasdale & Fogarty, 1979). Therefore researchers have since developed and used a variety of methods for inducing mood states including listening to music (Pignatiello, Camp, & Rasar, 1986; Sutherland, et al., 1982), watching film clips (Isen & Gorgoglione, 1983), autobiographical recall (Brewer, Doughtie, & Lubin, 1980), success/failure or feedback manipulation (Chartier & Ranieri, 1989), making (Laird, Wagener, Halal, & Szegda, 1982) or

viewing (Schneider, 1994) facial expressions of emotion, and a combination of methods (Spies, Hesse, Gerrards-Hesse, & Ueffing, 1991). A brief summary of the results of reviews and meta-analyses investigating the effectiveness of these MIPs at inducing the intended mood state is provided in Table 2.1.

	Percentage successful induction		Effect size (Mean weighted effect)	
	(Martin, 1990)	(Gerrards-Hesse, et al., 1994)	(Westermann, et al., 1996) ¹	
	Sad mood	Sad mood	Sad mood	Happy mood
Combination	-	-	0.759	-
Autobiographical recall	75	-	-	-
Facial expressions	50	-	0.08	0.193
Feedback	50-75	92	0.56	0.329
Film clips	75	94	0.743/0.499*	0.726/0.533*
Imagination/visualisation	-	100	0.522	0.359
Music	75	-	0.503/0.410*	0.333/0.317*
Self-referential statements	50	80	0.519	0.376

Table 2.1: Summary of the reviews and meta-analyses investigating the effectiveness of different types of MIPs at inducing sad and happy mood states

*=With/without instruction. ¹ = A correlation value was z-transformed and interpreted according to Cohen's d value (Cohen, 1977) such that values of 0.2, 0.5, and 0.8 correspond to small, medium, and large effect sizes, respectively.

In summary, the use of MIPs in healthy participants in a controlled, laboratory setting provides an opportunity for systematic and clinically relevant investigations of cognitive impairments and biases during various mood states.

2.2.1 Aims and hypotheses

The aim of this systematic review and meta-analysis was to first quantitatively analyse and confirm the effectiveness of MIPs at inducing sad mood states in healthy participants. As previously noted, MIPs are not effective in all participants therefore meta-regression was used to investigate the influence of current depressive symptoms and baseline (pre-MIP) mood state on the effectiveness of MIPs. After using these methods to establish the efficacy of MIPs, the aim was to investigate the influence of mood state on cognitive impairment and cognitive bias across a range of tasks designed to probe multiple domains of information processing.

This was intended to enable conclusions to be made that may have clinical relevance to the pathophysiology of depressive disorders.

It was hypothesised that:

- Participants would report greater negative affect following a sad compared with control (neutral and/or happy) MIP.
- Participants would demonstrate impairments in various measures of cognitive processing following a sad compared with control (neutral and/or happy) MIP.
- Impairments in cognitive processing following a sad MIP would be reduced in the context of task-relevant, mood-congruent (i.e. negative) stimuli and increased in the context of task-irrelevant, mood-congruent stimuli.
- Participants would demonstrate a bias towards negative stimuli.

2.3 Methods

2.3.1 Literature search

The scientific quality of this systematic review was informed by various AMSTAR statements prior to the search (Shea et al., 2007); see Appendix 1.1.

2.3.1.1 Data sources

Online searches of the databases Embase and MEDLINE¹ from 1990 were performed in November 2009, using the keywords 'mood induction' (which resulted in the search terms "induction", "mood", and "mood induction").

¹ Initially, a comprehensive literature search was performed using the databases EMBASE, Medline, and PsycINFO. Pre-defined search criteria determined that only original, peer-reviewed articles published in journals were to be included. However, there were a large number of dissertation abstracts identified in PsycINFO, which could not be automatically removed from the search or results; therefore it was decided to perform the search without using the PsycINFO database.

2.3.1.2 Study selection

Studies investigating mood induction and cognitive processing were included in this systematic review. Titles and abstracts were screened by two authors (Louisa Katie Coulson and Ukwuori-Gisela Kalu, Research Assistant) for the following inclusion criteria: original peer-reviewed journal articles, presenting a behavioural investigation of the effect of sad MIPs on cognitive processing in healthy adults with no current psychiatric diagnosis. Following this, full-text articles were retrieved and screened to ensure they met the inclusion criteria above. A flow diagram of the identification and attrition of studies is provided in Figure 2.1. In addition to a qualitative review of the literature, meta-analyses were conducted in a subset of those studies included in the qualitative review with the appropriate data available. Flow diagrams of the number of studies included are provided in Figure 2.2 and Figure 2.3 for mood state and task performance analyses, respectively.

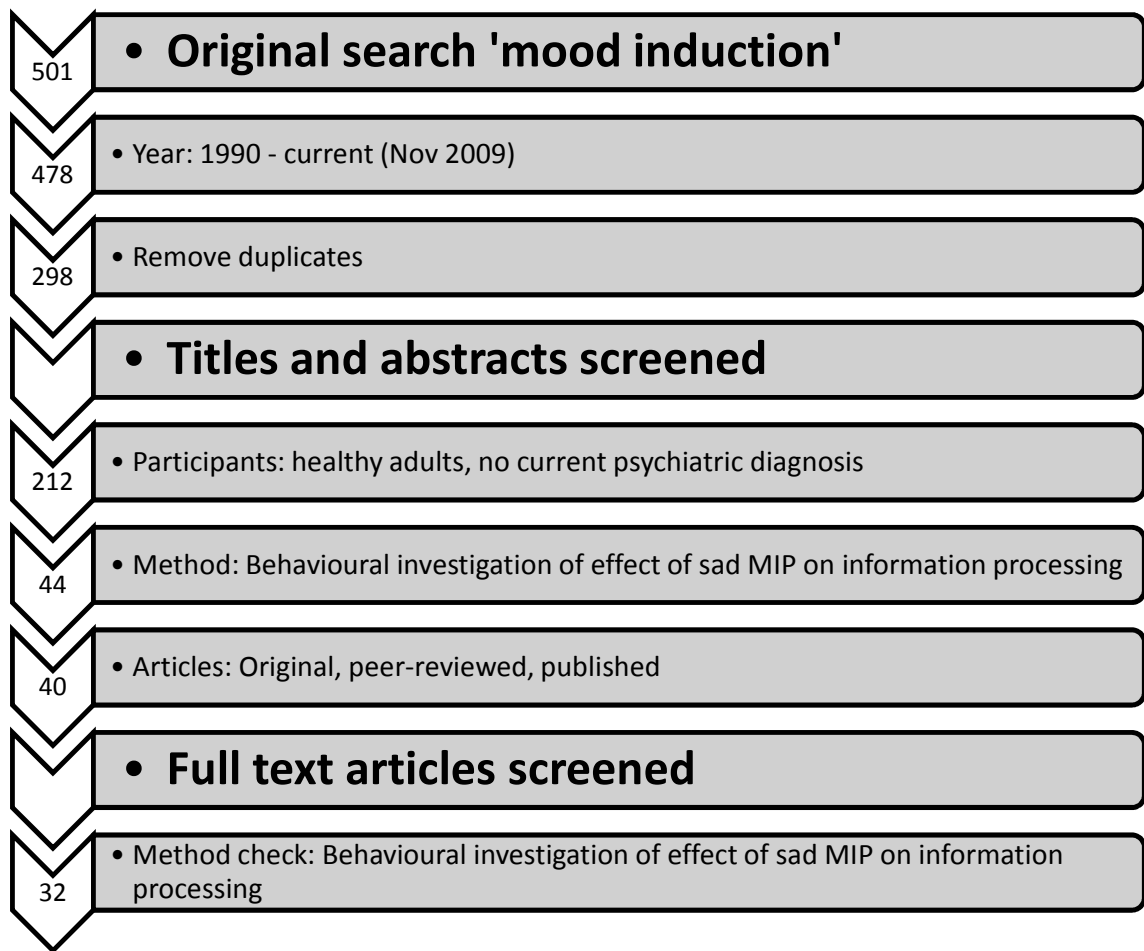


Figure 2.1: Identification and attrition of articles to be included in the systematic review

2.3.2 Review: data extraction and synthesis

Key details regarding the participants, method of mood induction, measurement of mood, method and measurement of cognitive processing, and data analysis were recorded for all studies using a structured data abstraction form.

2.3.3 Meta-analysis: data extraction, synthesis and statistical analysis

2.3.3.1 Data analysis

Studies included in the systematic review that reported means and standard deviations of measures of mood state (see Figure 2.2) and task performance (see Figure 2.3) or reported sufficient data for these to be derived (i.e. p -values from t -tests) were entered into the meta-analyses. If studies reported $p < 0.05$ or $p < 0.01$, a conservative estimate of $p = 0.049$ or $p = 0.01$ was assumed. Where means and standard deviations or p -values were not reported, authors were contacted and asked to provide these data.

Data included statistical comparisons between-groups (e.g. sad and neutral and/or sad and happy), as well as within-group comparisons (e.g. comparing pre- with post-sad MIP). For the between-group comparisons, data were entered as though separate studies following sad, neutral, and happy MIPs.

Data were analysed using Comprehensive Meta-Analysis (version 2.2.048, Biostat, Inc., Englewood, NJ, USA; www.Meta-Analysis.com) and a significance threshold of $p < 0.05$ was adopted. For the analysis of the effect of MIPs on mood state, it was decided *a priori* to use a random- rather than fixed-effect model. This model did not rely on any assumptions about the homogeneity of effect sizes (due to participant demographics [e.g. age and gender], MIPs, and other design features) across the studies. For the analysis of cognitive processing, a fixed-effect model was used to combine effect sizes from multiple outcome measures of a single study. A fixed- rather than a random-effect model was used because the variance between outcome measures was not thought to be systematically affected by different design features,

as outcomes were computed within each study (not pooled across studies). A fixed-effect model was used for the planned meta-regression analyses of current depressive symptoms and baseline (pre-MIP) mood state on the effectiveness of MIPs and cognitive processing. In accordance with published guidelines meta-regression was only conducted for continuous variables when six or more studies, and categorical variables when four or more studies, had the required data available (Fu et al., 2010).

Effect size was measured using Hedges's g to correct for sample size (Hedges & Olkin, 1985). Effect sizes between 0.2 and 0.5, 0.6 and 0.8, and greater than 0.8 were classified as small, medium, and large, respectively. Cochran's Q and I^2 were used to assess heterogeneity (Higgins, Thompson, Deeks, & Altman, 2003; Huedo-Medina, Sánchez-Meca, Marín-Martínez, & Botella, 2006). Cochran's Q computes the deviation of the estimate of each study from the overall meta-analytic estimate and derives a p -value of the significance of heterogeneity from this. I^2 provides a percentage of the total variation across studies due to heterogeneity with 0% indicating no variation due to heterogeneity. Where there was significant heterogeneity in either of these measures, fixed-effect meta-regression with Hedges's g was performed using age, percentage female participants, and number of methods of MIPs used (0=one method, 1=more than one method). This was in addition to the *a priori* planned meta-regression analyses using measures of current depressive symptoms and baseline (pre-MIP) mood state. Selection of studies was restricted to peer-reviewed published journal articles, which are more likely to report significant results. Accordingly publication bias² was assessed using Begg and Mazumdar's rank correlations (Begg & Mazumdar, 1994) as well as Egger's regression intercept (Egger, Smith, Schneider, & Minder, 1997).

² Publication bias occurs when authors are more likely to submit, or editors accept, positive than null (negative or inconclusive) results. These tests explore whether studies with a smaller sample size are more likely to report significant results than those with a larger sample size. This is based on the assumption that it is easier to publish positive than negative results from studies with small sample sizes, whereas publishers might more readily accept studies reporting negative results with larger sample sizes.

2.3.3.2 Efficacy of mood induction procedures

Meta-analyses were conducted to compare post-MIP mood state following sad compared with control (neutral and/or happy) MIPs. Furthermore, as the comparisons of sad and control (neutral and/or happy) MIPs did not account for baseline (pre-MIP) mood ratings, meta-regression was conducted in the subset of studies that provided measures of pre-MIP mood state. For those studies that did not include a control (neutral and/or happy) MIP, as well as those studies for which data were available, mood state was compared pre- and post-sad MIP. A meta-analysis was also planned to compare mood state post-sad MIP and post-task to investigate endurance of the effect of MIPs on mood state. However this analysis was not performed due to the small number of studies (N=2) with the required data.

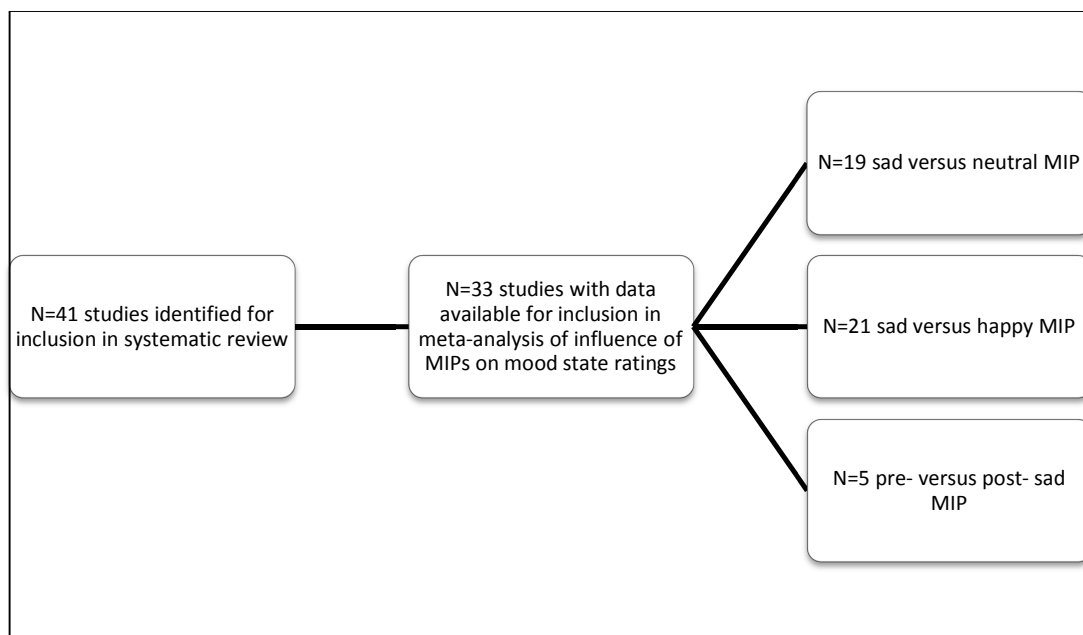


Figure 2.2: Number of studies included in meta-analyses of the effects of sad MIPs on mood state ratings

Some studies used multiple mood measures and their subscales. Here, selection criteria were closely aligned with those of a previously published meta-analysis (Westermann, et al., 1996). Specifically, standard scales including the Depression Adjective Checklist (DACL; Lubin, 1967), Multiple Affect Adjective Checklist (MAACL; Zuckerman & Lubin, 1965), Positive and Negative

Affect Schedule (PANAS; Watson, Clark, & Tellegen, 1988), and Profile of Mood States (POMS; McNair, 1992) were chosen over self-constructed scales such as Visual Analogue Scales (VAS), which were in turn chosen over other self-report measures. For those studies using multiple subscales, the measure deemed most appropriate to the induced mood state was chosen; for example the PANAS negative (as opposed to positive) affect scale (Watson, et al., 1988) when comparing sad and neutral MIPs.

2.3.3.3 Effect of mood induction procedures on cognitive task performance

Meta-analyses were then conducted to assess task performance in studies using neutral stimuli, task-relevant negative stimuli, and task-irrelevant negative stimuli following sad compared with control (neutral and/or happy) MIPs. Task-relevant refers to tasks in which the emotionally salient stimuli are those on which participants are required to perform a task. For example, participants are presented with pictures and asked to determine whether the pictures are neutral, negative, or positive (Hermans, De Houwer, & Helen, 1996). In contrast, task-irrelevant refers to tasks in which the emotionally salient stimuli are superfluous to task performance. For example, in the dot-probe task participants are presented with a dot that appears at one of two possible locations (e.g. above or below a fixation cross) and are required to determine the location at which the dot appeared (Bradley, Mogg, & Lee, 1997). Prior to presentation of the dot, two words appear (one neutral and one emotional), one at each location, but these words are irrelevant to determining where the dot appeared. Despite these words being task irrelevant, researchers have reported longer response times for participants to determine the location of the dot when the dot appears at the opposite location to the previously presented emotional word, suggesting attentional capture by the emotionally salient, task-irrelevant stimuli.

Meta-analyses were also conducted in those studies that did not measure task performance that was quantifiable as correct/incorrect, but rather measured bias towards/away from emotional stimuli. In one study the authors presented participants with words to be composed

into a meaningful sentence and the solutions could be either negative or positive. For example “was glass half empty the full” could be unscrambled to be “the glass was half empty” (negative solution) or “the glass was half full” (positive solution) (Beevers & Meyer, 2008). There were no right or wrong answers but a negative or positive bias could be determined.

Some studies used multiple measures of cognitive processing. Here, a fixed-effect model was used to combine across multiple outcome measures from a single study and yield the overall effect. When different tasks were used within the same study, the results were pooled across measures within each task but not across tasks.

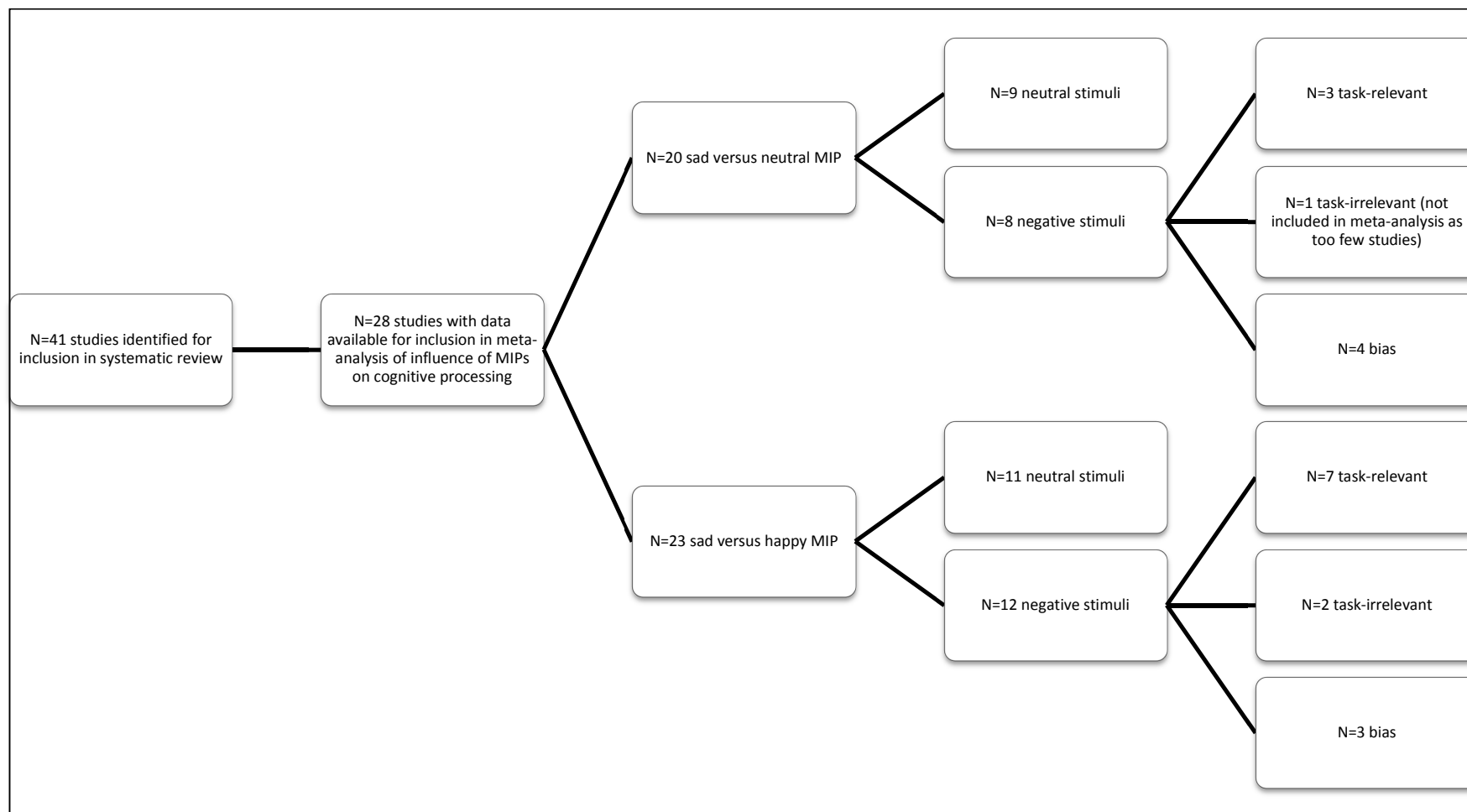


Figure 2.3: Number of studies included in meta-analyses of the effects of sad MIPs on cognitive processing

Studies were classified according to those that investigated cognitive processing, using neutral stimuli or negative stimuli. The latter were further subdivided into those studies in which negative stimuli were either task-relevant or task-irrelevant, or independent of task-performance and as such measured bias.

2.4 Results

Titles and abstracts of 298 identified citations were screened and 40 full-text articles were retrieved. A total of 41 studies reported in 32 articles met criteria to be included in this review. A flow diagram of the identification and attrition of studies is provided in Figure 2.1. Tables with participant demographics and results are provided in Appendix 1.2, and 1.3, respectively.

2.4.1 Meta-analysis: efficacy of mood induction procedures

Of those studies included in the review, 33 met criteria for inclusion in at least one of the meta-analyses of the effect of MIPs on self-report mood state (see Figure 2.2). Four studies did not meet criteria for inclusion in the meta-analyses; two only presented data for participants meeting a pre-defined mood change criterion so these data were not representative across all participants and would therefore have biased the results (Bisson & Sears, 2007; Kenealy, 1997). Another study did not present the required data (Klauer, Siemer, & Stöber, 1991). One study induced sad, angry, and anxious MIPs and did not compare mood state pre- and post-sad MIP (Siemer, 2001; study 1). For some studies included in the meta-analyses data were combined, using weighted means and standard deviations, across various participant and task characteristics including age (Ferraro, King, Ronning, Pekarski, & Risan, 2003; Knight, Maines, & Robinson, 2002; Phillips, Smith, & Gilhooly, 2002), trait measures (Kanayama, Sato, & Ohira, 2008), mood responders and non-responders (Kliegel et al., 2005), task blocks (MacLeod & Campbell, 1992) and different types of tasks (Jacoby, Brewin, & Watkins, 2008), and groups with the same MIP at encoding in mood-consistent retrieval studies³ (Philpot & Madonna, 1993).

³ Mood-consistent refers to those studies in which participants are induced into a mood state then given a list of items to memorise. Following this they are induced into the same/different mood state and asked to retrieve the list of items from memory.

The results of these meta-analyses showed that sad MIPs were effective at inducing the intended mood state when compared with neutral (see Figure 2.4) and happy MIPs (see Figure 2.5), as well as before and after a sad MIP (see Figure 2.6). Hedges's g was significant ($p's < 0.001$) in all three comparisons and represented a large effect size in the sad compared with neutral and happy MIP comparisons (see Table 2.2). The number of studies in each of the comparisons showing significant effects of the MIPs on mood state in the expected direction is presented in Table 2.2.

Comparison	N ^A	Hedges's g and 95% confidence interval				Heterogeneity			
		Hedges's g	p -value	Lower limit	Upper limit	Q-value	Q (df)	p -value	I^2
Sad vs. Neutral	17/19	-0.90	<0.0001	-1.21	-0.59	93.70	18	<0.0001	80.79
Sad vs. Happy	21/21	-1.52	<0.0001	-1.86	-1.19	122.54	20	<0.0001	83.68
Pre- vs. post-sad MIP	5/5	-0.40	<0.0001	-0.53	-0.28	1.87	4	0.7587	0

Table 2.2: Weighted mean effect sizes, 95% confidence intervals and measures of heterogeneity and bias in the meta-analyses of mood state data

Significant effects in red. ^ANumber of studies showing significant effects of MIPs on mood state in the expected direction/Number of studies included in the meta-analyses.

Due to the small number of studies ($N=2$) with the appropriate data available to compare mood state post-sad MIP and post-task, a meta-analysis was not performed. However the means of mood state ratings could be used to investigate endurance of the effect of MIPs on mood state (see Table 2.3). Across all studies, participants reported less negative/more positive affect after the task compared with immediately after the MIP. Nevertheless, in all of those studies that asked participants to rate their mood state at baseline (before the MIP), participants reported greater negative/less positive affect after the tasks compared with before the MIP.

1 st Author (Measure)	Pre-sad MIP	Post-sad MIP	Post- task
Allwood (4-point VAS pleasantness)	3.12 ^A	2.61 ^A	2.85 ^A
Badcock (PANAS negative affect)	13.31	18.78	14.43
Ferraro, combined age (DACL)	-	10.80	10.14
Jacoby, combined across tasks (10-point dysphoria VAS)	-	54.02	36.03
Kliegel, combined responders and non-responders (Unpleasant-pleasant scale)	12.81 ^A	9.97 ^A	11.10 ^A
Knight, combined age (DACL)	7.06	13.31	9.74
MacLeod (60-point happy-unhappy VAS)	-	26.30	23.23
Phillips, combined age (PANAS pos minus neg affect)	10.13 ^A	0.41 ^A	2.44 ^A
Stopa (100-point despondency VAS)	24.67	32.67	30.33

Table 2.3: Mean mood state ratings before and after sad MIPs and after task performance.

^AGreater score reflects greater positive affect; for all other data, greater score reflects greater negative affect.

Effect of sad versus neutral MIP on mood state

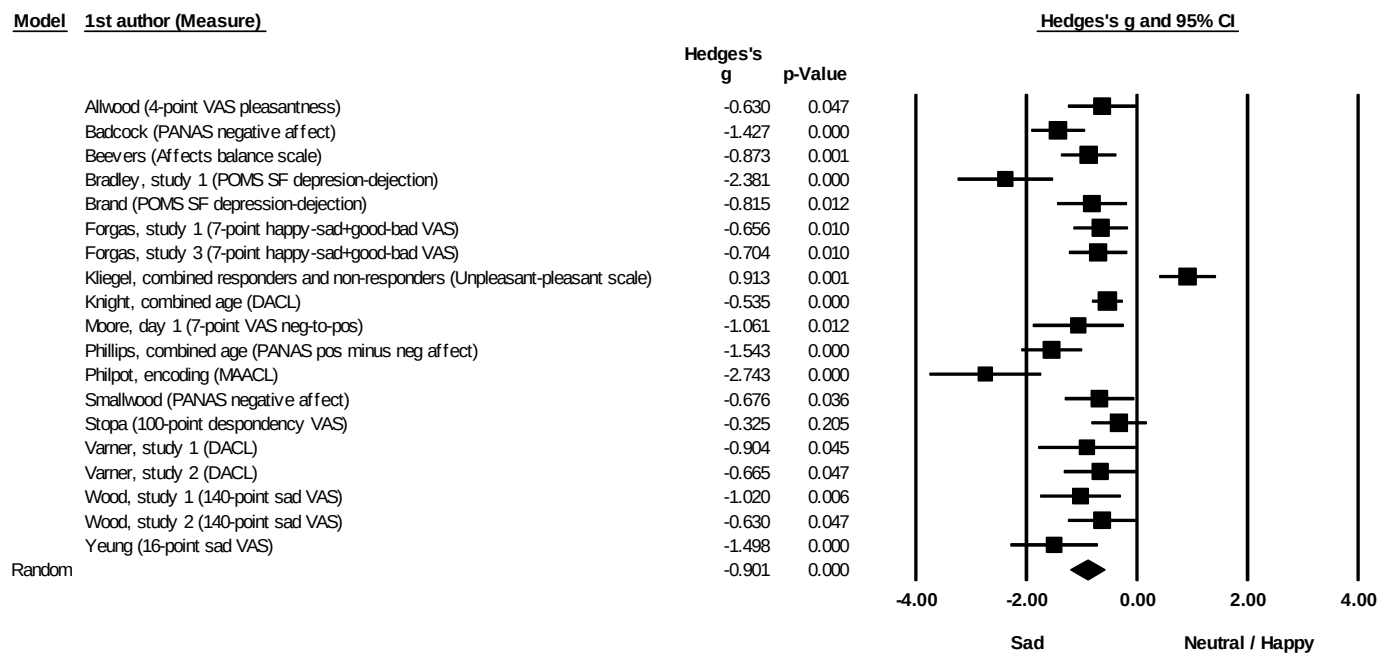


Figure 2.4: Results of the random-effect model meta-analysis comparing the effect of sad and neutral MIPs on self-reported mood state

Box size is proportion to study size.

Effect of sad versus happy MIP on mood state

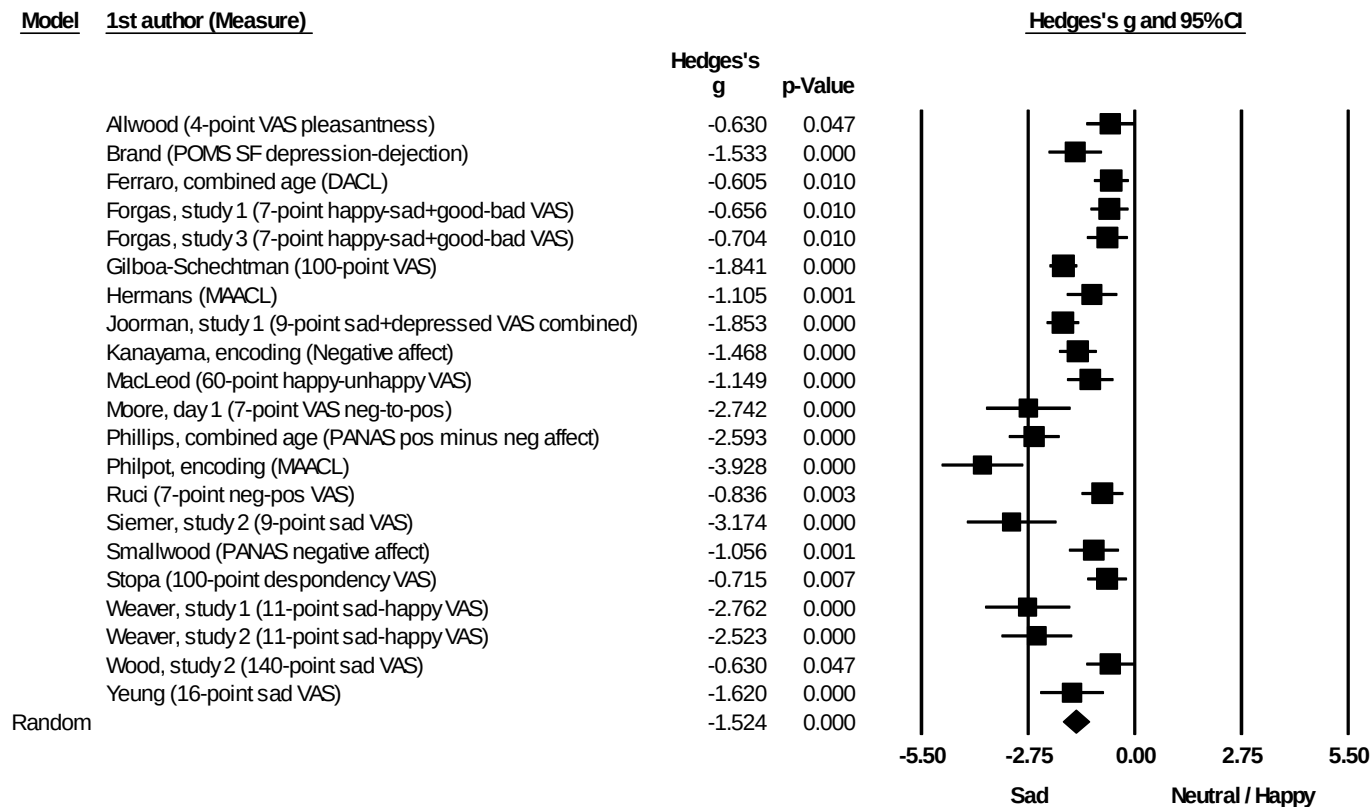


Figure 2.5: Results of the random-effect model meta-analysis comparing the effect of sad and happy MIPs on self-reported mood state

Box size is proportion to study size.

Effect of sad MIP on mood state measured before and after MIP

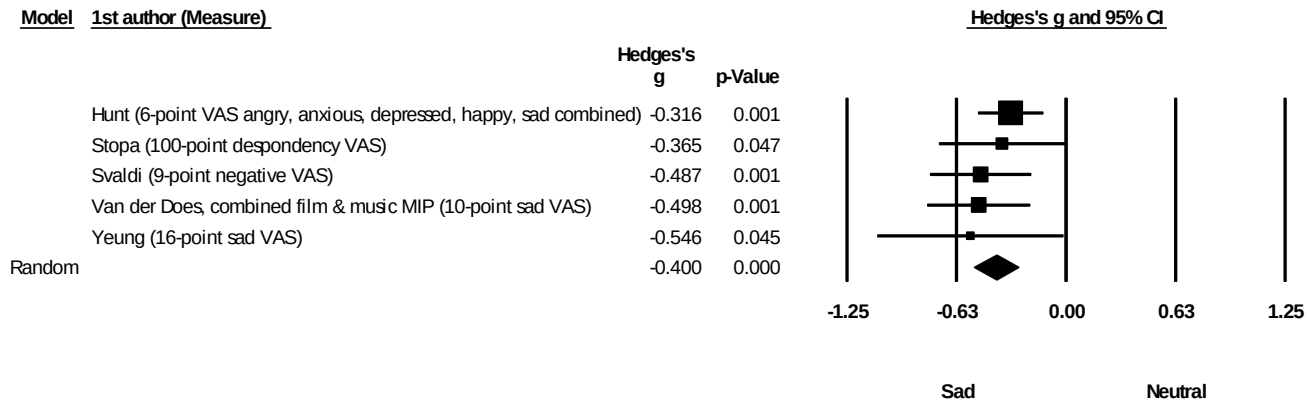


Figure 2.6: Results of the random-effect model meta-analysis comparing the effect of sad MIPs on self-reported mood state before and after the MIP

Box size is proportion to study size.

Planned meta-regression was conducted using measures of current depressive symptoms and baseline (pre-MIP) mood state in the sad versus neutral MIP comparison only (see Table 2.4). The other comparisons did not meet the recommended minimum number of studies required to perform meta-regression on continuous (≥ 6) and categorical (≥ 4) variables, as outlined in the methods section. There was no influence of baseline (pre-MIP) mood state. Lower current depressive symptoms were associated with a greater effect of sad compared with neutral MIPs on mood state (see Figure 2.7).

Tests for heterogeneity did not reach significance in the pre- and post-sad MIP comparison, but did in the comparisons of sad and neutral as well as sad and happy MIPs (see Table 2.2); therefore variability in mood state between studies exceeded that which would be expected by chance. Accordingly, meta-regression using Hedges's g was performed with age, percentage female participants, and number of methods of MIPs used (0=one method, 1=more than one method) for those two comparisons. There were no significant effects of the percentage of female participants on the efficacy of sad compared with control (neutral and/or happy) MIPs. A greater effect of sad compared with neutral MIPs on mood state was found for younger adults but this was not repeated in the sad and happy MIP comparison (see Table 2.4). There were differences in the effect of single versus multiple methods of MIPs for Hedges's g comparing sad versus neutral and sad versus happy MIPs. Whereas more than one method led to a significantly greater effect in the sad versus happy MIP comparison (see Figure 2.9), there was a non-significant trend towards a reduced effect in the sad versus neutral MIP comparison (see Figure 2.8). To further investigate this effect, meta-regression analyses were conducted only in those studies that had data for neutral, sad, and happy MIPs ($N=11$). This enabled a direct comparison between the number of methods of MIPs and responsiveness to a sad MIP in the sad versus neutral and sad versus happy MIP comparisons without the additional confound of different studies. Although not significant, results showed that studies using more

than one method of MIP led to a greater effect in the sad versus happy (Slope=-0.257; $p=0.217$) and sad versus neutral (Slope=-0.197; $p=0.314$) MIP comparisons.

Comparison	N	Regression variable	Fixed-effect model: meta-regression			
			Slope	p-value	Lower limit	Upper limit
Sad vs. Neutral	8	Current depressive symptoms	0.0713	0.0044	0.0223	0.1204
	10	Baseline mood state	0.0135	0.2654	-0.0102	0.0372
	11	Age	0.0833	0.0021	0.0301	0.1364
	16	Percentage females	-0.0055	0.1807	-0.0136	0.0026
	19	Number of methods of MIPs	0.2591	0.0500	0.0000	0.5182
Sad vs. Happy	3 ^A	Current depressive symptoms	-	-	-	-
	5 ^A	Baseline mood state	-	-	-	-
	11	Age	0.0217	0.1491	-0.0078	0.0513
	18	Percentage females	0.0075	0.1786	-0.0034	0.0185
	21	Number of methods of MIPs	-0.5780	<0.0001	-0.8545	-0.3016
Pre vs. post-sad MIP	3 ^A	Current depressive symptoms	-	-	-	-

Table 2.4: Results of the fixed-effect model meta-regression analyses on outcome measures of mood state

Significant effects in red. N=Number of studies with data available for inclusion in the meta-regressions. ^A Meta-regression was not performed in these comparisons with these variables as the recommended minimum number of studies required was not reached.

Both Begg and Mazumdar's rank correlations and Egger's regression intercept indicated a level of publication bias in the sad versus neutral ($\tau=-0.441$, $p=0.009$; $t=2.072$, $p=0.054$, respectively) and sad versus happy ($\tau=-0.459$, $p=0.004$; $t=2.174$, $p=0.043$, respectively), but not pre- versus post-sad MIP ($\tau= -0.100$, $p=0.807$; $t=1.774$, $p=0.174$, respectively) comparisons.

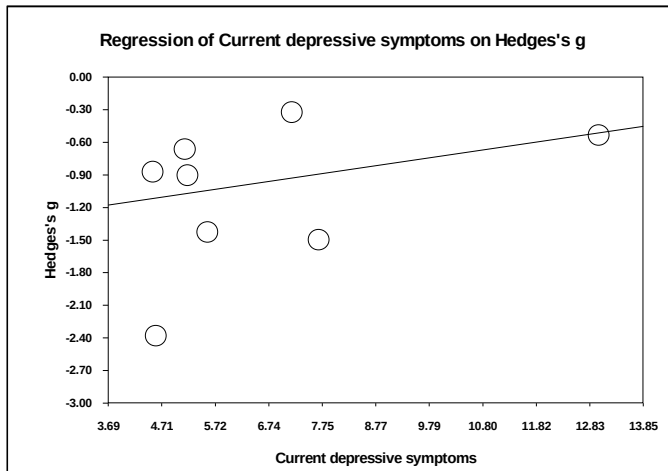


Figure 2.7: Meta-regression analysis to investigate the influence of current depressive symptoms on mood state following a sad compared with neutral MIP. Slope = 0.0713; $p=0.0044$

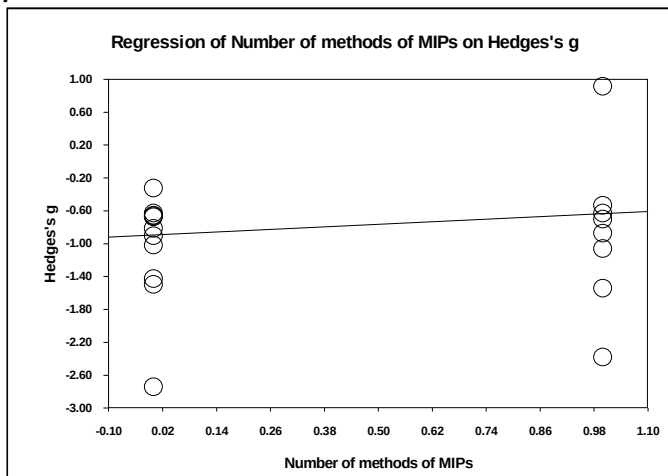


Figure 2.8: Meta-regression analysis to investigate the influence of number of methods of MIPs (0=one method, 1=more than one method) on mood state following a sad compared with neutral MIP. Slope = 0.2591; $p=0.0500$

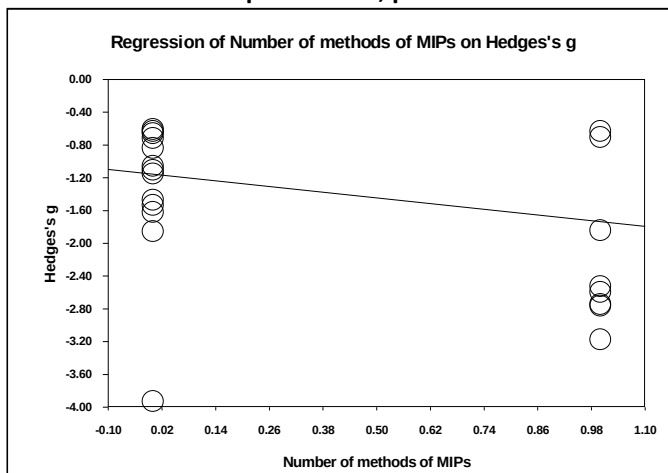


Figure 2.9: Meta-regression analysis to investigate the influence of number of methods of MIPs (0=one method, 1=more than one method) on mood state following a sad compared with happy MIP. Slope = -0.5780, $p<0.0001$

2.4.2 Systematic review: effect of mood induction procedures on cognitive processing

This section aims to present a qualitative review of the influence of mood state on cognitive processing.

Forty-one studies from 32 articles met criteria for inclusion in the systematic review. Of these, 22 reported results for cognitive impairment (tasks with neutral stimuli), 29 for task-relevant emotional stimuli, three for task-irrelevant emotional stimuli and seven for mood consistency. Seven studies included both neutral and emotional stimuli but only six reported data that could be used to compare performance in tasks with neutral (impairment) and emotional (bias) stimuli. The results of these studies are presented in Appendix 1.3 and described below.

2.4.2.1 Cognitive processing: neutral stimuli

Twenty-two studies investigated performance on tasks using neutral stimuli, of which 19 reported results that could be summarised here. Ten reported impairments, nine reported no effects, and none reported improvements in performance following a sad MIP.

Participants' responses were slower while making errors (Brand, Verspui, & Oving, 1997), or they made more errors and showed reduced post-error slowing but not increased post-correct speeding on attention tasks including the classic Stroop and Go/NoGo paradigms (Gilboa-Schechtman, Revelle, & Gotlib, 2000; Smallwood, Fitzgerald, Miles, & Phillips, 2009). Participants also demonstrated deficits in initial visual learning (Moore & Oaksford, 2002) and reduced autobiographical memory specificity across trials with neutral, negative, and positive cues (Yeung, Dalgleish, Golden, & Schartau, 2006) following a sad compared with a happy MIP. However another study demonstrated no difference following a sad compared with happy MIP in trials using neutral cues (Svaldi & Mackinger, 2003). There was evidence of general impairment in executive function and memory, such as poorer planning and problem solving on the tower of London test (Phillips, et al., 2002), impairment in a pattern recognition task

(Klauser, et al., 1991) and reduced prospective memory (Kliegel, et al., 2005) following a sad compared with a control (neutral and/or happy) MIP. Two of five studies from the same article reported impairment in delayed free recall, though the remaining three studies did not (Kenealy, 1997). The latter result was in keeping with a similar study reporting no effects of sad mood on immediate or delayed free recall (Philpot & Madonna, 1993). Participants were not impaired in the number of (and confidence of making) correct responses to general knowledge questions (Allwood & Bjorhag, 1991) following sad, happy, and neutral MIPs.

Three other studies investigated the effects of mood state on the encoding and retrieval of neutral words (Knight, et al., 2002; Ruci, Tones, & Zelenski, 2009) as well as the impact of task-irrelevant neutral words on attentional processing (Bradley, et al., 1997). Whereas one reported no impairments (Ruci, et al., 2009), the results were not reported in the other two as these were not the primary outcome measures of the studies, rather they focussed on mood-congruent biases (i.e. emotionally salient not neutral stimuli).

2.4.2.2 Cognitive bias: emotional stimuli

The concept of mood-congruence implies that performance on the task of interest is biased by congruence between the individual's mood state (e.g. an induced mood following a sad MIP, or an existing mood such as clinical depression) and the valence of the stimulus material (e.g. negative).

Task-relevant stimuli

A total of 29 studies used task-relevant emotional stimuli to probe cognitive processing. Nine reported improvements, eight reported no effects, and one reported impairments in performance following a sad MIP. Eleven of 29 used questionnaire-based methods to measure attitudes and judgements towards oneself and others. These could not be categorised according to impairments and improvements in performance, rather were categorised by the congruence of mood state to the attitude or judgement. Nine reported mood-congruent

negative attitudes and judgements whereas two reported no effects and none reported mood-incongruent attitudes and judgements.

Congruence between stimuli and mood state improved task performance by increasing mood-congruent autobiographical memory specificity (Svaldi & Mackinger, 2003), decreasing reaction time to recall (Ruci, et al., 2009) and increasing the number of items recalled following sad (Knight, et al., 2002; Varner & Ellis, 1998) as well as sad and happy MIPs (MacLeod & Campbell, 1992), although one study demonstrated this effect following a happy but not sad MIP (Joormann & Siemer, 2004).

Similar to these mood-congruent effects, the influence of the in-/consistence of mood state during encoding and retrieval has been explored in multiple studies. Results show improved recall performance when mood was consistent at encoding and recall, when stimuli were neutral (Kenealy, 1997; Philpot & Madonna, 1993) and emotional (Kanayama, et al., 2008), following both sad and happy MIPs. Unlike findings from previously reported studies (Joormann & Siemer, 2004; Knight, et al., 2002; MacLeod & Campbell, 1992; Varner & Ellis, 1998), there was no interaction between mood state at emotional stimuli on recall performance (Kanayama, et al., 2008).

The evidence for mood-congruent effects is less clear for tasks in which participants were required to make an appraisal, interpretation, judgement, or decision. Here, a similar number of studies reported no interaction between mood state and stimulus valence (Bisson & Sears, 2007; Forgas, 1998; Jacoby, et al., 2008; Weaver & McNeill, 1992) as those reporting a mood-congruent effect improving task performance following sad (Badcock & Allen, 2003) as well as sad and happy MIPs (Ferraro, et al., 2003; Hermans, et al., 1996). Interestingly, improvement in performance only occurred on those trials with mood-congruent task-relevant negative stimuli and not those with neutral stimuli where there was no effect of mood state on performance (Badcock & Allen, 2003; Ferraro, et al., 2003; Hermans, et al., 1996). However, in

one study improvement in performance was only found when participants were categorised according to amount of self-reported depressive mood change following the sad/happy MIPs, and not according to MIP group per se (Hermans, et al., 1996).

Studies have found evidence for mood-congruent negative attitudes and judgements towards oneself. This is demonstrated by higher scores of emotional deprivation, defectiveness, dysfunctional attitudes, and self-focus following a sad MIP (Stopa & Waters, 2005; Van der Does, 2002; Wood, Saltzberg, & Goldsamt, 1990), as well as higher scores of entitlement following a happy MIP (Stopa & Waters, 2005). In contrast to Van der Does (2002) another study found no influence of a sad MIP on scores of dysfunctional attitudes but did find that these scores predicted depressive state (measured using the Beck Depression Inventory; A.T. Beck, Steer, & Brown, 1996) one month later (Hunt & Forand, 2005). Another study demonstrated a mood-congruent effect (that neither facilitated nor impaired performance) when participants were instructed to suppress thoughts (which was hypothesised to subsequently increase accessibility to negative information) compared with no instruction (Beevers & Meyer, 2008). Despite evidence for mood-congruent effects (that neither facilitated nor impaired performance) on attitudes and judgments that were not self-relevant (Siemer, 2001), another study (Forgas, 1998) showed that participants made more attribution errors about others following both experimentally and naturally induced happy but not sad mood.

Task-irrelevant stimuli

All of the three studies that used task-irrelevant emotional stimuli to probe cognitive processing reported impairments in performance following a sad MIP.

In attentional processing paradigms, mood-congruent task-irrelevant word stimuli led to increased task-interference as measured by slower reaction times following a sad (Bradley, et al., 1997) as well as sad and happy MIPs (Gilboa-Schechtman, et al., 2000). Importantly, this

effect was specific to depression-related (i.e. mood-congruent) and not negative (e.g. anxiety-related) or emotional (e.g. positive) stimuli (Bradley, et al., 1997). In a memory paradigm, participants showed increased false memories for mood-congruent but not neutral stimuli, following both sad and happy MIPs (Ruci, et al., 2009).

Cognitive impairment or bias?

Seven studies used both neutral and emotional stimuli to investigate cognitive performance. One did not report effects for neutral stimuli (Knight, et al., 2002) and another did not report effects for neutral and emotional stimuli separately (Yeung, et al., 2006) so performance could not be compared. Of the five remaining studies, those reporting no impairments in conditions with neutral stimuli showed cognitive impairments to task-irrelevant mood-congruent stimuli (Ruci, et al., 2009) but improvements to task-relevant mood-congruent stimuli (Badcock & Allen, 2003; Hermans, et al., 1996; Svaldi & Mackinger, 2003). One study reported cognitive impairments in conditions with neutral and task-irrelevant mood-congruent stimuli (Gilboa-Schechtman, et al., 2000).

2.4.2.3 Overall summary

Following a sad MIP, participants were slower and more likely to make (more) errors and did not demonstrate the typical patterns of post-error slowing and post-correct speeding demonstrated by healthy participants (similar results have been demonstrated in a study comparing response times between depressed patients and healthy participants; see Steele, Kumar, & Ebmeier, 2007). They also showed deficits in initial visual learning, poorer planning and problem solving performance, as well as a reduced ability to retrieve memories and reduced prospective memory. While these studies demonstrated impairments in performance following a sad MIP, participants did show greater adaptive reasoning related to social risk situations and were more likely to account for external factors thus commit fewer fundamental attribution errors about others. Participants' confidence and emotion

judgements were unimpaired. However, when it comes to the self, participants were more likely to be self-focussed and make negative self-judgements.

Although these studies largely demonstrated that a sad mood state led to impairments in cognitive processing, such effects were nonetheless mediated by stimulus valence and congruence to participants' mood state. Specifically, while mood-congruent stimuli aided task-performance when those stimuli were task-relevant, they had the opposite effect (i.e. impaired performance) when task-irrelevant. Similarly to mood-congruent effects (where mood and task-relevant stimuli are the same/different), performance in memory paradigms with both neutral and emotional stimuli improved when mood was consistent at encoding and recall.

2.4.3 Meta-analysis: effect of mood induction procedures on cognitive task performance

In this section the results of quantitative meta-analyses of the influence of mood state on cognitive processing will be presented, as a supplement to the previously presented qualitative review.

Of those studies included in the qualitative review, 28 met criteria for inclusion in at least one of the meta-analyses of the effect of MIPs on information processing (see Figure 2.3). Four studies could not be included as there was no control MIP for comparison (Bisson & Sears, 2007; Hunt & Forand, 2005; Jacoby, et al., 2008; Van der Does, 2002). One study induced sad, angry, and anxious MIPs and did not compare mood state pre- and post-sad MIP (Siemer, 2001; study 1). For other studies data were not available or could not be derived (Allwood & Bjorhag, 1991; Forgas, 1998; Hermans, et al., 1996; Klauer, et al., 1991; Knight, et al., 2002; Varner & Ellis, 1998; Wood, et al., 1990). For some studies included in the meta-analyses, data were combined across various participant and task characteristics including age (Ferraro, et al., 2003; Phillips, et al., 2002), trait measures (Kanayama, et al., 2008), mood responders and non-

responders (Kliegel, et al., 2005), and groups with the same MIP at encoding in mood-consistent retrieval studies (Kenealy, 1997; Philpot & Madonna, 1993).

As outlined in the methods section, some studies used multiple measures of cognitive processing, therefore a fixed-effect model was used to combine across multiple outcome measures from a single study and yield the overall effect. The results presented here describe the overall effect pooled across measures within each study and then across studies. The number of measures and studies included in each of the analyses, along with Hedges's g , and heterogeneity values are provided in Table 2.5.

There was significant impairment in task performance following a sad compared with neutral MIP for studies using neutral ($p=0.002$; see Figure 2.10) but not task-relevant negative stimuli (see Figure 2.11). There was evidence for a significant bias towards negative/away from positive stimuli following a sad compared with neutral MIP ($p=0.022$; see Figure 2.12). The results of these analyses were confirmed in the sad versus happy MIP comparisons; there was significant impairment in task performance following a sad MIP for studies using neutral stimuli ($p<0.001$; see Figure 2.13), whereas participants showed no impairment/significant improvement in studies using task-relevant negative stimuli ($p=0.040$; see Figure 2.14). In contrast, task-irrelevant negative stimuli led to impairments in task performance ($p<0.001$). Finally, there was a non-significant trend towards a negative bias ($p=0.080$; see Figure 2.15).

Comparison	Stimulus	N ^A	N ^B	Hedges's g and 95% confidence interval				Heterogeneity			
				Hedges's g	p-value	Lower limit	Upper limit	Q-value	Q (df)	p-value	I ²
Sad vs. Neutral	Neutral	9	38	-0.16	0.002	-0.25	-0.06	93.43	37	<0.001	60.40
	Negative relevant	3	4	0.10	0.519	-0.2	0.39	4.00	3	0.263	24.77
	Bias	4	21	-0.14	0.021	-0.26	-0.02	20.26	20	0.442	1.30
Sad vs. Happy	Neutral	11	56	-0.15	<0.001	-0.23	-0.07	114.61	55	<0.001	52.01
	Negative relevant	7	10	0.16	0.040	0.01	0.32	20.78	9	0.014	56.70
	Negative irrelevant	2	4	-0.53	<0.001	-0.76	-0.31	10.35	3	0.016	71.01
	Bias	3	18	-0.11	0.080	-0.23	0.01	10.81	17	0.866	0

Table 2.5: Weighted mean effect sizes, 95% confidence intervals and measures of heterogeneity and bias in the meta-analyses of mood state data

Significant effects in red. ^ANumber of studies included in the meta-analyses. ^BNumber of measures included in the meta-analyses.

Due to the small number of studies with the appropriate data available to examine performance in studies using task-irrelevant negative stimuli in the sad versus neutral (N=1 study with N=3 measures) and sad versus happy (N=1 study with N=1 measure) MIP comparisons, meta-analyses were not performed. However, the means show that participants demonstrated greater impairments to task-irrelevant negative stimuli following a sad compared with neutral and/or happy MIP (Gilboa-Schechtman, et al., 2000; Ruci, et al., 2009); see Table 2.6.

1 st Author (Task, Measure, Stimulus valence)	Neutral MIP		Sad MIP		Happy MIP	
	Mean	SD	Mean	SD	Mean	SD
Ruci (Memory, # critical lures ¹ falsely recalled, negative)	0.30	0.24	0.55	0.35	0.18	0.27
Ruci (Memory, # critical lures falsely recognised, negative)	0.85	0.16	0.86	0.25	0.60	0.35
Ruci (Memory, # new items falsely recognised, negative)	0.02	0.01	0.06	0.02	0.06	0.02
Gilboa-Schechtman (Stroop, Interference response latency ms, negative)	-	-	809	146	752	115

Table 2.6: Mean and standard deviation (SD) scores for a study exploring the effects of task-irrelevant negative stimuli on performance following a Neutral, Sad, and Happy MIP

¹In this task, participants were presented with semantically related word lists to remember and later recall. It has been shown that participants are likely to falsely recall items that have similar meanings to those in the word lists but that were not presented in the word lists. These falsely recalled items are known as critical lures.

Planned meta-regression could not be conducted using measures of current depressive symptoms and baseline (pre-MIP) mood state in the sad versus neutral or sad versus happy comparisons for any of the outcome measures. This is because the recommended minimum number of studies required to perform meta-regression on continuous (≥ 6) and categorical (≥ 4) variables was not met, as outlined in the methods section.

Tests for heterogeneity only reached significance in the sad versus neutral comparison in those studies using neutral stimuli (Table 2.5). In the sad versus happy comparisons, however, only studies investigating bias towards emotional stimuli did not demonstrate significant heterogeneity, therefore variability in mood state between studies exceeded that which would be expected by chance. Accordingly, meta-regression using Hedges's g was performed with

age and percentage female participants, and number of methods of MIPs used (0=one method, 1=more than one method) for those comparisons in which enough data were available. A greater effect of sad compared with happy MIPs on cognitive impairment in studies using neutral as well as task-relevant negative stimuli was found in those with a more even percentage of female-to-male participants (see Table 2.7). In contrast, in studies investigating impairments using neutral stimuli in the sad versus neutral MIPs comparison, there was a trend towards a greater effect in those with more female participants, and no effect of age. There was consistency between the sad versus neutral and sad versus happy MIP comparisons regarding the influence of number of methods of MIPs on effect size. Studies using neutral stimuli reported impaired task-performance when using both one method (Hedges's $g=-0.211$; $p=0.002$ for the sad versus neutral comparison and Hedges's $g=-0.184$; $p<0.001$ for the sad versus happy comparison) and more than one method (Hedges's $g=-0.086$; $p=0.253$ for the sad versus neutral comparison and Hedges's $g=-0.032$; $p=0.716$ for the sad versus happy comparison). In the sad versus happy comparisons, there was greater improvement in performance in studies using task-relevant negative stimuli when one method of MIP was used (Hedges's $g=0.242$; $p=0.003$). This effect was reversed when more than one method was used; however there were only two studies reported in a single article that used more than one method of MIP in these comparisons (Weaver & McNeill, 1992). Whereas one showed significant impairment (study 1) the other showed improvement (study 2), therefore the former may be an anomalous result.

Comparison	Stimulus	N	Regression variable	Fixed-effect model: meta-regression			
				Slope	p-value	Lower limit	Upper limit
Sad vs. Neutral	Neutral	7	Percentage females	-0.01	0.074	-0.03	0.00
Sad vs. Happy	Neutral	7	Age	-0.01	0.540	-0.03	0.02
		10	Percentage females	0.01	0.038	0.00	0.01
	Negative relevant	6	Percentage females	0.01	0.007	0.00	0.02

Table 2.7: Results of the fixed-effect model meta-regression analyses on outcome measures of cognitive processing

Significant effects in red. N=number of studies with data available for inclusion in the meta-regressions. If data are not presented, meta-regression was not performed in these comparisons with these variables as the recommended minimum number of studies required was not reached.

There was no evidence for publication bias in the sad versus neutral comparisons for studies investigating cognitive impairments using tasks with neutral stimuli and task-relevant negative stimuli. There was evidence for publication bias in studies investigating bias towards emotional stimuli, however this was such that there may be reduced reporting of studies supporting a negative bias. Begg and Mazumdar's rank correlations and Egger's regression intercept were $\tau=-0.424$, $p=0.007$ and $t=2.851$, $p=0.010$, respectively. In the sad versus happy MIP comparisons, there was only evidence for publication bias in studies investigating cognitive impairments using tasks with neutral stimuli (Begg and Mazumdar's rank correlations and Egger's regression intercept were $\tau=-0.264$, $p=0.004$ and $t=2.731$, $p=0.009$, respectively).

Effect of sad versus neutral MIP on task performance with neutral stimuli

Model: 1st author (Task)

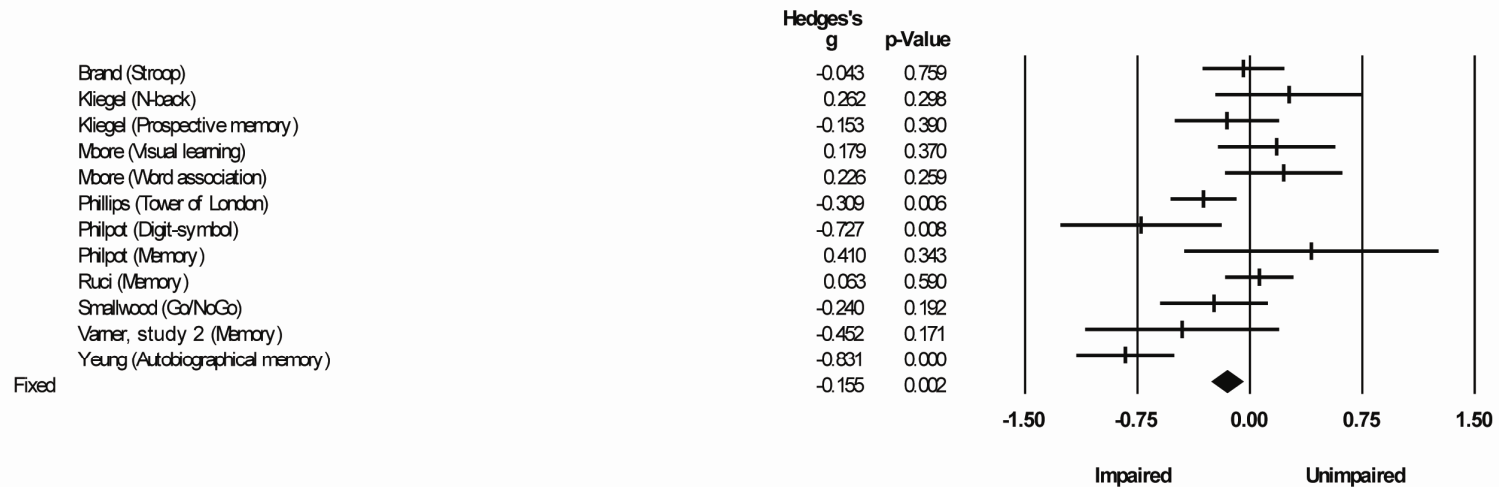


Figure 2.10: Results of the fixed-effect model meta-analysis comparing the effect of sad and neutral MIPs on task performance in studies using neutral stimuli

Horizontal and vertical lines represent the effect size and 95% confidence intervals for each study. The diamond represents the overall effect size and 95% confidence intervals across studies.

Effect of sad versus neutral MIP on task performance with task-relevant negative stimuli

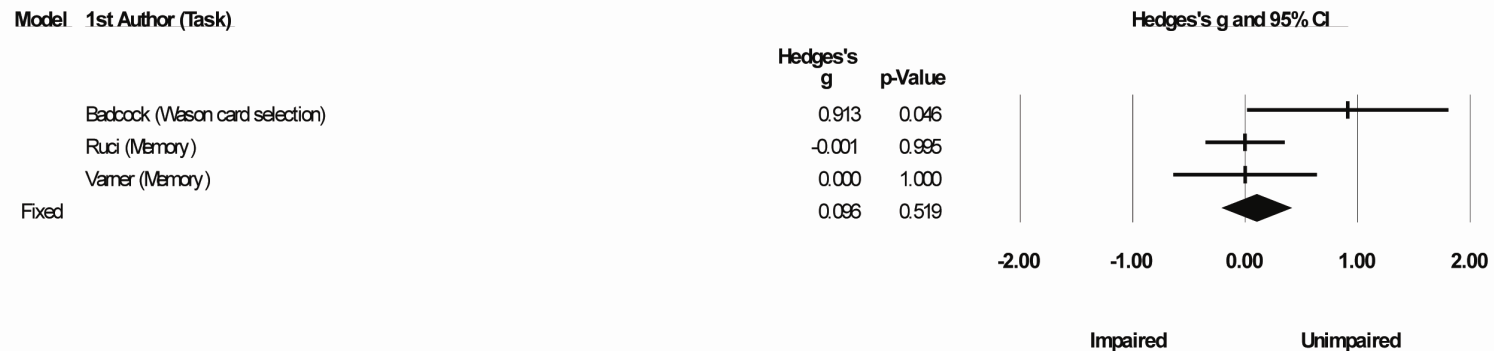


Figure 2.11: Results of the fixed-effect model meta-analysis comparing the effect of sad and neutral MIPs on task performance in studies using task-relevant negative stimuli

Horizontal and vertical lines represent the effect size and 95% confidence intervals for each study. The diamond represents the overall effect size and 95% confidence intervals across studies.

Effect of sad versus neutral MIP on bias towards emotional stimuli

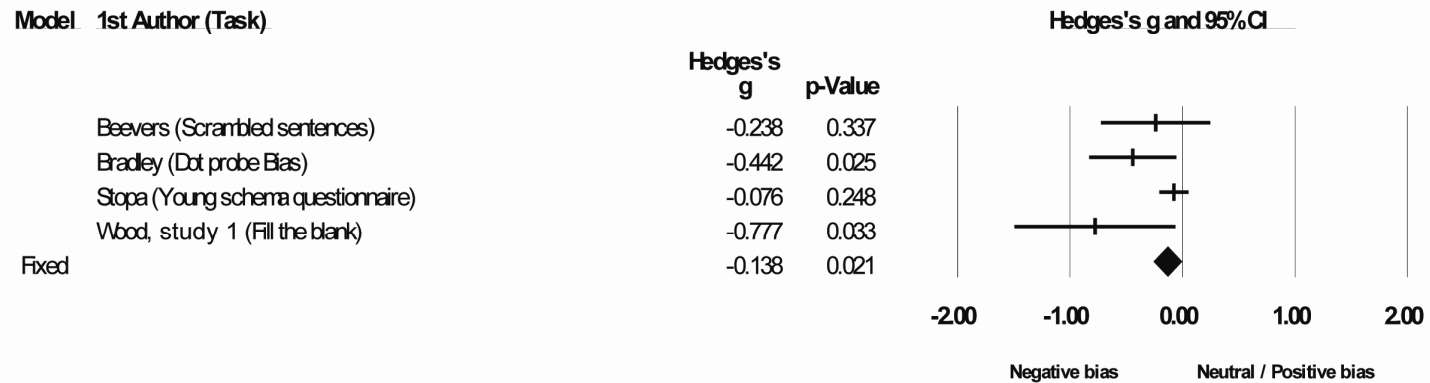


Figure 2.12: Results of the fixed-effect model meta-analysis comparing the effect of sad and neutral MIPs on bias in studies measured bias towards negative or neutral/positive stimuli

Horizontal and vertical lines represent the effect size and 95% confidence intervals for each study. The diamond represents the overall effect size and 95% confidence intervals across studies.

Effect of sad versus happy MIP on task performance with neutral stimuli

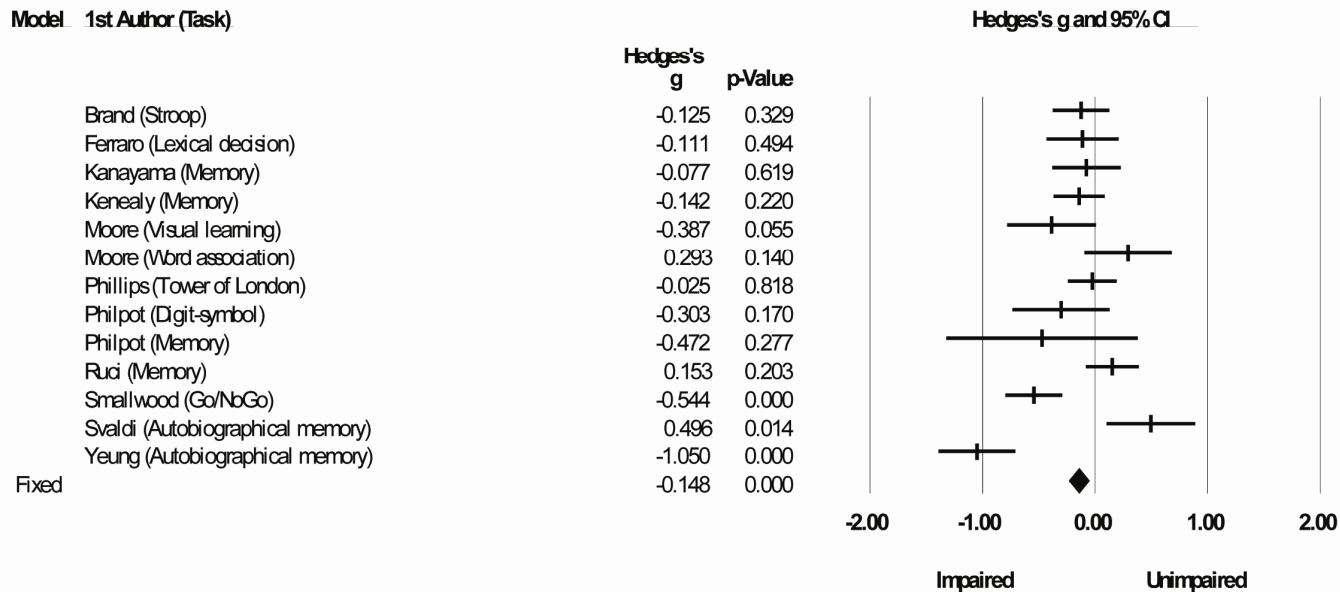


Figure 2.13: Results of the fixed-effect model meta-analysis comparing the effect of sad and happy MIPs on task performance in studies using neutral stimuli

Horizontal and vertical lines represent the effect size and 95% confidence intervals for each study. The diamond represents the overall effect size and 95% confidence intervals across studies.

Effect of sad versus happy MIP on task performance with task-relevant negative stimuli

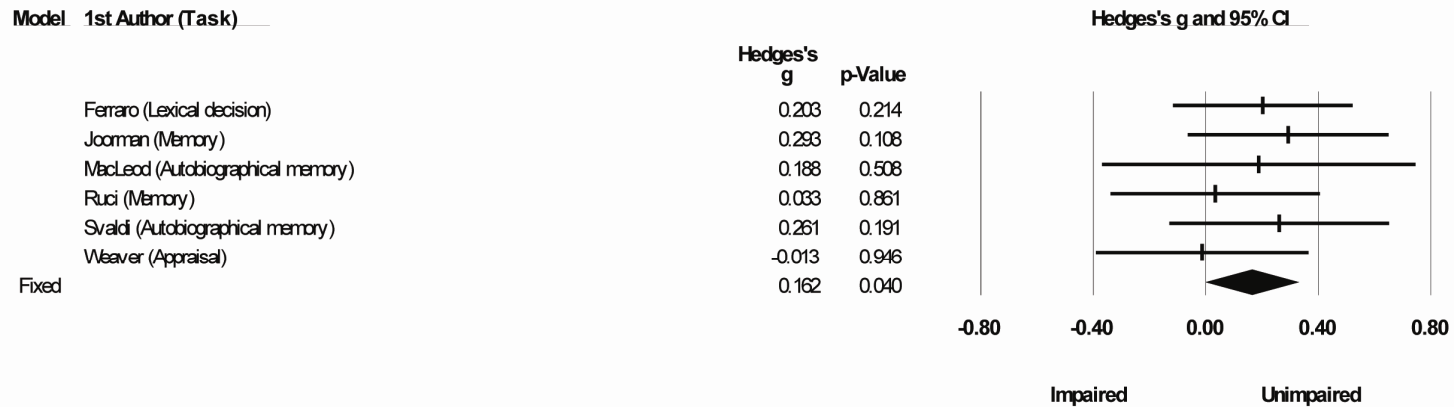


Figure 2.14: Results of the fixed-effect model meta-analysis comparing the effect of sad and happy MIPs on task performance in studies using task-relevant negative stimuli

Horizontal and vertical lines represent the effect size and 95% confidence intervals for each study. The diamond represents the overall effect size and 95% confidence intervals across studies.

Effect of sad versus happy MIP on bias towards emotional stimuli

Model 1st Author (Task)

MacLeod (Autobiographical memory)
Siemer (Hypothetical scenarios)
Stopa (Young schema questionnaire)
Fixed

Hedges's g	p-Value
-0.501	0.083
-0.318	0.258
-0.078	0.239
-0.109	0.080

Hedges's g and 95% CI

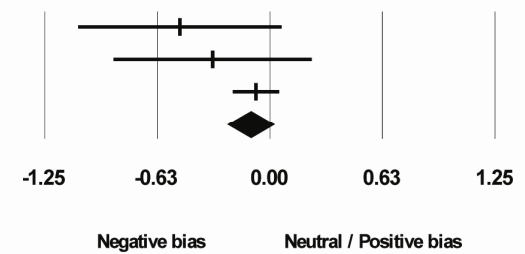


Figure 2.15: Results of the fixed-effect model meta-analysis comparing the effect of sad and happy MIPs on bias in studies measured bias towards negative or neutral/positive stimuli

Horizontal and vertical lines represent the effect size and 95% confidence intervals for each study. The diamond represents the overall effect size and 95% confidence intervals across studies.

2.5 Discussion

The aim of this chapter was to first investigate the efficacy of sad MIPs at inducing mood change. After establishing their efficacy, the influence of induced mood on cognitive performance and bias in healthy participants was explored in a qualitative review supplemented by quantitative meta-analyses. This review enables conclusions about the extent to which changes in performance reflect global impairments or cognitive biases in information processing. This was achieved by drawing together data from multiple studies that included neutral and/or emotional stimuli. Where these conclusions may otherwise be possible within a single study, some researchers either presented results grouped across neutral and emotionally salient stimuli or overlooked their distinction (for example, Gilboa-Schechtman, et al., 2000; Knight, et al., 2002; Yeung, et al., 2006).

2.5.1 Efficacy of mood induction procedures on mood state

Meta-analyses confirmed that sad MIPs increased participants self-reported negative affect. These results provide up-to-date and complimentary data for previous reviews and meta-analysis (Gerrards-Hesse, et al., 1994; Martin, 1990; Westermann, et al., 1996). There was, however, some evidence for publication bias therefore these results should be treated with caution.

There was no effect of baseline (pre-MIP) mood state in any of the comparisons. However individuals with lower scores on measures of current depressive symptoms reported the largest changes in negative affect following the sad compared with neutral MIPs. For a discussion of this result in relation to the previous literature and original data presented in this thesis see Chapter 6: General Discussion and Future Directions.

2.5.2 Effect of mood induction procedures on cognitive processing and bias

Both the systematic review and meta-analyses of the effects of MIPs on cognitive task performance supported the same conclusions, which are presented in Table 2.8.

Stimulus valence and task-relevance	Impairment	No effect	Improvement
Neutral, task-relevant	10 * +	9	0
Negative, task-relevant	1	8 +	9 *
Negative, task-irrelevant	3 *	0	0
Negative, bias	0 (Incongruent bias)	2 *	9 + (Congruent bias)

Table 2.8: Number of studies included in the systematic review demonstrating an influence of sad MIPs on task performance. *=significant in the meta-analysis comparing sad and happy MIPs; +=significant in the meta-analysis comparing sad and neutral MIPs

Sad mood states are associated with general impairments in cognitive processing across a range of tasks, which is in keeping with the literature summarising cognitive impairments in depressed patients. Mood-congruent stimuli led to impairments when those stimuli were task-irrelevant, and improvements when task-relevant. This is consistent with other reviews exploring the effects of mood on particular domains of cognitive processing such as attention (Peckham, et al., 2010; Yiend, 2010) and memory (Bower, et al., 1983; Leppanen, 2006). In studies where bias rather than correctness was measured, there was a bias towards negative/away from positive stimuli following a sad compared with control MIP.

2.5.3 Methodological considerations

As with all systematic reviews and meta-analyses, these results should be considered with caution. They may not be generally applicable due to the heterogeneity of participant details, tasks used, and the cognitive processes that these tasks were designed to investigate.

The total number of participants and the number of females in each study as well as in each experimental condition (e.g. sad MIP group) varied greatly. Therefore in the presence of

heterogeneity, meta-regression analyses were conducted to explore the influence of potential confound variables including age, percentage female participants, and number of methods of MIPs used. Sad compared with neutral MIPs were more effective in younger adults. Further, using more than one method of MIP led to a greater although non-significant effect in both the sad versus happy and sad versus neutral comparisons. With regard to cognitive performance, the percentage of female participants and number of methods of mood induction may be possible sources of heterogeneity.

There were also differences between studies in the participants that were included in the final sample for analysis. Where possible, data were pooled across mood responders and non-responders in the meta-analyses of mood state and cognitive processing (Kliegel, et al., 2005). If data were not available and therefore pooling not possible, studies were excluded from the meta-analysis of mood state (Bisson & Sears, 2007; Kenealy, 1997).

All participants were healthy individuals and mostly sampled from student populations. There are two main considerations in using such participants: 1) Can results be generalised from students to the general population? and 2) How appropriate is the use of participants sampled from student and general populations as an analogue of clinical depression in patient populations? These and other issues, including potential confounds in MIPs research such as demand characteristics and carry over effects, will be addressed in Chapter 6: General Discussion and Future Directions.

Studies included in this review used a wide range of experimental tasks to probe cognitive processes such as attention, memory, decision making and judgement. This was not intended to be a systematic review of any single domain of information processing, which can be found elsewhere for attention (Peckham, et al., 2010; Yiend, 2010), memory and judgement (Bower, et al., 1983) as well as interpretation, judgement, decision making, and reasoning (for a non-exhaustive review see Blanchette & Richards, 2010). Rather the aim was to review evidence for

cognitive impairment and bias across a wide range of experimental tasks and cognitive processes. That there was minimal evidence for heterogeneity in the sad versus neutral MIP comparisons suggests that the results of these analyses are generalizable across multiple tasks and domains of information processing. Despite evidence for heterogeneity in the sad and happy MIP comparisons, results were consistent with those of the sad versus neutral MIP comparisons. Finally, despite there being only minimal evidence for publication bias, the results of these published studies may not be representative of the results of all such studies.

2.6 Conclusions and future directions

MIPs are effective methods of inducing sad mood states in healthy participants, and produce larger effects in individuals with lower scores on measures of current depressive symptoms. Investigators should consider pre-screening participants using a measure of current depressive symptoms. This will enable selection of individuals that are more likely to experience the greatest change in mood state as well excluding those participants with high scores for ethical reasons. In addition, using a combination, rather than a single method of mood induction increases the effects of MIPs on self-reported mood state.

When using MIPs to study the relationship between mood state and cognition, results should be interpreted according to the valence of the stimulus presented. Following a sad MIP, cognitive impairments occur in the context of task-neutral stimuli and task-irrelevant mood-congruent stimuli, whereas improvements in performance occur in the context of task-relevant mood-congruent stimuli. Future studies investigating cognitive processing in depressed mood (using MIPs and/or patients with MD) should aim to include both neutral and emotional stimuli. This will to enable dissociations between cognitive impairments in task performance and cognitive biases that may facilitate performance.

A systematic review of happy MIPs was not conducted here; rather data from studies using both neutral and happy MIPs were used for comparison with the effects of a sad MIP on negative mood state and cognitive processing. Researchers have tended to focus on negative rather than positive mood states, which may be due to difficulties in inducing positive mood states. Happy MIPs do not induce significant changes in subjective emotional experience in 30% of cases, compared with 14% in sad MIPs (Gerrards-Hesse, et al., 1994). A preliminary investigation of the influence of happy compared with neutral MIPs on mood state demonstrated that happy MIPs had a significant and medium effect size (Hedges's $g = 0.582$; $p=0.001$) in the expected direction (i.e. more positive following the happy compared with neutral MIP) in eight out of nine studies; see Figure 2.16. This result indicates that happy MIPs induced the intended mood state but were less effective than sad MIPs which showed significant and large effect sizes. Nevertheless researchers should aim to explore the influence of positive (specifically happy) mood states on cognitive processing per se and not only as a comparison to sad mood states. A preliminary analysis with a total of 34 observations from seven different studies using neutral stimuli demonstrated no evidence for a significant improvement or impairment in performance following a happy compared with neutral MIP (Hedges's $g = -0.040$; $p=0.459$); see Figure 2.17.

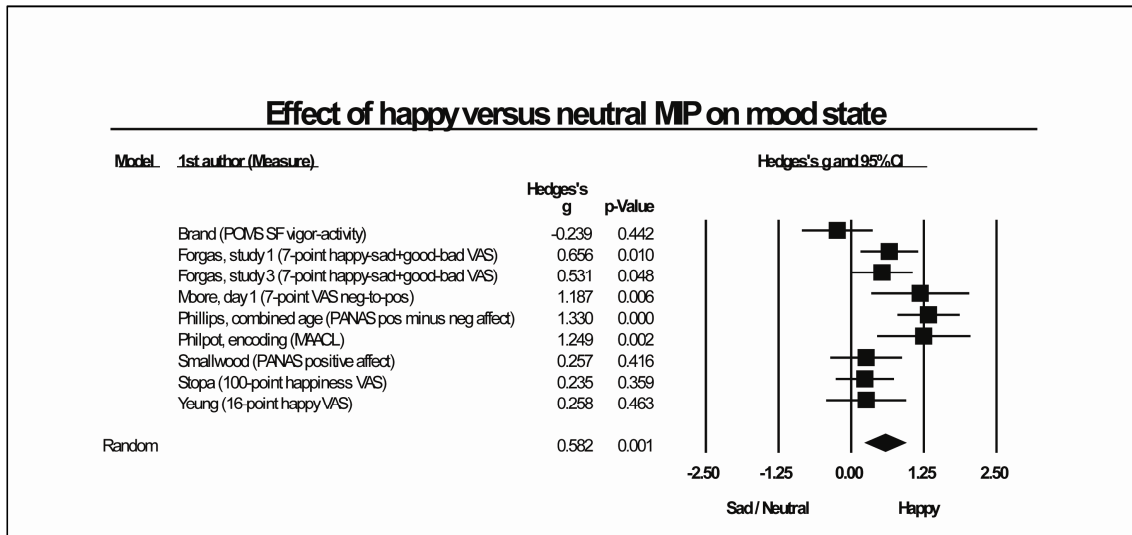


Figure 2.16: Results of the random-effect model meta-analysis comparing the effect of sad and neutral MIPs on self-reported mood state

Box size is proportion to study size.

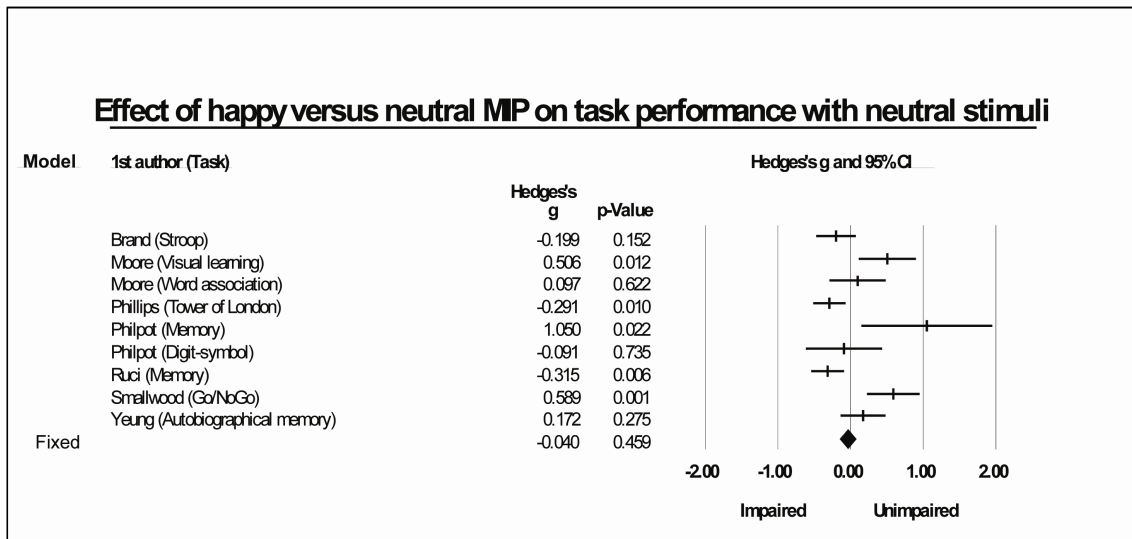


Figure 2.17: Results of the fixed-effect model meta-analysis comparing the effect of happy and neutral MIPs on task performance in studies using neutral stimuli

Horizontal lines represent the effect size for each study.

Chapter 3 Inductive Reasoning

“...cognition is not as logical as it was once thought and emotions are not always so illogical.”

Joseph LeDoux, 1998; pp.35

3.1 Abstract

Inductive reasoning is the process of making an inference based on the limited information available. The Beads Task was used to probe inductive reasoning. In this task, participants were shown two jars; one containing 85 blue and 15 pink beads, the other 85 pink and 15 blue beads. They were then shown a sequence of beads said to be drawn randomly from one of the two jars and asked to guess from which jar the beads had been drawn. The number of beads drawn until a decision was reached indicated the amount of information participants required to make an inference. Task difficulty was modulated using jars with more (60:40) and less (85:15) even proportions of beads. An emotional version of the Beads Task was developed using facial expressions of emotion (angry, fearful, sad, and smiling) masked by a scrambled neutral expression (17ms) that were rapidly presented (17ms) before each bead. In addition, the influence of mood state on inductive reasoning was probed using a combination of music and self-referential statements to induce neutral and sad (Experiments one, two, and three) or neutral and happy (Experiment one) mood states prior to the tasks. Finally, mood-congruent biases were explored through the interaction of mood state and emotional stimuli. There were a total of 197 healthy participants across the three experiments.

3.2 Introduction

This series of behavioural experiments aimed to investigate the influence of affect on inductive reasoning using rapidly presented emotional stimuli and mood induction. Inductive reasoning was probed using a paradigm with various levels of task demands.¹

3.2.1 Inductive reasoning

We rarely have every piece of information needed to draw conclusions and make accurate predictions about future events. Therefore, we rely on inductive reasoning (heuristics or rules-of-thumb) to make inferences and to extrapolate general principles from a particular situation with probabilistic information (Evans, 1989).

Probabilistic information processing has been explored using the “beads-in-a-jar” task (Huq, Garety, & Hemsley, 1988; Phillips & Edwards, 1966). Participants are shown two jars; one containing 85 blue and 15 pink beads, the other containing 85 pink and 15 blue beads. Participants are then shown a sequence of beads that they are told is randomly drawn from one of the two jars. Participants are asked to guess from which jar the beads have been drawn. The number of beads drawn until a decision is reached is an index of the amount of information required to make an inference. Task difficulty can be manipulated by presenting jars that contain beads in more (60:40; more difficult) and less (85:15; less difficult) even proportions (Dudley, John, Young, & Over, 1997b). Participants typically request fewer beads before deciding in the less even condition (see Table 3.1).

¹ Task demand, difficulty, and load are used interchangeably in the literature, so they will be used to refer to the same construct throughout this thesis.

First author	Stimuli	Ratio	Healthy: Mean (SD)	Deluded: Mean (SD)	Depressed: Mean (SD)
(Bentall et al., 2009)	Beads	60:40	5.59 (3.20)	3.08 (2.68)	5.09 (2.17)
	Emotion	60:40	4.93 (3.08)	3.22 (2.40)	4.96 (3.97)
(Corcoran et al., 2008)	Beads	60:40	5.6 (3.2)	3.1 (2.7)	5.1 (2.2)
	Emotion	60:40	4.9 (3.1)	3.3 (2.4)	5.0 (4.0)
(Dudley, John, Young, & Over, 1997a)	Social	60:40	8.0 (3.8)	5.2 (2.6)	7.5 (3.4)
	Emotion	60:40	7.3 (3.7)	4.2 (1.9)	7.1 (3.6)
(Dudley, et al., 1997b)	Beads	60:40	7.7 (2.0)	5.1 (2.4)	7.9 (2.7)
	Beads	85:15	4.9 (1.9)	2.5 (0.7)	4.5 (1.6)
(Garety, 1991)	Beads	85:15	5.4 (3.1)	3.0 (3.3)	-
(Huq, et al., 1988)	Beads	85:15	2.60 (1.17)	1.22 (1.57)	-
(Menon, Pomarol-Clotet, McKenna, & McCarthy, 2006; study 2)	Beads	60:40	4.50 (1.6)	2.81 (1.5)	-
	Beads	85:15	3.00 (1.2)	2.06 (1.0)	-

Table 3.1: Results of studies investigating the number of beads drawn before deciding in deluded and (non-deluded) depressed patients compared with healthy, non-psychiatric control participants

Beads=classic version, Social=names of children, Emotion=positive and negative statements about a person. In all of these studies depressed patients were included as non-deluded psychiatric control patients.

3.2.2 Emotional stimuli

Emotion influences a wide range of cognitive processes including perception, attention, memory, judgements, and decision making (see Chapter 2: Sad Mood Induction: A Systematic Review). Despite this, the effect of emotion on reasoning and in particular inductive reasoning has largely been overlooked (for a non-exhaustive review of the influence of emotion on reasoning, see Blanchette & Richards, 2010).

In his seminal book on the relation between emotion and reason, Antonio Damasio (1994) proposed that emotion *“may increase the saliency of a premise and, in doing so, bias the conclusion in favour of the premise”* (Preface, pp. xviii). Emotional versions of the Beads Task have been previously designed using negative and positive written words. Participants requested less information in the emotional compared with neutral word and classic beads trials (Bentall, et al., 2009; Corcoran, et al., 2008; Dudley, et al., 1997a); see Table 3.1. To

investigate the effects of covert emotional stimuli on reasoning, a novel variant of the Beads Task was developed by incorporating emotional trials. In these trials each picture of a bead was preceded by a rapidly presented (17ms) facial expression of emotion, followed by neutral mask (17ms). Research has shown that rapidly presented stimuli can be perceived without awareness (Merikle, Smilek, & Eastwood, 2001). Furthermore rapidly presented emotional stimuli can influence participants' behaviour towards subsequently presented, unrelated stimuli (Murphy & Zajonc, 1993; Winkielman, Berridge, & Wilbarger, 2005).

In summary, these studies demonstrate that reasoning about emotional material leads to a data-gathering bias in the Beads Tasks. Also rapidly presented task-irrelevant emotional stimuli influence participants' subsequent behaviour in a variety of tasks. Accordingly it was predicted that participants would request fewer beads before deciding in emotional compared with non-emotional trials.

3.2.2.1 Emotional stimuli and attention

This predicted effect of emotional stimuli was not expected to be uniform across trials rather influenced by the proportion of beads in a jar and therefore task difficulty. The rationale for this follows. Visual processing capacity is limited (Desimone & Duncan, 1995) and a mechanism known as selective attention distinguishes target from non-target information for further processing. As outlined previously (see Chapter 1: General Introduction) some researchers suggest that emotional information is processed automatically and therefore independently of top-down mechanisms such as attention (LeDoux, 1989, 1998; Öhman, Flykt, & Lundqvist, 2000; Vuilleumier, Armony, & Dolan, 2003; Winkielman & Berridge, 2004; Winkielman, et al., 2005). In contrast, Pessoa (2008) argues that emotion processing may be prioritized but is dependent upon the amount of processing resources available. In keeping with this, studies have shown that under conditions of high task difficulty, task-irrelevant stimuli (Doallo, Rodriguez-Hoiguin, & Cadaveira, 2006) and in particular task-irrelevant emotional stimuli

(Erthal et al., 2005; Okon-Singer, Tzelgov, & Henik, 2007; Pessoa, McKenna, Gutierrez, & Ungerleider, 2002; Van Dillen & Koole, 2009) do not influence or in fact impair performance.

Investigating reasoning performance by modifying task demands in the context of emotion may help to determine the extent to which emotional stimuli are processed automatically and independently of top-down attention mechanisms (a suggestion proposed by Pessoa, 2008). If emotional stimuli were processed independently of attention, the influence of emotional stimuli on reasoning would not differ under conditions of varying probabilities (e.g. 60:40 versus 85:15) and therefore task difficulty (more versus less difficult) in the Beads Tasks. In contrast, if emotional stimuli only influenced inductive reasoning under conditions of reduced task difficulty (e.g. 85:15), when more processing resources are available, this would suggest that emotion processing is affected by attention mechanisms.

The next two sections aim to present theories and experimental evidence for the influence of mood state and the interaction of mood and emotional stimuli with inductive reasoning.

3.2.3 Mood state

Garety and colleagues (2005) proposed a multifactorial model of psychosis in which emotional processes including depression contribute to the development and persistence of positive symptoms. Positive symptoms such as delusions are hypothesised to be due to biased reasoning processes, which have been studied using the Beads Task (Garety, et al., 2005). Although the results of their experimental investigation with deluded patients did not support the notion that emotional processes such as depression were associated with jumping to conclusions, they recommended that this should be assessed systematically using mood induction techniques. In this series of experiments, Mood Induction Procedures (MIPs) were used to investigate the effect of sad, happy, and neutral mood on inductive reasoning. Studies investigating reasoning biases in depressed patients have included them as a psychiatric

control group for the patient population of interest (deluded patients). These studies have shown no significant differences between depressed patients and healthy controls (Bentall, et al., 2009; Corcoran, et al., 2008; Dudley, et al., 1997a, 1997b). They have consistently shown that deluded patients typically request less information before making a decision than both non-deluded depressed patients and healthy control participants (Bentall, et al., 2009; Corcoran, et al., 2008; Dudley, et al., 1997a, 1997b; Garety, 1991; Huq, et al., 1988; Menon, et al., 2006); see Table 3.1.

Deluded patients request less information in the less compared with more difficult versions of the task; see Table 3.1 (Dudley, et al., 1997b; Menon, et al., 2006). Accordingly it was argued that they do not demonstrate a deficit in probabilistic reasoning, rather a data-gathering bias that may lead to erroneous inferences (Garety & Freeman, 1999). Extending such research to depression may have implications for the influence of mood state on the ability to perform sophisticated, abstract, and higher level cognitive processes. Depression is generally associated with deficits in performance, slowness, and inefficient inferential processing (Damasio, 1994), as well as more systematic and elaborative processing of stimuli (Blanchette & Richards, 2010; Palfai & Salovey, 1993). In the Beads Tasks this may present as difficulties in decision making thus more beads drawn before deciding. Alternatively there may be no statistical difference (as reported in Corcoran, et al., 2008; Dudley, et al., 1997a; Dudley, et al., 1997b).

Happy mood states have been associated with a greater reliance upon more heuristic or rule-of-thumb processing strategies (Blanchette & Richards, 2010) and ease of inference (Damasio, 1994), as well as an increased ability to organise and integrate information more efficiently within the reasoning process (Estrada, Isen, & Young, 1997). Accordingly participants may request fewer beads before deciding.

3.2.4 Emotional stimuli and mood state

The effects of mood state on task performance may also be influenced by the stimulus valence (cf. Badcock & Allen, 2003). Depression is associated with mood-congruent information processing biases (see Chapter 2: Sad Mood Induction: A Systematic Review), however the influence of mood state and emotional stimuli on reasoning has largely been ignored (Blanchette & Richards, 2010). Emotional and non-emotional trials were performed following both the neutral and emotional (sad or happy) MIPs. Therefore the design of these experiments allowed an investigation of the potential interaction of mood state and emotional stimuli with inductive reasoning.

In previous studies (see Table 3.1), depressed patients requested fewer beads before deciding in emotional compared with neutral trials (Bentall, et al., 2009; Corcoran, et al., 2008; Dudley, et al., 1997a). However there was no significant difference between depressed patients and healthy control participants in the number of beads requested in the neutral and emotional trials. In a different version of the Beads Task where participants had to indicate their certainty that beads had been drawn from one of two jars, depressed patients showed greater certainty compared with healthy controls in emotional but not non-emotional trials (Young & Bentall, 1997). Here, two alternative hypotheses were proposed. In line with the findings of previous studies using the Beads Task, there would be no interaction between mood state (sad) and emotional stimuli (negative face) on the number of beads drawn before deciding. Alternatively, participants' would request fewer beads before deciding in negative compared with positive emotional trials following a sad MIP.

Research on the influence of a happy mood state on attention processing is less clear. Some researchers suggest that a happy mood state broadens the scope of attention (Fredrickson, 1998) thus leading to a more general bias towards emotional stimuli whereas others suggest a mood-congruent processing bias (Bower, 1981). In the Beads Tasks, participants may request

fewer beads before deciding in both positive and negative emotional trials (Fredrickson, 1998) or specifically in positive emotional trials (Bower, 1981).

3.2.5 Summary

Deductive and possibly inductive reasoning tasks require the use of working memory capacity to be completed successfully (Copeland & Radvansky, 2004). There is limited capacity for processing incoming visual stimuli, therefore task-relevant information (e.g. colour of beads) is prioritized. In contrast, task-irrelevant stimuli (e.g. facial expressions of emotion) are outside the focus of attention and therefore largely ignored. However:

- Unattended, emotional stimuli can break through this selective attention filter.
- The ability of task-irrelevant, salient stimuli to break through is largely dependent upon task difficulty: the amount of processing capacity that is consumed by the processing of task-relevant stimuli.
- Mood state can alter an individual's goal-directed behaviour to facilitate processing of emotional stimuli (when stimuli are both task-relevant and task-irrelevant).

3.3 Experiment one

3.3.1 Aims and hypotheses

The aim of this experiment was to investigate the influence of mood state and emotional stimuli on inductive reasoning. Mood states were manipulated to test differences between sad and happy MIPs. In addition, emotional trials included rapidly presented angry and smiling faces, contrasted to a non-emotional 'no-face' condition.

Predictions were that:

- Participants would require fewer beads (thus demonstrate a tendency towards early decision) when presented with emotional (angry and smiling face) compared with non-emotional trials, consistent with previously reported findings (Bentall, et al., 2009; Corcoran, et al., 2008; Dudley, et al., 1997a).
- If the processing of emotional stimuli is influenced by top-down mechanisms such as selective attention, prediction one would be more certain under less difficult conditions (i.e. with less even proportions of beads; 85:15). This is because more resources would be available to process both task-relevant (i.e. beads) and task-irrelevant (e.g. facial expressions of emotion) information.
- Following the sad MIP, participants would require more information, as they engage in more systematic and elaborative processing, or may demonstrate no difference. However, they may request relatively less information in the negative (angry face) compared with positive (smiling face) emotional and non-emotional (no face) trials. Alternatively there may be no interaction of mood state and emotional stimuli, consistent with previously reported findings (Bentall, et al., 2009; Corcoran, et al., 2008; Dudley, et al., 1997a).
- Following the happy MIP, participants would request less information as they engage in more heuristic or rule-of-thumb processing. Additionally, in accordance with mood-congruent hypotheses, participants would require relatively less information on mood-congruent (smiling face) emotional compared with non-emotional trials (Bower, 1981). Alternatively, and in accordance with the Broaden and Build hypothesis (Fredrickson, 1998), participants would require less information on emotional (smiling and angry face) compared with non-emotional trials.

3.3.2 Methods

3.3.2.1 Participants

Recruitment

Ninety seven participants were recruited during a laboratory class at the University of Oxford Department of Experimental Psychology. Of these, 49 were assigned to the sad, and 48 to the happy mood induction groups. Data from one participant in the sad mood induction group was accidentally not recorded, thus leaving 48 participants in each group. Participants were blind to their own group membership prior to testing.

Inclusion and exclusion criteria

Participants were informed that they should not take part if currently suffering, or had suffered in the past, from any neurological, psychiatric or psychological problem, or major medical condition.

3.3.2.2 The Beads Task

A computerised version of a modified “beads-in-a-jar” task (Garety et al., 2005) was used. In the Beads Task, participants were shown two jars (‘Jar A’ and ‘Jar B’). In the less even version of the task, Jar A contained 85 pink and 15 blue beads while Jar B contained 85 blue and 15 pink beads. In the more even version of the task, Jar A contained 60 green and 40 yellow beads while Jar B contained 60 yellow and 40 green beads (see Figure 3.1). Task difficulty was manipulated using jars of beads containing less (85:15) and more (60:40) even proportions of beads, therefore less and more difficult respectively. Participants were then shown a sequence of beads drawn one at a time (to a maximum of 20 draws) in an apparently randomly drawn but actually predetermined order according to the proportions of beads in one of those jars, and had to guess which jar the beads had been drawn from. They were told that the beads would always come from the same jar and would be replaced afterwards, thus retaining the same proportion of beads in that jar. On each draw, participants chose whether they wanted

to see another bead or make their decision. To reduce working memory task demands, previously drawn beads were shown at the bottom of the screen (as in Dudley, et al., 1997b). The number of beads drawn before deciding measures the amount of information required to make an inference, and therefore the degree to which participants 'jump to conclusions'.

Of the 6 trials in each of the more and less even versions, there were two non-emotional control trials and four emotional trials. Emotional trials differed from non-emotional trials by the presence of an angry or smiling face (17ms) followed by a scrambled neutral face (17ms) prior to presentation of each bead (see Figure 3.2). Two of these trials showed negative (angry) faces and two showed positive (smiling) faces. The sequences of the colour of beads presented in the six trials are shown in Table 3.2. Parameters were chosen to minimise conscious awareness of the facial expressions of emotion; one study reported participants' above chance performance on a two-alternative forced choice emotional identification task only when the interval between the target (emotional face) and post-target mask (neutral face) was >100ms (Esteves & Öhman, 1993).

The experiment was programmed and run with E-Prime software (Psychology Software Tools Inc., Pittsburgh, USA) on Personal Computers (PCs).

85:15

Instruction screen A

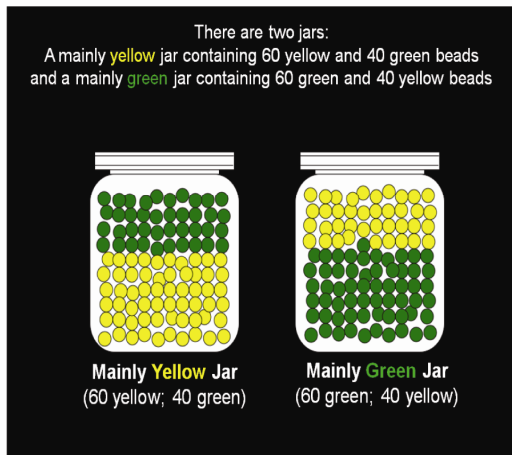


Instruction screen B



60:40

Instruction screen A



Instruction screen B



Figure 3.1: Instruction screens presented to participants in the 85:15 and 60:40 versions of the Beads Task

Trial	85:15 probability condition	60:40 probability condition
No face	PBPPPPBPPPPPPPPBPP	GYGYGGGYGGGYGGYYYYGG
No face	BBPB BBBB BBPBBPBBB PB	YYGGGGYYGYYYGYYYGYGY
Smiling face	BBBPBBBPPBBBBBBPBBB	YGYYYGGGYGGYYYYYYYYG
Smiling face	PPBPPPPBPPPBPPPPPP	GYGGYGYGYGYGGYYYYYYY
Angry face	BBBBPBBBBBPPBBPBBBBB	YGGGYGGGYGYGGYYGGGYG
Angry face	PPPBPPPPPPBPPPBPPPB	YGYYYGGGYGYGGYYGGYYG

Table 3.2: Sequence of beads presented in each of the six trials of the Beads Tasks in the 85:15 and 60:40 probability conditions

P = Pink, B = Blue; G = Green, Y = Yellow.

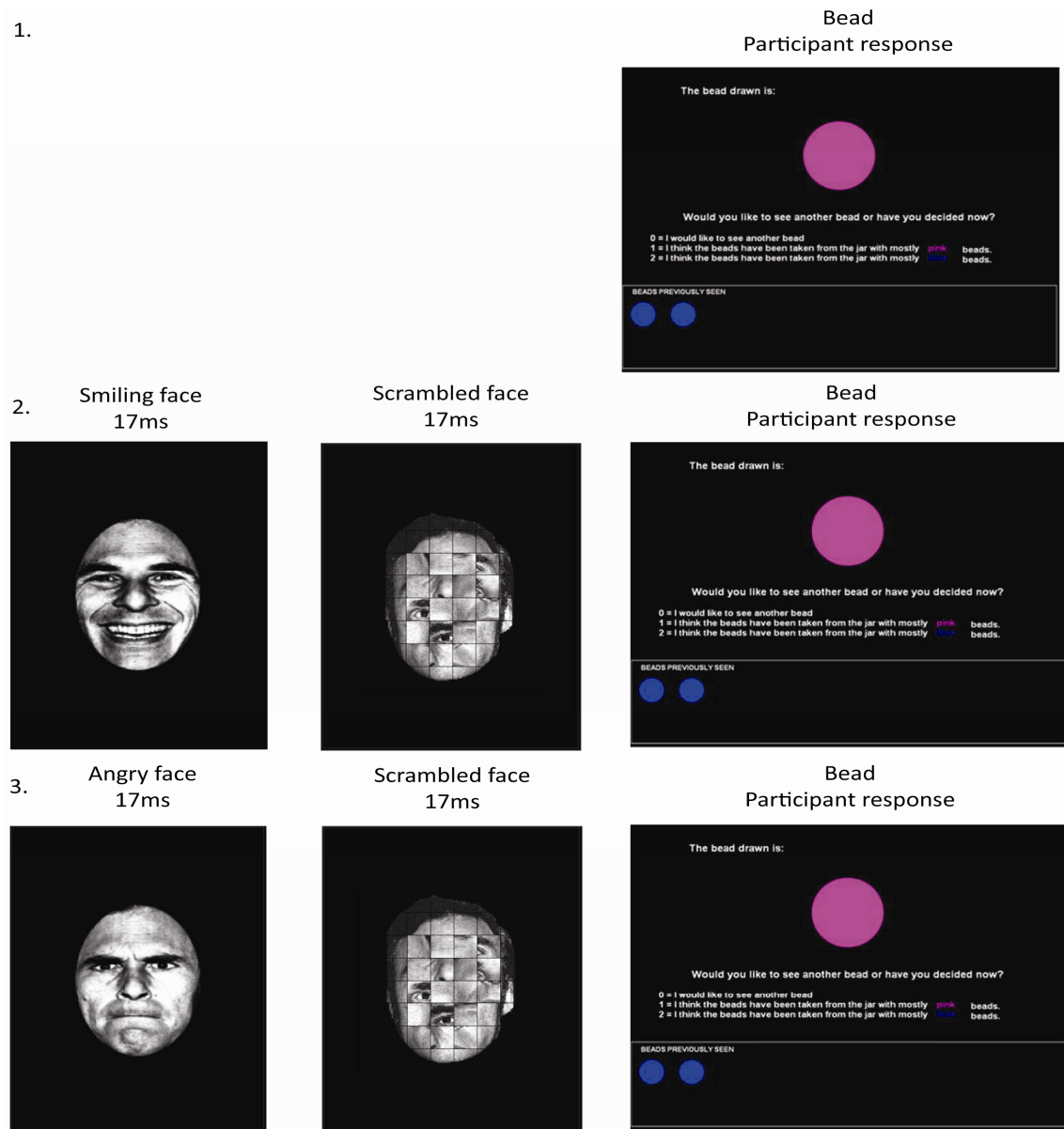


Figure 3.2: Example of screens presented to participants in the non-emotional (1), smiling face (2), and angry face (3) trials

In the emotional trials an angry or smiling face followed by a scrambled neutral face was presented prior to the bead and participant decision screen.

3.3.2.3 Mood induction

Neutral, sad and happy mood states were induced using a combination of self-referential statements and mood-congruent music. Participants viewed 25 statements (Richell & Anderson, 2004; Seibert & Ellis, 1991), each for a period of 20 seconds, which they were instructed to focus their full attention on, along with mood-congruent music. In the sad and happy MIPs, participants were told that the music and the self-referential statements represented a certain mood, and that they should try to respond to these moods and feelings. Sad and happy self-referential statements were those of Seibert and Ellis (1991) while neutral statements were modified (Richell & Anderson, 2004) to make them compatible with UK English. The instructions and statements for the MIPs are presented in Appendix 1.4. The musical pieces selected to induce neutral, sad, and happy moods were Gustav Holst's 'Neptune, The Mystic' (from The Planets VII), Samuel Barber's 'Adagio for Strings' (played at half speed) and a jazz version of Johann Sebastian Bach's 'Brandenburg Concerto No.3, First Movement' played by Hubert Laws, respectively.

3.3.2.4 Measures of mood state

Trait mood symptoms

Scores of the severity of depressive symptoms were obtained using the 21-item Beck Depression Inventory Second Edition (BDI-II; A.T. Beck, Steer, & Brown, 1996); a self-report measure consisting of four or five self-evaluative statements of increasing severity scored on a four-point scale from 0 to 3. Psychometric data quantify the reliability and validity of the BDI-II as a self-report measure of depressive symptoms in clinical and nonclinical populations, including college and university students (A.T. Beck, Steer, & Garbin, 1988; Dozois, Dobson, & Ahnberg, 1998; Steer & Clark, 1997).

The 20-item State-Trait-Anxiety-Inventory (STAI; Spielberger, 1983) in which items either describe the symptoms or indicate the absence of anxiety, was used as a measure of anxiety

symptoms. Psychometric data quantify the reliability and validity of the STAI-T as a self-report measure of anxiety, in clinical and nonclinical populations (Andrade, Gorenstein, Vieira Filho, Tung, & Artes, 2001).

Mood state ratings

The Profile of Mood States (POMS; McNair, 1992) is a widely used, reliable self-report measure of current mood state, and related changes, validated for use with psychiatric outpatients, as well as healthy college and university student and adult samples (McNair, 1992; Nyenhuis, Yamamoto, Luchetta, Terrien, & Parmentier, 1999). The standard version contains 65 self-referential adjectives for which participants indicate how they are feeling at that moment using a 5-point Likert scale (0 = not at all; 1 = a little; 2 = moderately, 3 = quite a lot; 4 = extremely); see Appendix 1.5. This instrument provides subscale scores for six factor-based mood states and an overall Total Mood Disturbance (TMD) score. In the original paper, TMD scores were calculated by first summing across the subscales anger-hostility, confusion-bewilderment, depression-dejection, fatigue-inertia, and tension-anxiety and then subtracting the subscale vigour-activity score (McNair, 1992). However to facilitate interpretations of the data, such that the more negative scores reflected a more negative mood-state, here the summed subscale scores were subtracted from the subscale vigour-activity score. A shortened, 17-item version of the POMS consists of the same subscales but with fewer items; Table 3.3.

Anger- Hostility	Confusion- Bewilderment	Depression- Dejection	Fatigue- Inertia	Tension- Anxiety	Vigor- Activity
Ready to fight	Bewildered	Blue	Weary	On edge	Alert
	Muddled	Discouraged		Relaxed	Carefree
		Gloomy		Uneasy	Cheerful
		Miserable			Energetic
		Sad			
		Unhappy			

Table 3.3: Items included in the shortened 17-item version of the POMS, categorised by subscale

3.3.2.5 Participant questionnaire

At the end of the experimental procedures, participants completed a questionnaire which included questions about their age, gender, level of education, and ethnicity, as well as questions about the Beads Task and MIPs (see Appendix 1.6).

3.3.2.6 Procedures

As the MIPs and Beads Tasks were computerised, testing took place in a computing laboratory in a single session lasting between 60 and 90 minutes (for a timeline of experimental procedures see Figure 3.3). Participants were briefed about the experimental procedures and tasks. Baseline mood state, and depressive and anxiety symptoms were assessed using the standard version of the POMS, BDI-II and STAI-T, respectively. If any participant recorded a BDI-II equal to or greater than 19 (moderate to severe depressive symptoms range), the person supervising the experiment spoke to the participant to remind them of the experimental procedures and ask if they wanted to continue. In Phase 1, participants received the *neutral* MIP then rated their mood state using the shortened form of the POMS. This was followed by the non-emotional and emotional versions of the Beads Tasks in the less (85:15) and more (60:40) even proportion conditions. After the tasks, participants rated their mood again. In Phase 2, participants received either the *sad* or *happy* MIP, and then rated their mood. This was followed again by the non-emotional and emotional versions of the Beads Tasks in the less (85:15) and more (60:40) even proportion conditions, and participants rated their mood again. Participants completed the standard version of the POMS and a brief participant questionnaire at the end of the experimental procedures and were fully debriefed. All participants who received the sad MIP were given the opportunity to receive the happy MIP before leaving. A decision was taken to not counterbalance the order of neutral and emotional MIPs for two reasons. Firstly, beginning the experiment with a neutral MIP could potentially reduce variability in participants' mental state to provide a more stable baseline for the emotional mood induction. Second, inducing all participants into the same mood state at the

same time might facilitate any potential group-induction effects; that is the influence of peers in the same mood state, in order to amplify the desired mood state. The possibility of emotion contagion effects could have been lost, or even reversed, by inducing different mood states in different individuals (Bates, Thompson, & Flanagan, 1999; Elaine, John, & Richard, 1993).

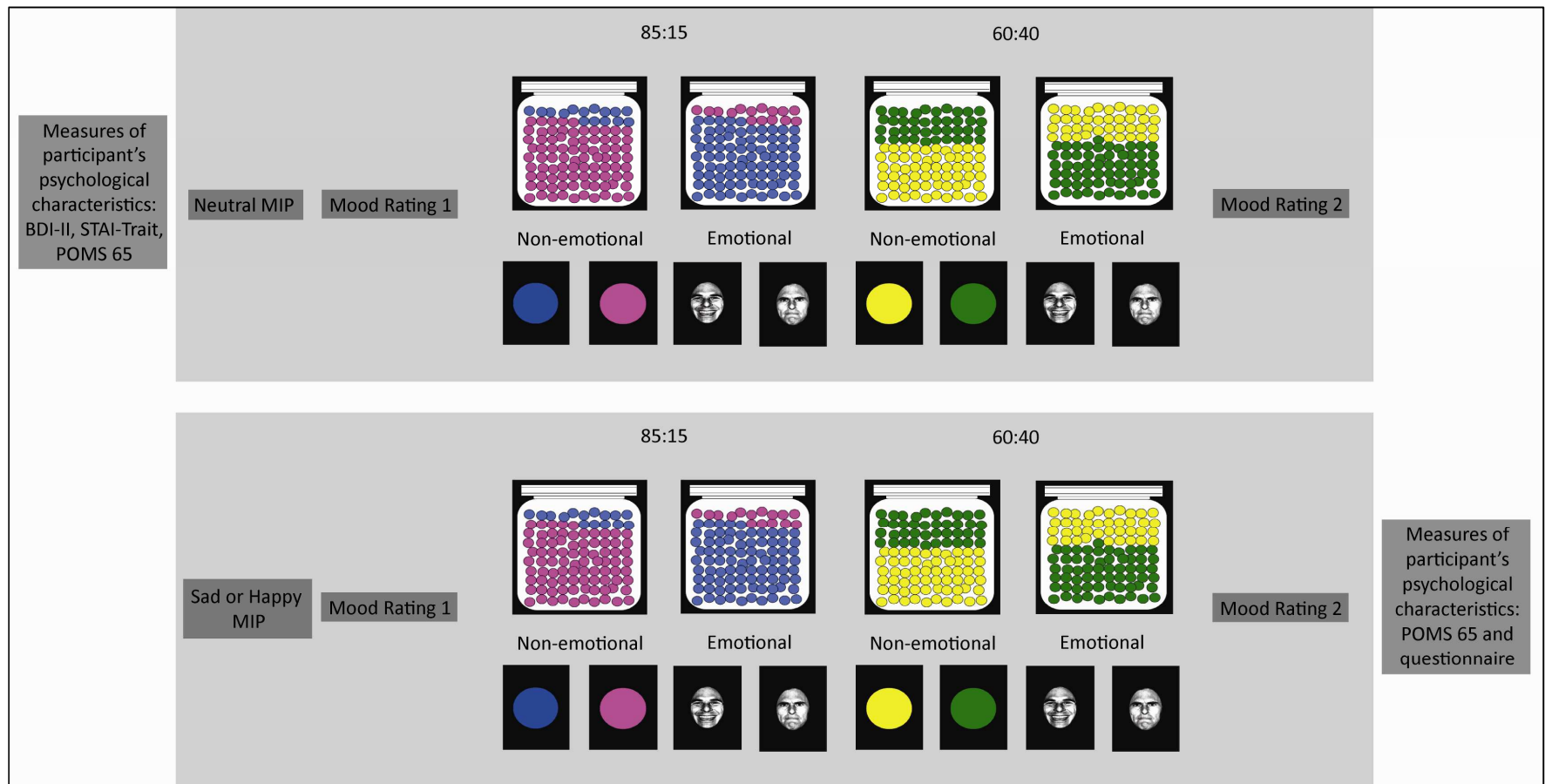


Figure 3.3: Timeline of experimental procedures. Neutral MIP=Phase 1 and Sad/Happy MIP=Phase 2

3.3.2.7 Statistics

Mood data

A shortened, 17-item version of the POMS (and its subscales) was used to measure mood state on four separate occasions: immediately after the MIP/before the tasks (Time 1) and after the tasks (Time 2) following neutral (Phase 1) and valenced (Phase 2) MIPs; for participants in the sad and happy groups. POMS-TMD and subscale scores were analysed with separate repeated measures analysis of variance (ANOVAs). Planned comparisons included investigating the assumptions that mood state would:

- Differ following the valenced MIPs for participants in the sad and happy groups,
- Not differ following the neutral MIPs for participants in the sad and happy groups, and
- Remain consistent over time (from post-MIP to post-task).

Behavioural data

Expert advice was sought from a statistician, Dr Marriott, through the Statistical Consultancy Service (http://www.stats.ox.ac.uk/about_us/statistical_consultancy_service) provided by the University of Oxford, Department of Statistics: a Univariate ANOVA was used to analyse the data because there was a single outcome measure (number of beads drawn before deciding). Methods conventionally used by experimental psychologists include Repeated Measures ANOVAs and Mixed ANOVAs. The design of this experiment was not suited to be analysed using either of these methods. The design was not Repeated Measures because although participants completed the tasks following a neutral and emotional MIP, the emotional MIP was a between-subjects factor (either sad or happy) for experiment one. Similarly in experiment two although all participants received a neutral and sad MIP (a repeated measure) and neutral and smiling face emotion, there was a between-subjects factor of negative face emotion (either angry, fearful, or sad). A Mixed ANOVA could not be used in experiment one because although there was both a between (sad or happy MIP) and within (no face, angry and

smiling face emotion) subjects design, this would not account for data following the neutral MIP. In summary, when multiple measures on a single outcome variable are obtained for participants, a Repeated Measures ANOVA cannot be used because there would almost certainly be correlation of the errors. Consequently each response can be entered as a separate Univariate observation and Participant ID included as a random blocking factor that is able to account for this correlation and eliminate any effects of participant on the outcome variable (<http://www.stat.cmu.edu/~hseltman/309/Book/chapter14.pdf>).

A Univariate ANOVA was used with the fixed factors Mood (neutral, sad, and happy), Faces (neutral, angry, and smiling), and Probability (85:15, 60:40) as well as the random factor of Participant ID on the independent variable: number of beads drawn before deciding. Planned comparisons included investigating the assumptions that participants would draw fewer beads:

- On emotional (angry and smiling face) than non-emotional (no face) trials.
- On emotional (angry and smiling face) than non-emotional (no face) trials, in the less (85:15) compared with more (60:40) even probability conditions.
- Following the sad MIP on angry compared with smiling face trials.
- Following the happy MIP on smiling compared with angry face trials or on emotional (angry and smiling face) compared with non-emotional (no face) trials.

3.3.3 Results

3.3.3.1 Participants

There were no significant between-group differences for any of the presumed confounder variables; age, gender, education, BDI-II ², STAI-T, and baseline mood state before or after

² In the sad MIP group, one participant had a BDI-II score of 21 and another of 27. In the happy MIP group, two participants had BDI-II scores of 21, one of 23, one of 24, one of 25, one of 30, and one of 32. The person supervising the experiment spoke to each participant and all wanted to continue with the experiment.

experimental procedures for the POMS-TMD scores (see Table 3.4). Mean POMS-TMD scores were within two standard deviations of the mean of the college student normative sample (McNair, 1992).

	Sad group (N=48)	Happy group (N=48)	p-value
Age, Mean (SD)	20.83 (2.08)	20.38 (0.87)	0.16
Gender, No. (%)			
Male	20 (41.7)	19 (39.6)	0.84
Female	28 (58.3)	29 (60.4)	
Educational Level, No. (%)			
A-Level	43 (89.6)	40 (83.3)	0.32
Degree	5 (10.4)	6 (12.5)	
Other (IB)	0 (0)	2 (4.2)	
BDI-II, Mean (SD)	8.02 (5.80)	10.27 (7.71)	0.11
STAI-T, Mean (SD)	37.75 (8.24)	40.27 (9.47)	0.16
Baseline Mood, Mean (SD)			
POMS ^A before experiment	-16.2 (21.58)	-20.4 (22.06)	0.35
POMS ^A after experiment	-18.0 (24.78)	-12.0 (17.23)	0.18

Table 3.4: Summary of participant characteristics

Missing data for one participant in each of the Sad and Happy groups for POMS score after the experiment. Contrast: t-test (or χ^2), two-tailed significance.

IB=International Baccalaureate; BDI-II = Beck Depression Inventory Second Edition (A.T. Beck, et al., 1996); STAI-T = State Trait Anxiety Inventory (Spielberger, 1983); POMS = Profile of Mood States (McNair, 1992) standard 65 item version. ^APOMS scores were reverse coded to those of the original paper, such that more negative scores indicate a more negative mood state.

3.3.3.2 Mood data

A parallel-groups repeated-measures ANOVA compared mean POMS-TMD scores immediately after the MIP/before the tasks (*Time 1*) and after the tasks (*Time 2*) following neutral (*Phase 1*) and valenced (*Phase 2*) MIPs. The between-subjects factor was *Group* (sad or happy). These analyses were repeated with the POMS subscale scores to assess the specificity of the MIPs to a depressed (using the depression-dejection subscale) and happy (using the vigor-activity subscale) mood state.

Overall mood state ratings

There was a *Mood by Group* interaction [$F_{(1, 94)}=49.27, p<0.001$]. Participants in the sad and happy groups did not differ following the neutral MIP but did following the emotional MIPs; see Figure 3.4. Participants in the sad group were significantly more negative following the sad than neutral MIPs ($t_{(47)} = 4.890; p<0.001$) and participants in the happy group were more positive following the happy than neutral MIPs ($t_{(47)} = -5.357; p<0.001$). Thus, sad and happy mood induction resulted in significant changes in mood state in the expected direction.

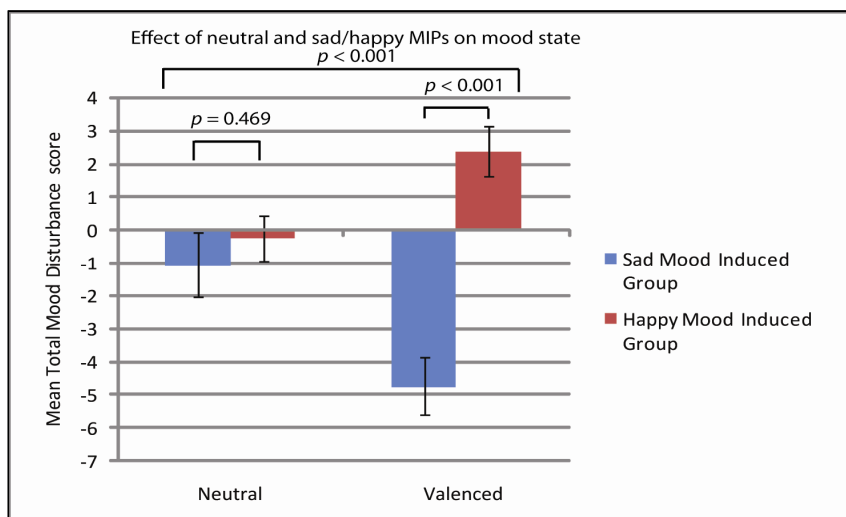


Figure 3.4: Mean POMS-TMD scores and standard error bars for the sad and happy mood induction groups at Phase 1 (Neutral mood) and Phase 2 (Valenced mood)

Data are collapsed across time (i.e. mood state rating taken immediately after the MIP/before the tasks [Time 1] and after the tasks [Time 2]). *P*-values are of post-hoc independent samples *t*-tests comparing mood state ratings between the sad and happy MIP groups.

There was a significant main effect of *Time* [$F_{(1, 94)}=32.20, p<0.001$] showing that participants' mood state ratings varied from Time 1 to Time 2. The main effect of *Time* was qualified by significant interaction effects of *Time by Group* [$F_{(1, 94)}=15.02, p<0.001$] and *Mood by Time by Group* [$F_{(1, 94)}=16.62, p<0.001$]. This 3-way interaction demonstrates that the effect of sad and happy MIPs on mood state was somewhat diluted after performing the Beads Tasks (*Time 2*) compared with immediately after the MIP/before the tasks (*Time 1*), particularly after the sad

mood induction, when mood was improved (see Figure 3.5).³ However, after the Beads Tasks, mood was still significantly more negative in the sad compared with happy mood induced groups ($t_{(94)} = -3.689$; $p < 0.001$).

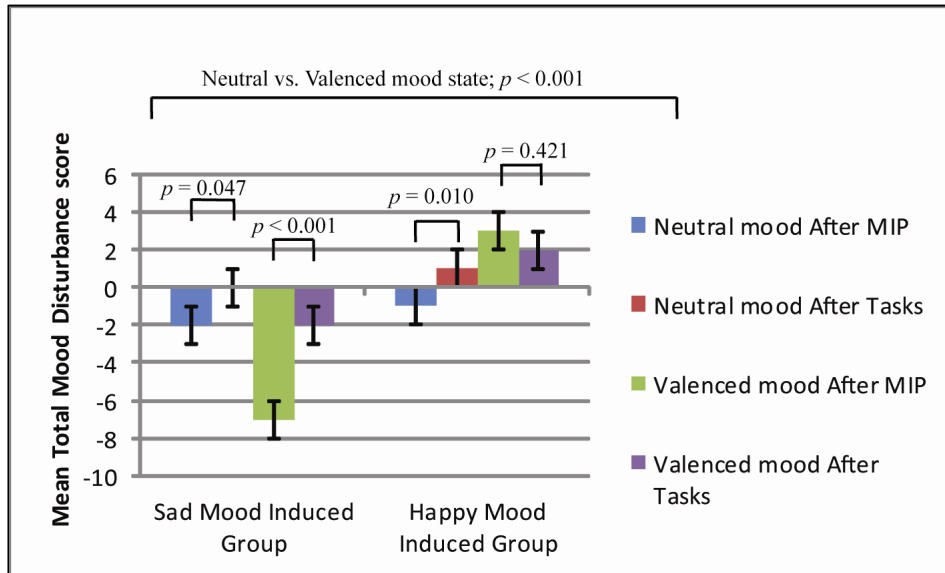


Figure 3.5: Mean POMS-TMD scores and standard error bars for the sad and happy mood induction groups at Phase 1 (Neutral mood) Time 1 (immediately after the MIP/before the tasks) and Time 2 (after the tasks) and Phase 2 (Valenced mood) Time 1 and 2

P-values are of post-hoc paired samples *t*-tests.

Subscale mood state ratings

A significant *Mood by Group* effect [$F_{(1, 94)} = 32.84$, $p < 0.001$] showed that participants reported more depression-dejection immediately following the sad compared with happy MIP ($t_{(94)} = 6.01$; $p < 0.001$) and after the tasks ($t_{(94)} = 3.32$; $p = 0.001$). There was no between-group difference immediately following the neutral MIP ($t_{(94)} = 0.27$; $p = 0.784$) or after the tasks ($t_{(94)} = 1.55$; $p = 0.124$). There was also a *Mood by Time by Group* effect [$F_{(1, 94)} = 25.41$, $p < 0.001$] such that participants in the sad group were significantly more depressed immediately following the sad compared with neutral MIP ($t_{(47)} = -5.32$; $p < 0.001$), but only showed a trend towards being

³ Twelve participants reported potentially lasting (“Possibly short term [for a few hours]”) adverse effects of the sad MIP (e.g. “A little less chirpy than before I came in”) at the end of the experimental procedures but none took the opportunity to receive the happy MIP.

more depressed following the tasks ($t_{(47)} = -1.74$; $p = 0.088$). Participants in the happy group were significantly less depressed immediately following the happy compared with neutral MIP ($t_{(47)} = 3.40$; $p = 0.001$) but there was no such difference following the tasks ($t_{(47)} = 1.61$; $p = 0.114$).

There was a significant *Mood by Group* effect for the vigor-activity subscale scores [$F_{(1, 94)} = 59.38$, $p < 0.001$] such that participants reported significantly higher vigor-activity scores following the happy compared with sad MIP ($t_{(94)} = -4.67$; $p < 0.001$), whereas there was no group difference following the neutral MIP ($t_{(94)} = -0.22$; $p = 0.826$). This effect was qualified by a significant *Mood by Time by Group* effect [$F_{(1, 94)} = 5.15$, $p = 0.026$]. Post-hoc paired samples t-tests showed that within the happy induced group, participants reported significantly more vigor-activity immediately following the happy compared with neutral MIPs ($t_{(47)} = -3.55$; $p = 0.001$) as well as after the tasks ($t_{(47)} = -2.13$; $p = 0.038$). In contrast in the sad induced group, although participants reported significantly less vigor-activity immediately following the sad compared with neutral MIPs ($t_{(47)} = 5.69$; $p < 0.001$) as well as after the tasks ($t_{(47)} = 6.31$; $p < 0.001$), they reported higher levels of vigor-activity after the tasks following the sad MIP compared with immediately after the sad MIP ($t_{(47)} = -2.52$; $p = 0.015$). This latter effect was not present for participants in the happy induced group who reported the same levels of vigor-activity immediately after the MIP and tasks following the neutral ($t_{(47)} = -1.02$; $p = 0.311$) and happy ($t_{(47)} = 1.17$; $p = 0.247$) MIPs. This 3-way interaction demonstrates that the effect of the sad MIP on reducing levels of vigor-activity was somewhat diluted after performing the tasks. Mean values and post-hoc t-tests for POMS TMD, and depression-dejection and vigor-activity subscale scores are presented in Table 3.5.

			Sad group	Happy group	Sad vs. Happy group
POMS-TMD	Neutral MIP	Time 1	-1.75	-1.04	$p=0.538$
		Time 2	-0.38	0.54	$p=0.467$
		Time 1 vs. 2	$p=0.047$	$p=0.01$	
	Valenced MIP	Time 1	-7.27	2.56	$p<0.001$
		Time 2	-2.23	2.19	$p<0.001$
		Time 1 vs. 2	$p<0.001$	$p=0.421$	
POMS Depression-Dejection	Neutral MIP	Time 1	1.71	1.56	$p=0.784$
		Time 2	1.71	0.92	$p=0.124$
		Time 1 vs. 2	$p=1.000$	$p=0.003$	
	Valenced MIP	Time 1	5.58	0.65	$p<0.001$
		Time 2	2.40	0.63	$p=0.001$
		Time 1 vs. 2	$p<0.001$	$p=0.883$	
POMS Vigor-Activity	Neutral MIP	Time 1	6.96	7.04	$p=0.887$
		Time 2	7.19	7.35	$p=0.783$
		Time 1 vs. 2	$p=0.283$	$p=0.311$	
	Valenced MIP	Time 1	5.04	8.33	$p<0.001$
		Time 2	5.81	7.96	$p<0.001$
		Time 1 vs. 2	$p=0.015$	$p=0.247$	

Table 3.5: Mean mood rating scores for participants in the sad and happy groups immediately after the MIP/before the tasks (Time 1) and after the tasks (Time 2)

P-values show post-hoc independent samples t-test comparing scores between groups (far column) as well as post-hoc paired samples t-tests comparing scores between Time 1 and 2 (row highlighted in grey).

Importantly, there was no significant *Mood by Group* effect for the subscales anger-hostility [$F_{(1, 94)}=2.81, p=0.097$], confusion-bewilderment [$F_{(1, 94)}=1.89, p=0.172$], and tension-anxiety [$F_{(1, 94)}=2.36, p=0.128$]. There was, however, a significant *Mood by Group* effect for the subscale fatigue-inertia [$F_{(1, 94)}=16.213, p<0.001$]. Across *Time 1 and 2*, participants reported increased fatigue following the sad compared with happy MIP ($t_{(94)}=3.04; p=0.003$), whereas there was no group difference following the neutral MIP ($t_{(94)}=0.40; p=0.691$).

3.3.3.3 Behavioural data

The outcome measure (the *Number* of beads drawn before deciding) was log-transformed to adjust for skewing of the data prior to analysis in a Univariate ANOVA, with *Mood* induction (neutral, sad and happy), *Faces* (none, angry or smiling), and *Probability* (85:15 and 60:40) as

fixed factors and *Participant ID* as a random factor. The Mean: M (and standard deviation: SD) number of beads drawn before deciding are shown in Table 3.6 and the results of the Univariate ANOVA are summarised in Table 3.7.

	Neutral mood	Sad mood	Happy mood
85:15 No face	5.10 (1.68)	4.35 (1.43)	4.81 (1.58)
85:15 Angry face	4.22 (1.72)	3.60 (1.49)	4.06 (1.63)
85:15 Smiling face	4.44 (1.73)	3.82 (1.58)	4.18 (1.72)
60:40 No face	9.03 (1.77)	8.41 (1.52)	7.92 (1.55)
60:40 Angry face	9.39 (1.68)	8.08 (1.68)	8.08 (1.90)
60:40 Smiling face	8.76 (1.75)	8.00 (1.63)	7.77 (1.80)

Table 3.6: Mean (and standard deviation) number of beads drawn before deciding by Mood, Probability, and Face emotion

Effects	df	F	p-value
Mood	2, 95.19	11.78	0.000***
Faces	2, 221.03	10.24	0.000***
Probability	1, 98.62	324.34	0.000***
Probability * Faces	2, 649.00	12.14	0.000***
Mood * Faces	4, 649.00	0.71	0.584
Probability * Mood	2, 649.00	0.50	0.605
Probability * Mood * Faces	4, 649.00	0.24	0.915

Table 3.7: Results of the Univariate analysis of variance for number of beads drawn before deciding

* $p < 0.05$; ** $p < 0.01$; *** $p < 0.001$. df = degrees of freedom, F = F-statistic.

There were main effects of *Mood* [$F_{(2, 95.19)}=11.78$, $p < 0.001$], *Faces* [$F_{(2, 221.03)}=10.24$, $p < 0.001$] and *Probability* [$F_{(1, 98.62)}=324.34$, $p < 0.001$]. The 85:15 condition (M=4.33, SD=1.66) was associated with a smaller number of beads drawn before deciding than the 60:40 condition (M=8.52, SD=1.71). To tease apart the main effect of *Mood*, pairwise comparisons (adjusted with least significant difference: LSD) showed that participants requested fewer beads before deciding following sad ($p=0.006$) and happy ($p=0.043$) compared with neutral MIPs but no differences between sad and happy MIPs ($p=0.32$). Sad: M=5.67, SD=1.79; Happy: M=5.86, SD=1.84; Neutral: M=6.42, SD=1.90. The main effect of *Faces* showed that participants

requested fewer beads before deciding when the beads were preceded by rapidly presented emotional faces but not no faces (Angry faces: $M=5.91$, $SD=1.92$; Smiling faces: $M=5.91$, $SD=1.89$; No faces: $M=6.43$, $SD=1.76$). This was qualified by a 2-way *Faces by Probability* interaction [$F_{(2, 649)}=12.14$, $p<0.001$]. One-way ANOVAs demonstrated that the effect of faces occurred in the 85:15 [$F_{(2, 568)}=6.95$, $p=0.001$] but not 60:40 [$F_{(2, 571)}=0.38$, $p=0.682$] probability condition; see Figure 3.6. The simple random effects of *Participant ID* and its two-way interactions with Mood, Faces, and Probability were all highly significant, demonstrating individual variability in responding. Finally, the three-way interaction of *Mood by Faces by Probability* was not significant [$F_{(4, 649)}=0.24$, $p=0.915$].

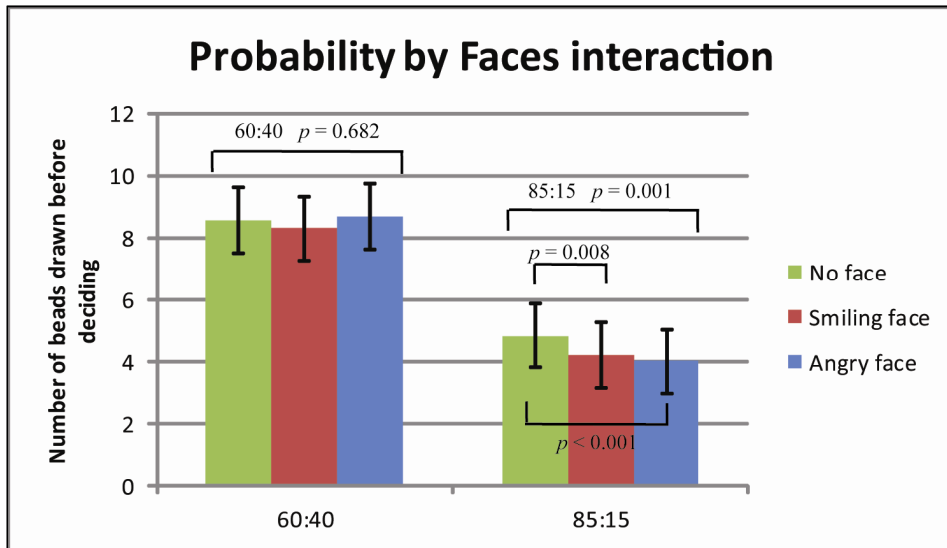


Figure 3.6: Mean and standard error bars for Probability by Faces interaction

Paired samples t-tests were conducted to explore the influence of sad and happy mood states, separately, on biases towards emotional stimuli (i.e. the number of beads drawn before deciding on angry and smiling face trials). In the 85:15 probability condition, participants drew fewer beads before deciding on the angry compared with smiling face trials following a sad ($t_{(46)}=2.45$; $p=0.018$) but not happy ($t_{(47)}=1.10$; $p=0.279$) MIP; see Figure 3.7. There were no differences in the number of beads drawn before deciding on the angry and smiling face trials following either sad ($t_{(47)}=-0.378$; $p=0.707$) or happy ($t_{(47)}=-0.693$, $p=0.492$) MIP in the 60:40

probability condition. Participants drew fewer beads before deciding on emotional (pooled across angry and smiling) face trials compared with non-emotional trials in the 85:15 but not the 60:40 probability conditions following both the sad ($t_{(46)} = 5.95$; $p < 0.001$) and happy ($t_{(47)} = 4.43$; $p < 0.001$) MIPs.

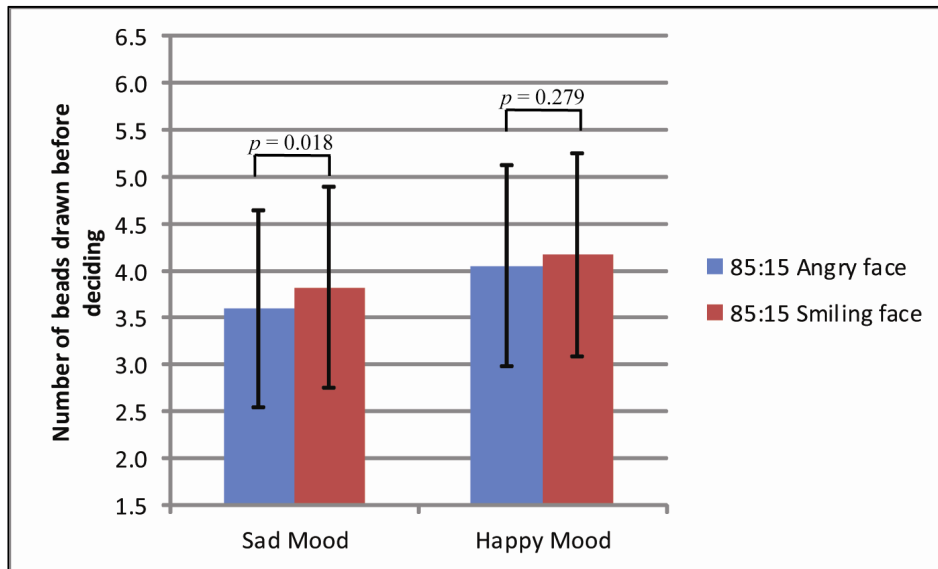


Figure 3.7: Mean and standard error bars for Mood by Faces interaction

Percentage of incorrect responses was explored to determine whether these data-gathering biases led to erroneous inferences. Overall participants made very few incorrect responses ($M = 8.89\%$; $SD = 20.04\%$). For individual participants, seven made errors on $\geq 20\%$ of trials and only one made errors on more than 40% of trials. Participants made significantly more errors in the 60:40 ($M = 16.51\%$, $SD = 24.87\%$) compared with 85:15 ($M = 1.58\%$, $SD = 9.25\%$) probability condition [$F_{(1, 1113)} = 179.291$, $p < 0.001$]. There was no influence of mood state [$F_{(2, 1001)} = 1.361$, $p = 0.257$], and no difference in the percentage of errors between different face trials in the 85:15 condition [$F_{(2, 568)} = 1.069$, $p = 0.344$]. There were too few participants that made errors ($N = 2$ angry face trials following the sad MIP, and $N = 2$ smiling face trials following the happy MIP) to conduct a meaningful analysis of the Mood (sad, happy) by Face (angry, smiling) interaction.

The effect of *Mood* may be interpreted as a simple order effect given that participants first performed the tasks following neutral mood induction and then following sad or happy mood induction. To explore whether the success of sad and happy MIPs influenced these results, a linear regression analysis (stepwise backwards elimination) was performed with “Number of beads drawn following emotional mood induction” as the dependent variable and “Number of beads drawn following neutral mood induction”, dummy variables for “Smiling, Angry and No Face”, “Probability” (85:15 versus 60:40), “Mood” (sad=1, happy=2), and “Absolute change in POMS-TMD score”⁴ as independent predictor variables. This analysis demonstrated that greater mood change from neutral to sad or happy mood was associated with a greater reduction in the number of beads required to make a decision following emotional mood induction ($\beta = 0.07, p=0.04$). The analysis also showed independent contributions from Number of beads drawn following neutral mood induction ($\beta = 0.33, p=0.001$), Mood (sad versus happy; $\beta = -0.14, p=0.001$), Probability ($\beta = 0.57, p=0.001$), and Face ($\beta = -0.07, p=0.04$).

3.3.4 Discussion

3.3.4.1 Mood data

Before considering the effects of induced mood and emotional stimuli on reasoning performance, it is essential to first establish the influence of the MIPs on mood state to determine their efficacy. The overall mood state data (POMS-TMD) and depression-dejection and vigor-activity subscales showed that participants’ mood state altered in the expected directions following the sad and happy MIPs, thus supported the hypotheses. Specifically, participants reported more depression-dejection and less vigor-activity immediately following the sad compared with neutral MIPs but these effects became less intense following the tasks.

⁴ Absolute magnitude of mood change was calculated as the sum of POMS Phase 1, Time 1 and 2 (neutral mood) minus the sum of POMS Phase 2, Time 1 and 2 (emotional mood). Negative outcomes (i.e. following the sad compared with neutral MIP) became positive outcomes so that a greater outcome reflected a greater change in mood.

Participants reported less depression-dejection and more vigor-activity following the happy compared with neutral MIPs. The effect of happy MIPs on vigor-activity scores was maintained, whereas the effect on depression-dejection scores was reduced after performing the tasks. Although the effects became less intense, participants were still more depressed following the sad compared with happy MIP both immediately after the MIPs and after the tasks.

3.3.4.2 Behavioural data

The effects of mood state and emotional stimuli on inductive reasoning were examined using a novel variant of the Beads Task.

Participants requested less information (fewer beads drawn before deciding) and made fewer erroneous decisions in the 85:15 compared with 60:40 probability conditions. This a) supports the validity that the Beads Tasks are probing probabilistic inference rather than impulsivity (Dudley, et al., 1997b) and b) suggests that any interactions of probability and mood state or emotional stimuli with the number of beads drawn before deciding are indicative of a data-gathering bias and not of abnormalities with reasoning per se.

The tendency to make a decision on the basis of less information occurred when stimuli were preceded by either a negative (angry) or a positive (smiling) facial expression, but only in the less even probability, less difficult condition (85:15). However, the comparison condition for the emotional stimuli was a no face condition. Therefore it is unclear whether this effect was specific to the emotional stimuli per se or because there was a rapidly presented face and scrambled face in the emotional but not the non-emotional conditions. Accordingly the second experiment was modified such that the control condition included the presentation of a neutral and scrambled face prior to the bead.

Participants required less information to make a decision following a sad or happy compared with neutral MIP. This result could be interpreted as a simple order effect, as emotional MIPs

always followed the neutral MIP. It is not therefore possible to exclude that familiarity or impatience with the Beads Tasks following the emotional mood induction played a role in the reduced number of beads drawn before decision. However, the regression analysis showed that the degree of mood change (following the emotional compared with neutral MIPs) was related to the number of beads drawn before decision after the emotional MIPs, and therefore tentatively suggested an actual effect of success of emotional mood induction (or mood state) on inductive reasoning. The potential order effect was examined specifically in Experiment three.

There was some evidence to support the hypothesis that participants in a sad mood state demonstrate a negative bias as they drew fewer beads before deciding in the angry compared with smiling face trials in the 85:15 probability condition only. That this effect did not occur in the 60:40 probability condition may seem to be in contrast to a previous study demonstrating that depressed patients requested significantly fewer beads in an emotional compared with neutral condition (Dudley, et al., 1997b). However, in that study emotional trials included both negative and positive stimuli, thus was probing a general emotion and not specific mood-congruent (negative) data-gathering bias. There was no evidence for a mood-congruent bias following the happy MIP in either the 85:15 or 60:40 probability conditions, which is in contrast to Bower's model of mood (1981). Importantly the stimuli in these comparisons only differed in valence (angry or smiling face) so these results are not therefore subject to the previously outlined confound of having no presentation of a face and scrambled face prior to the bead. Furthermore this comparison eliminates the problem associated with the potential order effect as both sad and happy MIPs occurred in Phase 2. Despite evidence showing a reduced number of beads drawn before deciding in emotional face (pooled across angry and smiling) compared with non-emotional trials in the 85:15 probability condition, this occurred following both sad and happy MIPs, and does not therefore exclusively support the Broaden

and Build hypothesis (Fredrickson, 1998). These results should, however, be treated with caution as emotional and non-emotional trials were not matched (i.e. there was no neutral and scrambled face presented before the bead in the non-emotional trials).

3.4 Experiment two

3.4.1 Aims and hypotheses

The previous experiment demonstrated that overall participants performed the task similarly following the sad and happy MIPs. Consequently the current experiment employed a within-subjects design in which all participants were induced into a neutral and sad MIP. To investigate whether the previously reported differences in inductive reasoning between emotional and non-emotional trials was due to the lack of a face stimulus in the non-emotional comparison condition, a neutral face was used in the non-emotional trials in the current experiment. Finally, whereas the previous experiment used angry faces in the negative face emotion trials, the specificity of this negative bias was probed using different types of negative facial expressions of emotion; angry, fearful, and sad. The results of previously published studies investigating the influence of depressed mood on attention biases to negative facial expressions of emotion give inconsistent results as to whether such biases are specific to angry, sad, or fearful facial expressions (Gotlib, Krasnoperova, Yue, & Joormann, 2004; Mogg, Millar, & Bradley, 2000). The addition of different types of negative faces made in this experiment enables an exploration of whether a data-gathering bias occurs to negative stimuli in general (angry and fearful faces) or is specific to mood-congruent negative stimuli (sad faces).

In keeping with the results from Experiment one, predictions were that:

- Participants would require less information to make a decision following a sad compared with neutral MIP. As with Experiment one, participants always had the neutral MIP before the sad MIP, therefore the predicted effect would be (partially) supported if the degree of mood change following neutral compared with sad mood induction was related to the number of beads drawn before decision after the sad MIP.
- Participants would request fewer beads before deciding when presented with emotional (smiling and negative) compared with neutral face stimuli, in the less even (85:15) probability condition.
- Following the sad MIP, there would be no difference in the number of beads drawn before deciding between the angry, fearful (both negative), and sad (mood-congruent) trials. In keeping with the results of Experiment one, participants would request fewer beads before deciding in the angry as well as sad and fearful compared with smiling face trials, in the less even (85:15) probability condition.

3.4.2 Methods

3.4.2.1 Participants

Recruitment

Eighty seven participants were recruited during a laboratory class at the University Of Oxford Department Of Experimental Psychology. Of these, 28 were assigned to the angry, 28 to the fearful, and 31 to the sad face presentation groups. Participants were blind to their own group membership prior to testing.

Inclusion and exclusion criteria

Participants were informed that they should not take part if currently suffering, or have suffered in the past, from any neurological, psychiatric or psychological problem, or major medical condition.

3.4.2.2 The Beads Task

Similarly to Experiment one, this experiment used a computerised version of a modified “beads-in-a-jar” task (Garety et al., 2005). Variations from the task described in Experiment one were the following:

- During non-emotional trials, participants were presented with a face displaying a *neutral expression* (17ms), followed by a scrambled neutral face (17ms) immediately before the presentation of the bead (see Figure 3.8).
- Two of the emotional trials had a *negative face* (17ms) followed by a scrambled neutral face (17ms) prior to presentation of each bead. Depending on group membership, the negative face was *angry*, *fearful*, or *sad* (see Figure 3.8).

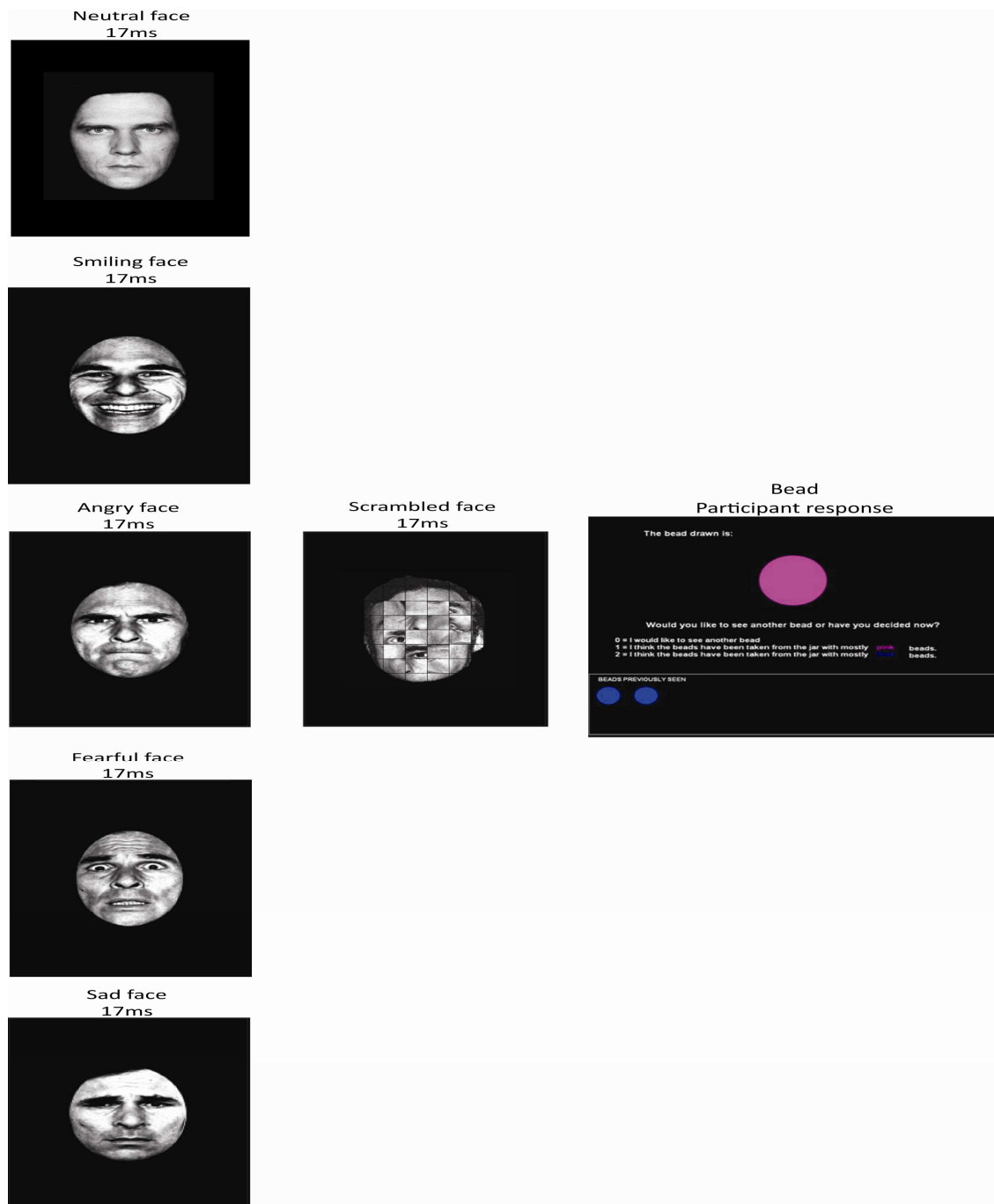


Figure 3.8: Example of screens presented to participants in the neutral, smiling, angry, fearful, and sad face trials

The facial expression was followed by a scrambled face prior to presentation of the bead and participant decision screen.

3.4.2.3 Mood induction

Neutral and sad mood states were induced using identical apparatus and stimuli as those used in Experiment one. The instructions and statements for the MIPs are presented in Appendix 1.4.

3.4.2.4 Measures of mood state

Trait mood symptoms

As in Experiment one, the BDI-II and STAI-T were used to obtain scores of current depressive and anxiety symptoms.

Mood state ratings

The standard and shortened versions of the POMS were used to measure baseline mood and changes in mood state, respectively, as in Experiment one (see Appendix 1.5).

3.4.2.5 Participant questionnaire

At the end of the experiment participants completed the same questionnaire used in Experiment one (see Appendix 1.6).

3.4.2.6 Procedures

The MIPs and Beads Tasks were computerised; testing took place in a computer laboratory in a single session that lasted between 60 and 90 minutes (for a timeline of experimental procedures see Figure 3.9). Participants were briefed about the experimental procedures and tasks. Baseline mood state, and depressive and anxiety symptoms were assessed using the standard version of the POMS, BDI-II and STAI-T, respectively. If any participant recorded a BDI-II equal to or greater than 19 (moderate to severe depressive symptoms range), the person supervising the experiment spoke to the participant individually to remind them of the experimental procedures and ask if they wanted to continue with the experiment. In Phase 1, participants received the *neutral* MIP and then rated their mood state using the shortened form of the POMS. This was followed by the non-emotional and emotional versions of the

Beads Tasks in both the less (85:15) and more (60:40) even proportions. After the tasks, participants rated their mood again. In Phase 2, participants received the *sad* MIP, and then rated their mood. This was followed again by the non-emotional and emotional versions of the Beads Tasks in both the less (85:15) and more (60:40) even proportions, and participants rated their mood again. Participants then completed a brief participant questionnaire at the end of the experimental procedures following which all participants were fully debriefed. All participants were given the opportunity to receive the happy MIP before leaving.

3.4.2.7 Statistics

The statistics used to analyse both the mood and behavioural data were in keeping with those described in Experiment one with the exceptions that there was:

- No between-groups factor of sad or happy MIP for the mood and behavioural data.
- A between-groups factor of negative face emotion (i.e. angry, fearful, sad) for the behavioural data. Therefore planned comparisons included investigating the effects of different types of negative face emotion on the number of beads drawn before deciding following the sad MIP, as well as comparing negative and smiling face trials in the less even (85:15) probability condition.

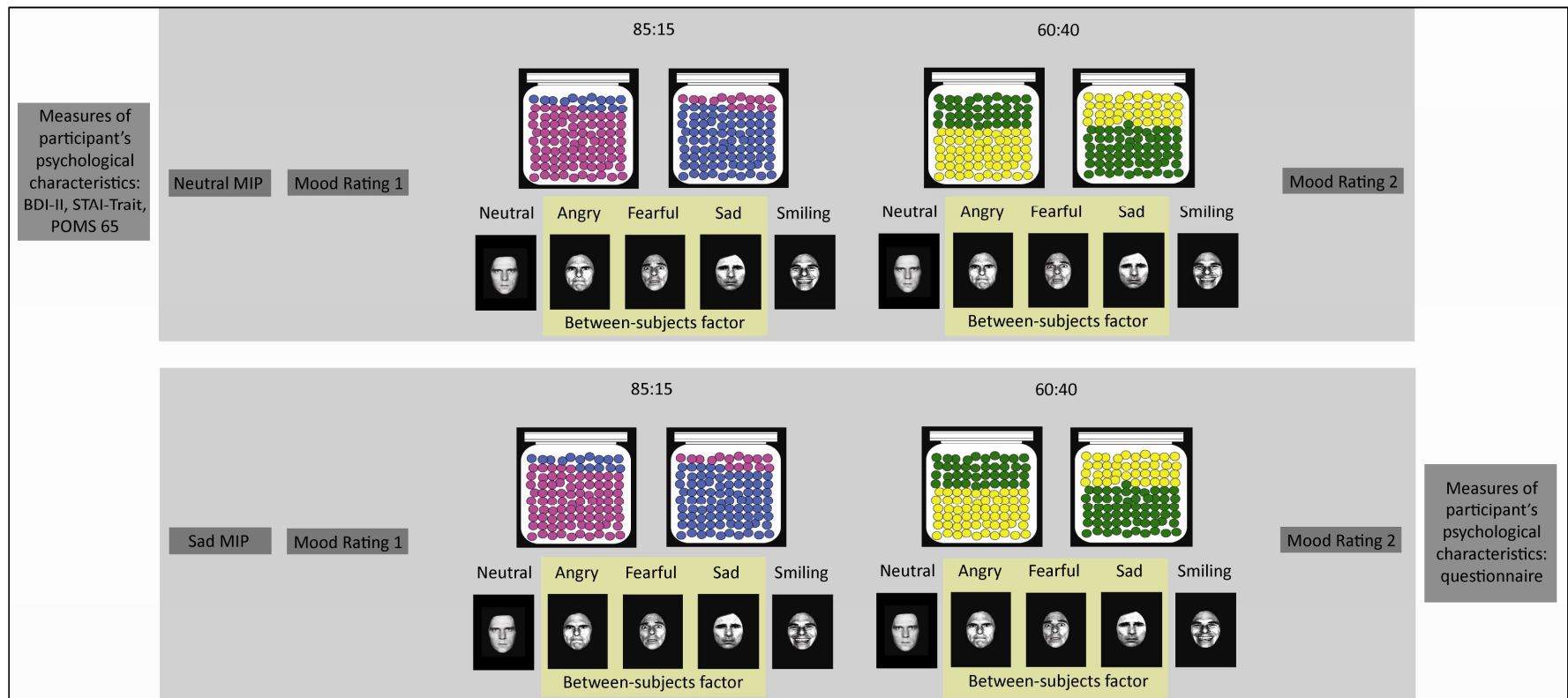


Figure 3.9: Timeline of experimental procedures. Neutral MIP = Phase 1 and Sad MIP = Phase 2

The between-subjects factor was type of face presented in the negative emotion trials: angry, fearful, or sad.

3.4.3 Results

3.4.3.1 Participants

There were no differences in age, gender, education, BDI-II ⁵, STAI-T, and baseline mood state before or after experimental procedures for the POMS-TMD scores (see Table 3.8). Mean POMS-TMD scores were within two standard deviations of the mean of the college student normative sample (McNair, 1992).

	Angry face group (N=28)	Fearful face group (N=28)	Sad face group (N=31)	p-value
Age, Mean (SD)	20 (1)	19.96 (1)	20.03 (1)	0.95
Gender, No. (%)				
Male	11 (39.3)	11 (42.3)	13 (43.3)	0.95
Female	17 (60.7)	15 (57.7)	17 (56.7)	
Educational Level, No. (%)				
A-Level	25 (89.3)	28 (100)	28 (90.3)	0.54
Degree	1 (3.6)	0 (0)	1 (3.2)	
Other (IB)	2 (7.1)	0 (0)	2 (6.5)	
BDI-II, Mean (SD)	6.36 (6.02)	6.96 (5.97)	6.45 (5.30)	0.91
STAI-T, Mean (SD)	38.75 (10)	38.32 (8.86)	38.71 (8.71)	0.98
Baseline Mood, Mean (SD)				
POMS ^A before experiment	-12.04 (21.28)	-10.36 (17.24)	-12.19 (22.33)	0.93

Table 3.8: Summary of participant characteristics

Fearful face group missing data for Gender of two participants, Sad face group missing data for Gender of one participant. Contrast: t-test (or χ^2), two-tailed significance.

IB=International Baccalaureate; BDI-II = Beck Depression Inventory Second Edition (A.T. Beck, et al., 1996); STAI-T = State Trait Anxiety Inventory (Spielberger, 1983); POMS = Profile of Mood States (McNair, 1992) standard 65 item version. ^APOMS scores were reverse coded to those of the original paper, such that more negative scores indicate a more negative mood-state.

3.4.3.2 Mood data

A parallel-groups repeated-measures ANOVA compared mean POMS-TMD scores immediately after the MIP/before the tasks (*Time 1*) and after the tasks (*Time 2*) following the *neutral* and *sad* MIPs. The between-subjects factor was *Negative Face Condition* (angry, fearful, or sad),

⁵ Two participants had BDI-II scores of 21 and one had a BDI-II of 25. The person supervising the experiment spoke to each of these participants and all wanted to continue with the experiment.

however all main and interaction effects of *Negative Face Condition* were non-significant. Accordingly the analysis was repeated without the between-groups factor *Negative Face Condition* and the data are presented here. These analyses were repeated with the POMS subscale scores to assess the specificity of the MIPs to a depressed mood state (using the depression-dejection and vigor-activity subscales).

Overall mood state ratings

There was a significant main effect of *Mood* [$F_{(1, 86)}=44.11$, $p<0.001$] and of *Time* [$F_{(1, 86)}=60.94$, $p<0.001$] in addition to a *Mood by Time* interaction [$F_{(1, 86)}=10.61$, $p=0.002$]. Following the sad compared to neutral MIP, participants reported a significantly more negative mood state immediately after the MIP ($t_{(86)}=6.63$; $p<0.001$); see Figure 3.10. Although this difference was still apparent after the Beads Tasks ($t_{(86)}=4.24$; $p<0.001$), the effect was somewhat diluted such that improvement in mood was greater after receiving the sad than the neutral MIP.⁶

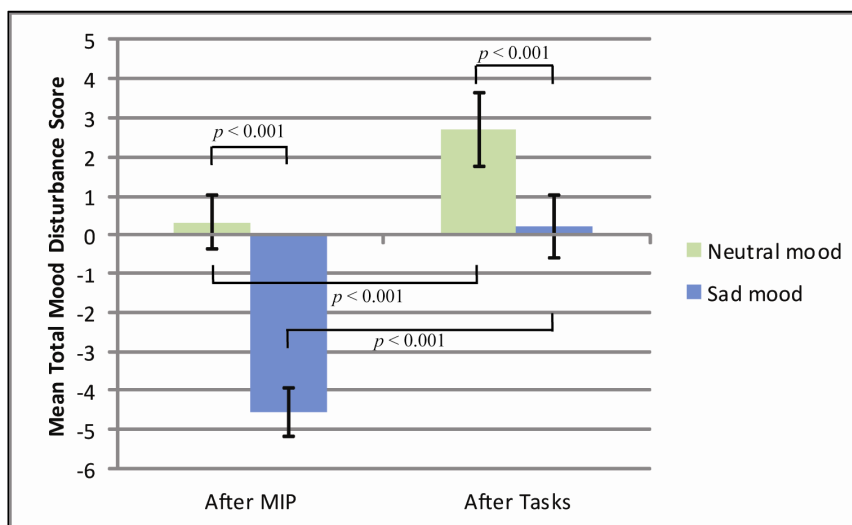


Figure 3.10: Mean POMS-TMD scores and standard error bars at Phase 1 (Neutral mood) Time 1 (immediately after the MIP/before the tasks) and Time 2 (after the tasks) and Phase 2 (Sad mood) Time 1 and 2

Data are collapsed across the angry, fearful, and sad negative face condition groups. *P*-values are of post-hoc paired samples *t*-tests.

⁶ Twelve participants reported potentially lasting adverse effects of the sad MIP at the end of the experimental procedures but none took the opportunity to receive the happy MIP.

Subscale mood state ratings

The above effects were replicated for POMS depression-dejection subscale scores with main effects of *Mood* [$F_{(1, 86)}=47.87, p<0.001$] and *Time* [$F_{(1, 86)}=48.19, p<0.001$] and an interaction of *Mood by Time* [$F_{(1, 86)}=28.25, p<0.001$]. The sad compared with neutral MIP resulted in significantly greater depression-dejection immediately after the MIP ($t_{(86)} = -6.99; p<0.001$). This effect was somewhat diluted but still significantly different after performing the Beads Tasks ($t_{(86)} = -4.15; p<0.001$). The interaction effect shows that greater mood improvement occurred from immediately after the MIP to after the tasks following the sad ($t_{(86)} = 6.86; p<0.001$) compared with neutral ($t_{(86)} = 2.32; p=0.023$) MIP.

There was a significant Main effect of *Mood* [$F_{(1, 86)}=57.11, p<0.001$], *Time* [$F_{(1, 86)}=30.36, p<0.001$], and a *Mood by Time* interaction [$F_{(1, 86)}=4.72, p=0.033$] for the vigor-activity subscale scores. Post-hoc paired samples t-tests show that participants reported significantly lower vigor-activity scores immediately following the sad compared with neutral MIPs ($t_{(86)} = 6.76; p<0.001$). This was somewhat diluted, though still significant after performing after the Beads Tasks ($t_{(86)} = 4.75; p<0.001$). Mean values and post-hoc t-tests for POMS TMD, and depression-dejection and vigor-activity subscale scores are reported in Table 3.9.

		Neutral MIP	Sad MIP	Sad vs. Neutral MIP
POMS-TMD	Time 1	0.32	-4.55	$p<0.001$
	Time 2	2.71	0.23	$p<0.001$
	Time 1 vs. 2	$p<0.001$	$p<0.001$	
POMS Depression-Dejection	Time 1	1.22	4.34	$p<0.001$
	Time 2	0.79	1.79	$p<0.001$
	Time 1 vs. 2	$p=0.023$	$p<0.001$	
POMS Vigor-Activity	Time 1	7.60	5.63	$p<0.001$
	Time 2	8.37	7.16	$p<0.001$
	Time 1 vs. 2	$p=0.012$	$p<0.001$	

Table 3.9: Mean mood rating scores for participants immediately after the neutral and sad MIP/before the tasks (Time 1) and after the tasks (Time 2)

P-values show post-hoc paired samples t-tests comparing scores between MIPs (far column) and between Time 1 and 2 (row highlighted in grey).

Importantly, there was no significant main effect of *Mood* for the subscales anger-hostility [$F_{(1, 86)}=1.92, p=0.170$], confusion-bewilderment [$F_{(1, 86)}=1.86, p=0.176$], or tension-anxiety [$F_{(1, 86)}=3.39, p=0.069$]. There was, however, a significant main effect of *Mood* for the subscale fatigue-inertia [$F_{(1, 86)}=19.42, p<0.001$]. Participants reported more fatigue following the sad compared with neutral MIP. There was also a main effect of *Time* [$F_{(1, 86)}=18.15, p<0.001$] such that participants reported increased fatigue immediately after the MIPs (both neutral and sad) compared with after the Beads Tasks.

3.4.3.3 Behavioural data

The outcome measure (the *Number* of beads drawn before deciding) was log-transformed to adjust for skewing of the data prior to analysis in a Univariate ANOVA, with *Mood* induction (neutral and sad), *Faces* (neutral, smiling, angry, fearful, and sad) and *Probability* (85:15 and 60:40) as fixed factors and *Participant ID* as a random factor. The mean number (and standard deviation) of beads drawn before deciding are shown in Table 3.10 and the results of the Univariate ANOVA are summarised in Table 3.11. As there was no significant higher order Probability by Mood by Faces interaction in Experiment one, only simple and two-way interactions were computed in Experiment two.

		Neutral mood	Sad mood
85:15	Neutral face	5.41 (1.02)	4.97 (1.02)
	Angry face	4.58 (1.04)	4.19 (1.04)
	Fearful face	3.60 (1.04)	3.67 (1.04)
	Sad face	4.61 (1.03)	4.32 (1.03)
	Smiling face	4.53 (1.02)	4.42 (1.02)
60:40	Neutral face	9.94 (1.02)	9.48 (1.02)
	Angry face	9.93 (1.04)	9.55 (1.04)
	Fearful face	9.18 (1.04)	10.02 (1.04)
	Sad face	11.30 (1.03)	10.14 (1.04)
	Smiling face	9.41 (1.02)	9.14 (1.02)

Table 3.10: Mean (standard deviation) number of beads drawn before deciding by Mood, Probability, and Face emotion

Effects	df	F	p-value
Mood	1, 96.89	2.19	0.142
Faces	4, 170.79	12.02	0.000***
Probability	1, 91.83	462.39	0.000***
Probability * Faces	4, 591.00	20.42	0.000***
Mood * Faces	4, 591.00	2.68	0.031*
Probability * Mood	1, 591.00	0.67	0.412

Table 3.11: Results of the Univariate analysis of variance for number of beads drawn before deciding

* $p < 0.05$; ** $p < 0.01$; *** $p < 0.001$. df = degrees of freedom, F = F-statistic.

There were main effects of *Faces* [$F_{(4, 170.79)}=12.02$, $p < 0.001$] and *Probability* [$F_{(1, 91.83)}=462.39$, $p < 0.001$]. The 85:15 condition (M=4.59, SD=1.75) was associated with a smaller number of beads drawn before deciding than the 60:40 condition (M=9.69, SD=1.69). Participants requested fewer beads when they were preceded by rapidly presented emotional but not neutral faces (Angry faces: M=6.53, SD=1.88; Fearful faces: M=5.83, SD=2.01; Sad faces: M=6.95, SD=2.06; Smiling faces: M=6.43, SD=1.98; Neutral faces: M=7.09, SD=1.83). To tease apart the *Faces by Probability* interaction [$F_{(4, 591)}=20.417$, $p < 0.001$], one-way ANOVAs demonstrated that the effect of faces occurred in the 85:15 [$F_{(4, 521)}=4.83$, $p = 0.001$] but not

60:40 [$F_{(4, 521)}=1.064$, $p=0.374$] probability condition. There was no main effect of *Mood* [$F_{(1, 96.89)}=2.19$, $p=0.142$] but there was a significant *Mood by Faces* interaction [$F_{(4, 591)}=2.68$, $p=0.031$]. Participants required more beads before deciding following the neutral compared with sad mood induction for the neutral, smiling, angry, and sad face trials, and fewer on the fearful face trials (see Figure 3.11). The simple random effects of *Participant ID* and its two-way interactions with *Mood*, *Faces*, and *Probability* were all highly significant, demonstrating individual variability in responding.

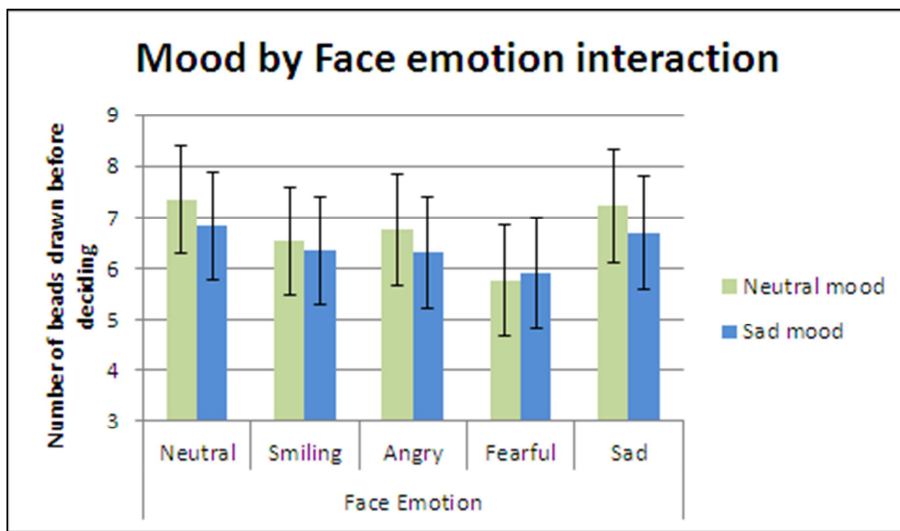


Figure 3.11: Means and standard error bars for Mood by Face emotion interaction

Planned comparisons demonstrated that there were no significant differences between the negative (angry, fearful, and sad) face trials on the number of beads drawn before deciding following the sad MIP in either the 85:15 [$F_{(2, 86)}=0.774$, $p=0.465$] or 60:40 [$F_{(2, 86)}=1.266$, $p=0.287$] probability conditions. In the 85:15 probability condition participants requested fewer beads before deciding following the sad (but not neutral) MIP on the angry ($t_{(27)}=4.25$; $p<0.001$) and fearful ($t_{(27)}=2.87$; $p=0.008$) but not sad ($t_{(30)}=1.40$; $p=0.171$) compared with smiling face trials.

As in Experiment 1, percentage of incorrect responses was explored to determine whether these data-gathering biases led to erroneous inferences. Overall participants made very few

incorrect responses ($M=6.82\%$; $SD=17.60\%$). For individual participants, two made errors on $\geq 20\%$ of trials and none made errors on more than 21% of trials. Participants made significantly more errors in the 60:40 ($M=13.06\%$, $SD=22.70\%$) compared with 85:15 ($M=1.16\%$, $SD=7.52\%$) probability condition [$F_{(1, 989)}=127.268$, $p<0.001$]. There was no influence of mood state [$F_{(1, 884)}=0.001$, $p=0.970$], and no difference in the percentage of errors between different face trials in the 85:15 condition [$F_{(4, 518)}=1.327$, $p=0.259$].

3.4.4 Discussion

3.4.4.1 Mood data

Similarly to Experiment one and as hypothesised, participants reported being significantly more negative (POMS-TMD and depression-dejection subscale scores) and less positive (vigor-activity subscale scores) after the sad compared with neutral MIP. Again, these effects became less intense after the tasks compared with immediately after the MIPs. Participants also reported more fatigue after the sad compared with neutral MIP and after the tasks compared with immediately after the MIPs. There were no effects of MIPs on the anger-hostility, confusion-bewilderment, and tension-anxiety subscale scores.

3.4.4.2 Behavioural data

The current experiment aimed to replicate the finding reported in Experiment one of fewer beads drawn before deciding in emotional trials, with the additional control of a neutral and scrambled facial expression (rather than no face) in the non-emotional trials. Further, to investigate whether these effects extended to different negative facial expressions and to explore the interaction between mood state and different negative emotional stimuli, the current experiment employed angry, fearful, and sad emotional face trials in a between-groups design.

In keeping with the results of Experiment one, participants required less information before making a decision in emotional (angry and smiling as well as fearful face) compared with non-

emotional (neutral face) trials. This result suggested that the finding obtained in Experiment one was not therefore due to rapidly presenting a facial expression in the emotional conditions and not in the non-emotional conditions. Once again, there was no difference in the number of beads drawn before deciding in the negative (angry as well as fearful and sad face) and positive (smiling face) emotional conditions. The results of Experiment two replicated the findings reported in Experiment one that the emotional face trials only influenced decision making in the less even probability, less difficult condition (85:15).

Again participants made fewer erroneous decisions with less information in the 85:15 than 60:40 probability condition.

An interaction between mood induction and emotional face presentation showed that whereas participants requested more beads on the neutral, angry, sad, and smiling face trials following the neutral compared with sad MIP, they requested fewer on fearful face trials. There was also a non-significant trend towards participants requesting less information following both sad and neutral MIPs in fearful compared with all other face trials. These results are in keeping with the literature demonstrating a preferential bias towards processing fear-related stimuli. This bias has been shown to result in more rapid responses to subsequently presented task-relevant stimuli in the case that the fearful face was task-irrelevant (Mogg & Bradley, 1999).

Following the sad MIP there were no differences in the amount of information requested between the different types of negative information: angry, fearful, and sad. There were, however, differential effects of negative and mood-congruent compared with smiling face trials in the 85:15 probability condition. Specifically, results supported the finding of Experiment one that participants requested less information on the angry compared with smiling face trials, a finding that was extended to the fearful face trials, therefore consistent

across negative stimuli. This was not, however, present for the mood-congruent sad face trials. Possible reasons for these results will be presented in the general discussion.

Unlike Experiment one, participants did not draw fewer beads before deciding following the sad compared with neutral MIP, which is in keeping with previously reported results comparing depressed patients and healthy control participants (Bentall, et al., 2009; Corcoran, et al., 2008; Dudley, et al., 1997a, 1997b). It is unlikely that these differences can be attributed to differences in mood state as participants in Experiments one and two reported the same effects of the sad MIP on both the overall (POMS-TMD) and subscale scores. It is possible that the mood effect found in Experiment one can be interpreted as a simple order effect that was not present in Experiment two. It may be that the participants in Experiment one became more impatient with the experimental procedures and therefore performed the tasks faster (i.e. requested less information) on the second occasion than the participants in Experiment two. Experiment three was carried out to provide control data pertaining to the possibility that the main effect of induced sad mood on the number of beads drawn before deciding reported in Experiment one was actually attributable to the effects of order.

3.5 Experiment three

3.5.1 Aims and hypotheses

Experiment one demonstrated that participants drew fewer beads before deciding following the emotional (sad and happy) compared with neutral MIPs and that amount of mood change was related to the number of beads drawn after the emotional mood induction. However, these results may have been due to an order effect as neutral MIPs always preceded emotional MIPs. In addition, this effect was not demonstrated in Experiment two. Therefore in the current experiment, participants always received a sad MIP before the neutral MIP to investigate the potential order effect on number of beads drawn before deciding in each mood

state. Further, Experiments one and two showed that participants drew fewer beads before deciding in emotional face but not non-emotional trials in the 85:15 probability condition only. Therefore in the current experiment, participants completed the 85:15 but not 60:40 probability conditions for the neutral, angry, and smiling face trials.

It was predicted that:

- If the main effect of Mood demonstrated in Experiment one was not an effect of order, participants would draw fewer beads before deciding following the sad (first) compared with neutral (second) MIP.
- Replicating the results of Experiments one and two, participants would request fewer beads before deciding when presented with emotional (smiling and angry) compared with neutral face stimuli.

3.5.2 Methods

3.5.2.1 Participants

A power calculation was used to determine the required number of participants: see Appendix 1.4.

Recruitment

Fourteen participants who were students and staff of the University Of Oxford were recruited by advertisement and word of mouth.

Inclusion and exclusion criteria

Participants were informed that they should not take part if currently suffering, or have suffered in the past, from any neurological, psychiatric or psychological problem, or major medical condition.

3.5.2.2 The Beads Tasks

Similarly to Experiments one and two, this experiment used a computerised version of a modified “beads-in-a-jar” task (Garety et al., 2005). Variations from the task described in Experiment two are the following:

- All participants completed the 85:15 probability condition only.

Note that to keep the methods of this experiment in line with Experiments two, all participants completed the same non-emotional (neutral face) and emotional (angry and happy face) trials (see Figure 3.12) but the hypotheses and power calculations were only valid for detecting differences between the neutral and angry face trials.



Figure 3.12: Example of screens presented to participants in the neutral, smiling, and angry face trials

In all trials the facial expression was followed by a scrambled face prior to presentation of the bead and participant decision screen.

3.5.2.3 Mood induction

Neutral and sad mood states were induced using identical apparatus and stimuli as those used in Experiments one and two. The instructions and statements for the MIPs are presented in Appendix 1.4.

3.5.2.4 Measures of mood state

Mood state ratings

As in Experiments one and two, the BDI-II and STAI-T were used to obtain scores of current depressive and anxiety symptoms.

Trait mood symptoms

The standard and shortened versions of the POMS were used to measure baseline mood and changes in mood state, respectively, as in Experiments one and two (see Appendix 1.5).

3.5.2.5 Participant questionnaire

At the end of the experiment participants completed the same questionnaire used in Experiments one and two (see Appendix 1.6). This had an additional question to probe participants' awareness of perceiving the faces: "Did you see any faces displayed on the screen? If so, what did you notice?"

3.5.2.6 Procedure

As the MIPs and Beads Tasks were computerised, testing took place in a computer laboratory in a single session that lasted between 60 and 90 minutes (for a timeline of experimental procedures see Figure 3.13). Participants were briefed about the experimental procedures and tasks. Baseline mood state, and depressive and anxiety symptoms were assessed using the standard version of the POMS, BDI-II and STAI-T, respectively. If any participant recorded a BDI-II equal to or greater than 19 (moderate to severe depressive symptoms range), the person supervising the experiment spoke to the participant individually to remind them of the experimental procedures and ask if they wanted to continue with the experiment. In Phase 1, participants received the *sad* MIP and then rated their mood state using the shortened form of the POMS. This was followed by the non-emotional and emotional versions of the Beads Tasks in the less (85:15) even proportions. After the tasks, participants rated their mood again. In Phase 2, participants received the *neutral* MIP, and then rated their mood. This was followed by the non-emotional and emotional versions of the Beads Tasks in the less (85:15) even proportions, and participants rated their mood again. Participants also completed the standard version of the POMS and a brief participant questionnaire at the end of the experimental procedures following which they were fully debriefed. All participants were given the opportunity to receive the happy MIP before leaving.

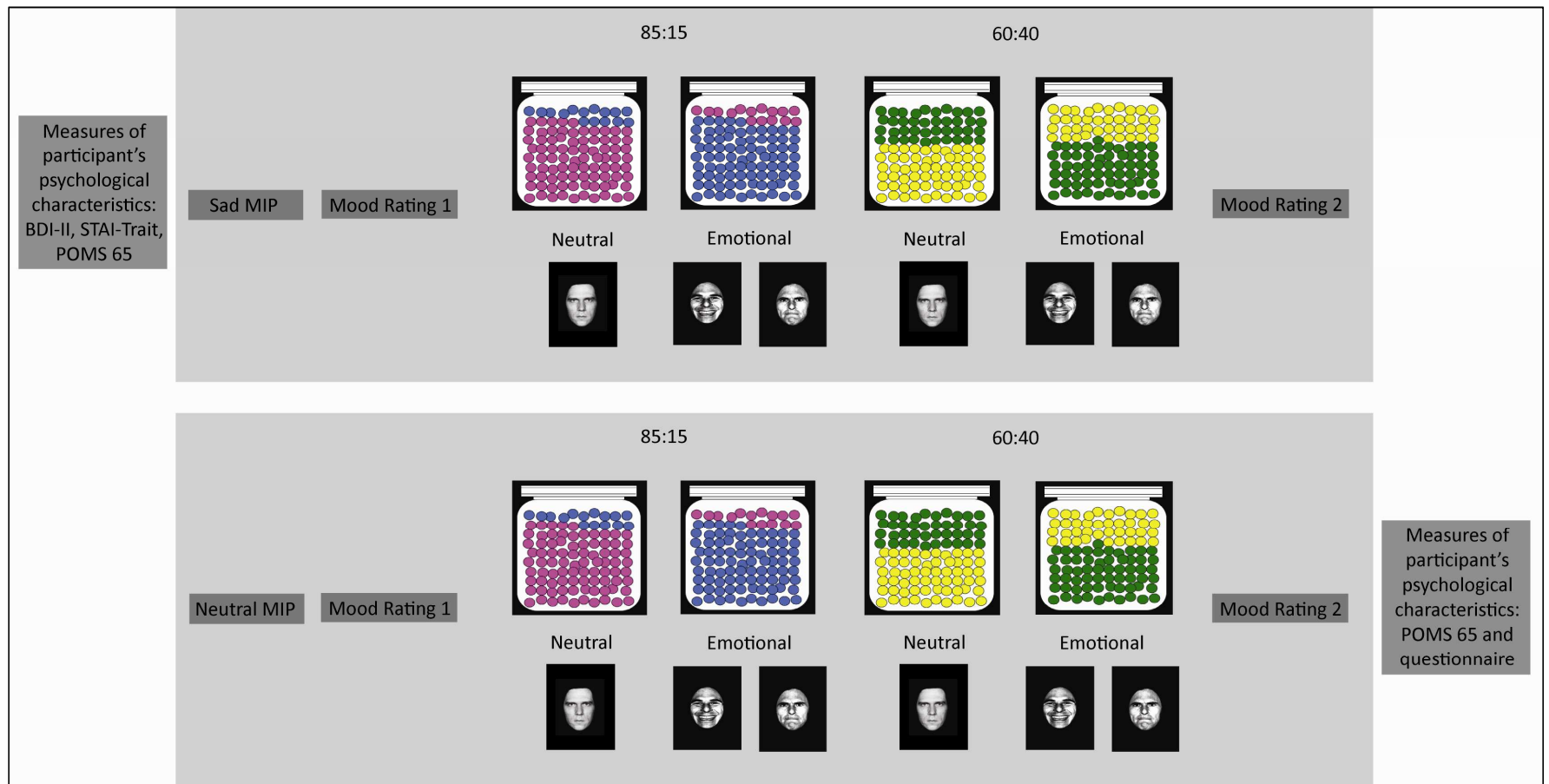


Figure 3.13: Timeline of experimental procedures. Sad MIP = Phase 1 and Neutral MIP = Phase 2

3.5.2.7 Statistics

The statistics used to analyse both the mood and behavioural data were in keeping with those described in Experiment two with the exceptions that:

- Analysis of behavioural data was restricted to neutral and angry face trials only.
- There was a comparison of behavioural data from Experiments two and three to investigate the potential effect of order of MIPs (neutral first, neutral second) on the influence of mood (neutral, sad) on the number of beads drawn before deciding.

3.5.3 Results

3.5.3.1 Participants

Participant characteristics are presented in Table 3.12.⁷ Mean POMS-TMD scores were within two standard deviations of the mean of the college student normative sample (McNair, 1992).

N=14	
Age, Mean (SD)	25.64 (6)
Gender, No. (%)	
Male	1 (7.1)
Female	13 (92.9)
Educational Level, No. (%)	
A-Level	2 (14.3)
Degree	7 (50)
Post-graduate degree	5 (35.7)
BDI-II, Mean (SD)	8.07 (8.3)
STAI-T, Mean (SD)	39.29 (8.2)
Baseline Mood, Mean (SD)	
POMS ^A before experiment	-21.29 (26.03)
POMS ^A after experiment	-11.46 (19.87)

Table 3.12: Summary of participant characteristics

No missing data. Contrast: t-test (or χ^2), two-tailed significance.

BDI-II = Beck Depression Inventory Second Edition (A.T. Beck, et al., 1996); STAI-T = State Trait Anxiety Inventory (Spielberger, 1983); POMS = Profile of Mood States (McNair, 1992) standard 65 item version. ^APOMS scores were reverse coded to those of the original paper, such that more negative scores indicate a more negative mood-state.

⁷ Two participants had BDI-II scores of 21. The person supervising the experiment spoke to each participant and all wanted to continue with the experiment.

3.5.3.2 Mood data

Overall mood state ratings

A parallel-groups repeated-measures ANOVA compared mean POMS-TMD scores immediately after the MIP/before the tasks (*Time 1*) and after the tasks (*Time 2*) following *sad* and *neutral* MIPs. These analyses were repeated with the POMS subscale scores to assess the specificity of the MIPs to a depressed mood state (using the depression-dejection and vigor-activity subscales).

There were significant main effects of *Mood* [$F_{(1, 13)}=30.02$, $p<0.001$] and *Time* [$F_{(1, 13)}=45.66$, $p<0.001$] and a *Mood by Time* interaction [$F_{(1, 13)}=32.75$, $p<0.001$]. Following the sad compared with neutral MIP, participants reported a significantly more negative mood state immediately after the MIP ($t_{(13)} = -6.32$; $p<0.001$); see Figure 3.14. Although this difference was still apparent after the Beads Tasks ($t_{(13)} = -3.11$; $p=0.008$) the effect was somewhat diluted such that improvement in mood was greater after receiving the sad than the neutral MIP.⁸

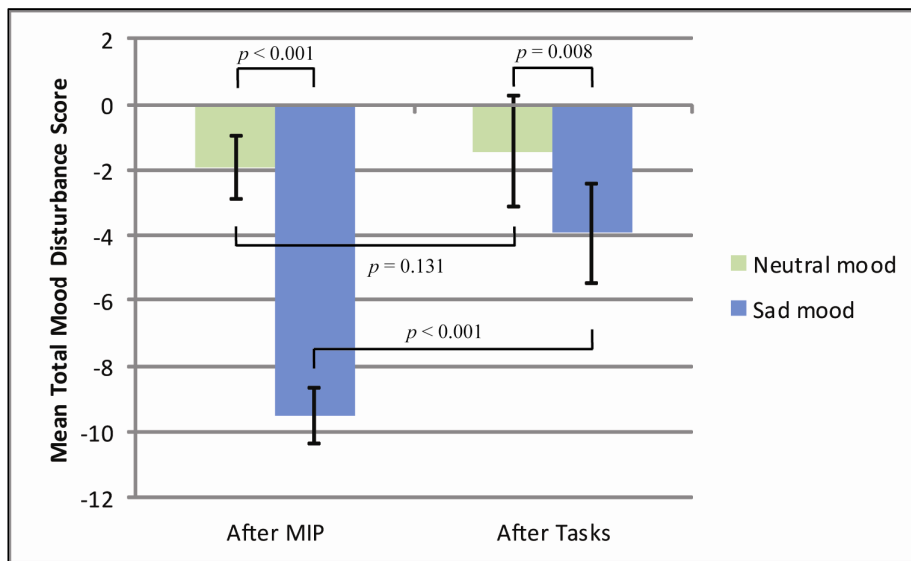


Figure 3.14: Mean POMS-TMD scores and standard error bars at Phase 1 (Sad mood) Time 1 (immediately after the MIP/before the tasks) and Time 2 (after the tasks) and Phase 2 (Neutral mood) Time 1 and 2

⁸ One participant reported potentially lasting adverse effects of the sad MIP (e.g. “Maybe a little”) at the end of the experimental procedures but did not take the opportunity to receive the happy MIP.

Subscale mood state ratings

The POMS depression-dejection subscale scores confirm the main effects of *Mood* [$F_{(1, 13)}=29.68, p<0.001$] and *Time* [$F_{(1, 13)}=22.85, p<0.001$] and an interaction of *Mood by Time* [$F_{(1, 13)}=19.93, p=0.001$]. The sad compared with neutral MIP resulted in significantly greater depression-dejection scores immediately after the MIP ($t_{(13)}=6.26; p<0.001$). This effect was somewhat diluted but still significantly different after performing after the Beads Tasks ($t_{(13)}=2.83; p=0.014$). The interaction effect shows that mood improvement occurred after the sad ($t_{(13)}=4.83; p<0.001$) but not neutral ($t_{(13)}=1.59; p=0.136$) MIP. Mean values and post-hoc t-tests for POMS TMD, and depression-dejection and vigor-activity subscale scores are presented in Table 3.13.

		Neutral MIP	Sad MIP	Sad vs. Neutral MIP
POMS-TMD	Time 1	-1.93	-9.50	$p<0.001$
	Time 2	-1.43	-3.93	$p=0.008$
	Time 1 vs. 2	$p=0.131$	$p<0.001$	
POMS Depression-Dejection	Time 1	1.79	6.79	$p<0.001$
	Time 2	1.43	3.21	$p=0.014$
	Time 1 vs. 2	$p=0.136$	$p<0.001$	
POMS Vigor-Activity	Time 1	3.71	3.86	$p=0.793$
	Time 2	3.14	3.57	$p=0.321$
	Time 1 vs. 2	$p=0.218$	$p=0.486$	

Table 3.13: Mean mood rating scores for participants immediately after the neutral and sad MIP/before the tasks (Time 1) and after the tasks (Time 2)

P-values show post-hoc paired samples t-tests comparing scores between MIPs (far column) and between Time 1 and 2 (row highlighted in grey).

Importantly, there was no significant main effect of *Mood* for the subscales tension-anxiety [$F_{(1, 13)}=3.55, p=0.082$] and anger-hostility [$F_{(1, 13)}=0.34, p=1.000$], nor was there an effect for

vigor-activity [$F_{(1, 13)}=0.65, p=0.435$]. There was, however, a significant main effect of *Mood* [$F_{(1, 13)}=9.42, p=0.009$] and *Time* [$F_{(1, 13)}=9.16, p=0.010$] as well as a *Mood by Time* interaction [$F_{(1, 13)}=6.16, p=0.028$] for the subscale fatigue-inertia. Post-hoc paired samples t-tests revealed that participants reported significantly more fatigue immediately after the sad compared with neutral MIP ($t_{(13)} = 3.31; p=0.006$), whereas there was no such difference after performing the Beads Tasks ($t_{(13)} = 1.30; p=0.218$). There were also main effects of *Mood* [$F_{(1, 13)}=17.33, p=0.001$] and *Time* [$F_{(1, 13)}=11.42, p=0.005$] as well as a trend towards an interaction of *Mood by Time* [$F_{(1, 13)}=4.50, p=0.054$] for the subscale confusion-bewilderment. Participants reported significantly less confusion following the sad MIP after the Beads Tasks compared with immediately after the MIP ($t_{(13)} = 3.23; p=0.007$), whereas participants reported no such difference following the neutral MIP ($t_{(13)} = 1.88; p=0.082$).

3.5.3.3 Behavioural data

Experiment three

The outcome measure (the *Number* of beads drawn before deciding) was log-transformed to adjust for skewing of the data prior to analysis in a Univariate ANOVA, with *Mood* induction (neutral and sad) and *Faces* (neutral and angry) as fixed factors and *Participant ID* as a random factor. The mean number (and standard deviation) of beads drawn before deciding are shown in Table 3.14 and the results of the Univariate ANOVA are summarised in Table 3.15.

		Neutral mood	Sad mood
85:15	Neutral face	4.41 (1.86)	5.08 (2.02)
	Angry face	3.43 (2.10)	4.03 (2.07)

Table 3.14: Mean (standard deviation) number of beads drawn before deciding by Mood and Face emotion

Effects	df	F	p-value
Mood	1, 13.30	3.38	0.070
Faces	1, 13.28	10.84	0.006**
Mood * Faces	1, 12.00	0.41	0.535

Table 3.15: Results of the Univariate analysis of variance for number of beads drawn before deciding

* $p < 0.05$; ** $p < 0.01$; *** $p < 0.001$. df = degrees of freedom, F = F-statistic.

There was a main effects of *Faces* [$F_{(1, 13.28)}=10.84$, $p=0.006$] such that participants requested fewer beads before deciding when they were preceded by a rapidly presented angry ($M=3.73$, $SD=2.06$) compared with neutral face ($M=4.73$, $SD=1.92$). The main effect of *Mood* did not reach significance [$F_{(1, 13.30)}=3.38$, $p=0.070$] although there was a trend towards participants requesting fewer beads following the neutral ($M=3.83$, $SD=1.98$) compared with sad ($M=4.67$, $SD=1.99$) MIPs. Finally, there was no significant interaction between *Mood and Faces* [$F_{(1, 12)}=0.41$, $p=0.535$].

The simple random effects of *Participant ID* and its two-way interactions with Mood and Faces were all highly significant, demonstrating individual variability in responding.

Comparing experiments two and three: order effects analysis

To examine the hypothesis that the main effect of *Mood* obtained in Experiment one was not due to the order of the MIPs, log transformed data from the 85:15 angry and neutral face trials following neutral and sad mood induction in Experiments two and three were combined.⁹ The outcome measure (the *Number* of beads drawn before deciding) was analysed in a Univariate ANOVA, with *Mood* induction (neutral and sad), *Order* of neutral mood induction (neutral first as in Experiment two and neutral second as in Experiment three), and *Faces* (neutral and angry) as fixed factors, and *Participant ID* as a random factor.

⁹ All effects reported here were also observed in an unreported analysis comparing Experiments one and three, for which a power calculation determined a sample size of fourteen would have 95% power to yield a significant result.

There was a significant interaction between *Mood and Order* [$F_{(1, 121)}=10.95, p=0.001$]. Participants requested fewer beads before deciding following the second MIP (sad in Experiment two and neutral in Experiment three) compared with the first MIP (neutral in Experiment two and sad in Experiment three); see Figure 3.15.

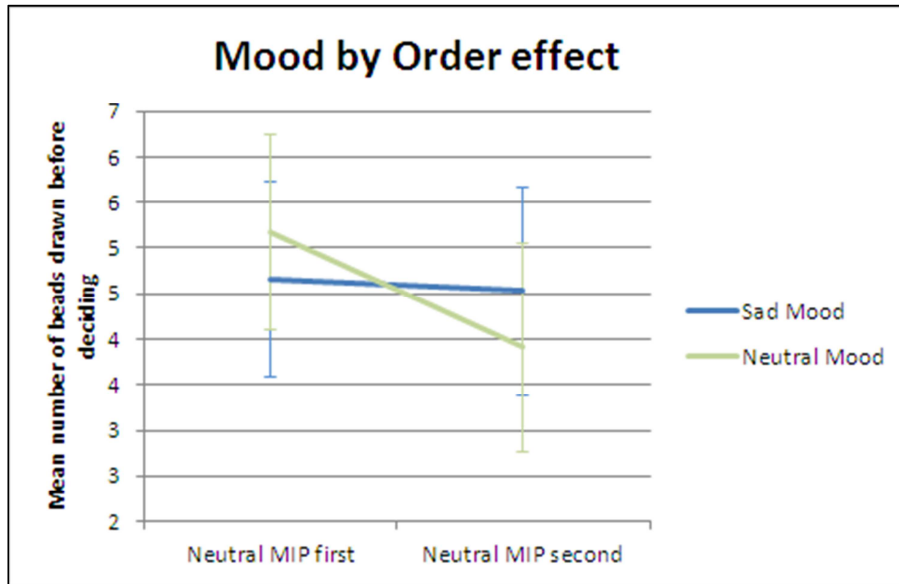


Figure 3.15: Mean (and standard error bars) number of beads drawn before deciding following the neutral and sad MIPs in Experiment two (Neutral MIP first) and Experiment three (Neutral MIP second)

Results confirmed the main effect of *Faces* [$F_{(1, 121)}=50.25, p<0.001$] that participants requested fewer beads before deciding when they were preceded by a rapidly presented angry ($M=4.16, SD=1.77$) but not neutral face ($M=5.23, SD=1.72$). There was no significant interaction between *Mood and Faces* [$F_{(1, 121)}=0.00, p=0.99$]. Finally, the simple random effect of *Participant ID* was significant, demonstrating individual variability in responding.

3.5.4 Discussion

3.5.4.1 Mood data

In accordance with the results from Experiments one and two, participants reported a significantly greater negative mood state (POMS-TMD and depression-dejection subscale

scores) following the sad compared with neutral MIP. Once again, these effects were diluted after performing the tasks compared with immediately after the MIPs. There were also no effects on tension-anxiety and anger-hostility subscale scores. However, unlike the previous two experiments, there were no effects on the vigor-activity subscale scores, and participants reported greater fatigue-inertia and less confusion-bewilderment immediately after the sad MIP.

3.5.4.2 Behavioural data

This experiment was carried out to investigate whether the mood effect observed in Experiment one was due to an order effect by inducing the sad and neutral mood states in the opposite order. The results from Experiment three showed that participants did not request fewer beads before deciding following the sad MIP, which was in keeping with the finding from Experiment two. This adds weight to the notion that the mood effect reported in Experiment one was due to an order effect. Furthermore, the combined results from Experiments two and three showed a significant mood by order effect demonstrating that participants requested fewer beads before deciding following the second MIP, independent of whether the second MIP was sad (Experiment two) or neutral (Experiment three). These results confirmed the null hypothesis that the mood effect observed in Experiment one was an order effect.

The data from Experiment three and the combined data from Experiments two and three confirm the results from Experiments one and two alone showing that participants require fewer beads before deciding when they are preceded by rapidly presented angry faces compared with non-emotional trials. Finally, these data show no interaction between mood state and emotional stimuli on inductive reasoning.

3.6 Efficacy of mood induction procedures and influence of current depressive symptoms

In this section, the aim was to establish the efficacy of the sad MIPs across all three experiments. In addition the influence of current depressive symptoms (measured using the BDI-II) on response to sad MIPs was explored.

3.6.1.1 Statistics

Efficacy of mood induction procedures

To explore the influence of the neutral and sad MIPs on mood state across participants in experiments one, two, and three, a parallel-groups repeated-measures ANOVA was used to compared mean POMS-TMD scores immediately after the MIP/before the tasks (*Time 1*) and after the tasks (*Time 2*) following neutral and sad MIPs. The between-subjects factor was *Experiment* (one, two, and three).

This analysis was repeated with the POMS depression-dejection subscale scores to assess the specificity of the sad MIP to a depressed mood state.

Regression analysis

The influence of current depressive symptoms on response to a sad MIP was examined with mood change scores which were calculated using POMS-TMD scores with mood state immediately after the sad MIP minus mood state immediately after the neutral MIP. Accordingly the greater the negative score, the greater the change. A linear regression analysis (enter method) was performed with “Mood change” as the dependent variable and “BDI-II”, “Baseline mood state (standard version of the POMS)”, and dummy variables for “Experiment one”, “Experiment two”, and “Experiment three” as independent predictor variables.

This analysis was repeated with the POMS depression-dejection subscale scores to assess the specificity of the sad MIP to a depressed mood state. Here, the greater the positive score, the greater the change.

3.6.1.2 Results

There were a total of 149 participants that received both the neutral and sad MIPs across experiments one (N=48), two (N=87), and three (N=14).

Efficacy of mood induction procedures

In keeping from the results from experiments one, two, and three there was a significant main effect of *Mood* [$F_{(1, 146)}=57.995, p<0.001$] and *Time* [$F_{(1, 146)}=58.054, p<0.001$] in addition to a *Mood by Time* interaction [$F_{(1, 146)}=24.497, p<0.001$]. Mood state was more negative following the sad compared with neutral MIP. Following both the sad and neutral MIPs mood state became less negative after the Beads Tasks compared with immediately after the MIP; an effect that was greater following the sad than neutral MIP (see Figure 3.16). Importantly, participants reported greater negative affect following the sad compared with neutral MIP both immediately after the MIP ($t_{(148)}=9.317; p<0.001$) and after the Beads Tasks ($t_{(148)}=5.432; p<0.001$). There were no interaction effects with *Experiment*, demonstrating that these effects were consistent across experiments.

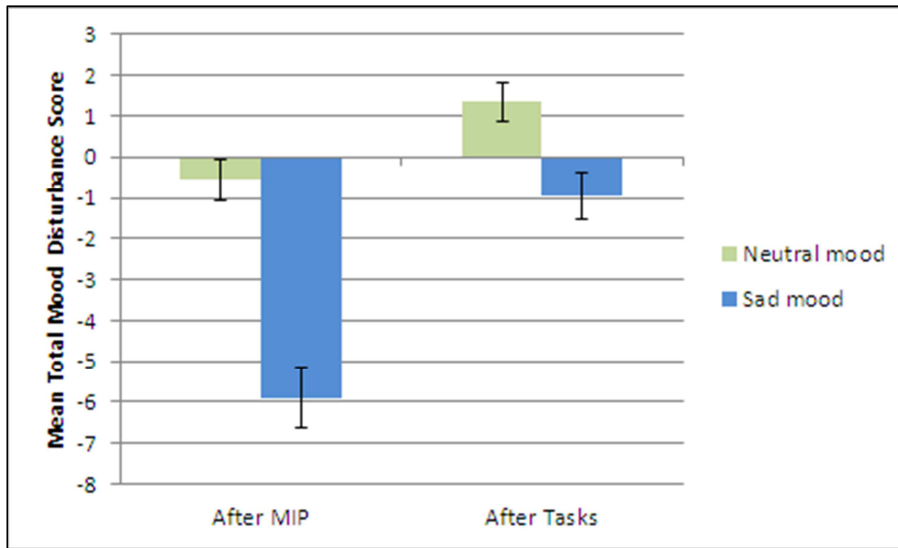


Figure 3.16: Mean POMS-TMD scores and standard error bars after Neutral MIP and Sad MIP at Time 1 (immediately after the MIP/before the tasks) and Time 2 (after the tasks)

When this analysis was repeated using the POMS depression-dejection subscale scores, the same pattern of effects was observed as those from the analysis with POMS-TMD scores. There were significant main effects of *Mood* [$F_{(1, 146)}=68.352, p<0.001$] and *Time* [$F_{(1, 146)}=63.874, p<0.001$], and an interaction of *Mood by Time* [$F_{(1, 146)}=42.478, p<0.001$]. Mean values and post-hoc t-tests for POMS TMD and depression-dejection subscale scores are provided in Table 3.16.

		Neutral MIP	Sad MIP	Sad vs. Neutral MIP
POMS-TMD	Time 1	-0.56	-5.89	$p<0.001$
	Time 2	1.33	-0.95	$p<0.001$
	Time 1 vs. 2	$p<0.001$	$p<0.001$	
POMS Depression-Dejection	Time 1	1.43	4.97	$p<0.001$
	Time 2	1.15	2.12	$p<0.001$
	Time 1 vs. 2	$p=0.057$	$p<0.001$	

Table 3.16: Mean mood rating scores for participants immediately after the neutral and sad MIPs (Time 1) and after the tasks (Time 2) across experiments one, two, and three

P-values show post-hoc paired samples t-tests comparing scores between MIPs (far column) and between Time 1 and 2 (row highlighted in grey).

Influence of current depressive symptoms

The regression analysis showed that the model was significant $F_{(4, 148)}=3.358$, $p=0.012$ and explained 6% of the variance (Adjusted $R^2=0.060$). *BDI-II* had a significant effect on the amount of post-MIP mood change ($\beta=-0.257$, $p=0.009$), whereas *Baseline mood state* ($\beta= 0.024$, $p=0.805$) and dummy variables for *Experiment* did not. Participants with a higher BDI-II score reported the largest changes in mood state following the sad compared with neutral MIP (see Figure 3.17).

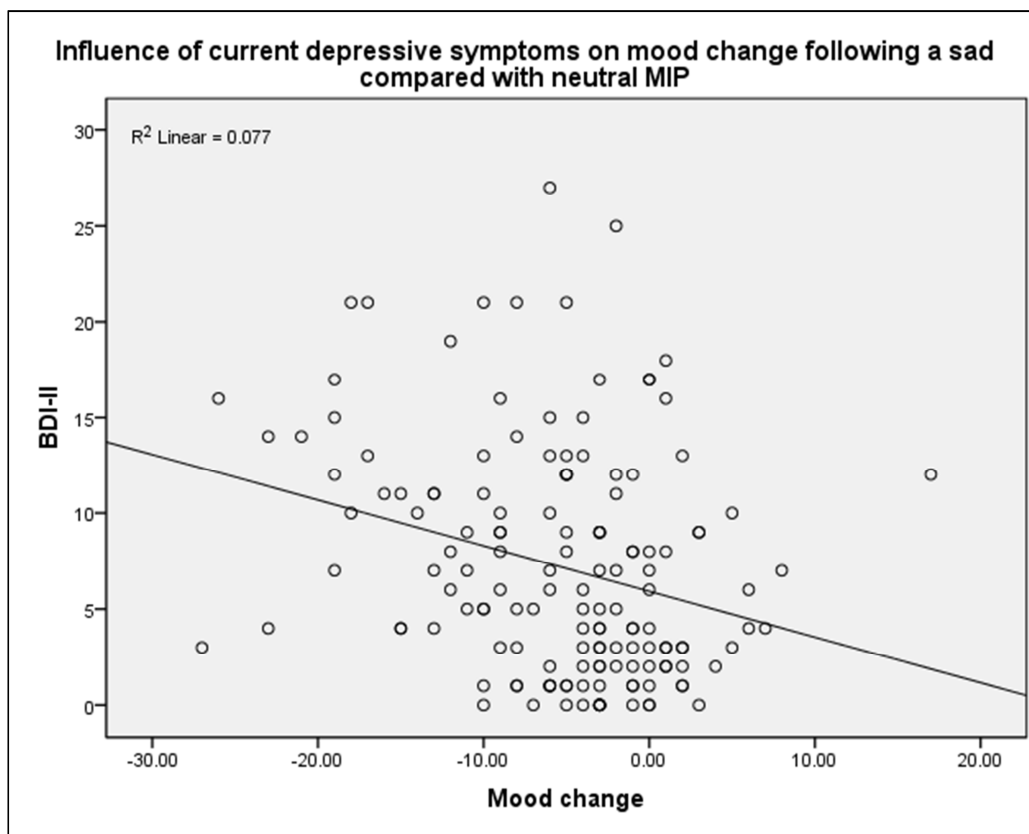


Figure 3.17: Influence of current depressive symptoms on mood change following a sad compared with neutral MIP

When this analysis was repeated using the POMS depression-dejection subscale scores, the model was significant ($F_{(4, 148)}=4.416$, $p=0.002$), explained 8.5% of the variance, and only BDI-II was a significant predictor of mood change ($\beta=0.309$, $p=0.002$).

3.6.1.3 Discussion

The influence of MIPs on mood state across experiments one, two, and three confirmed the effects reported for each experiment individually. Specifically participants reported a significantly greater negative mood state following the sad compared with neutral MIP, and that these effects were diluted after performing the Beads Tasks compared with immediately after the MIPs.

Effects of MIPs on mood state were consistent across, and did not differ between experiments. Subsequently a regression analysis across experiments demonstrated that participants with increased levels of current depressive symptoms reported greater negative affect following the sad compared with neutral MIP. These results support those of previous studies demonstrating that a higher BDI predicts greater mood change following a sad MIP. In one study, the investigators used BDI-II scores to group healthy control participants into low ($BDI-II < 6$) and high ($BDI > 13$) negative affect groups (Bisson & Sears, 2007). They found a bigger difference in mood state, measured using a 21-point VAS scale, for participants in the low (10.91 point difference) compared with high (8.80 point difference) negative affect group for mood ratings after compared to before a sad MIP. Another study comparing mood ratings found that higher BDI was associated with greater negative affect after compared with before a sad MIP, when mood state was measured using a standard scale and a self-constructed visual analogue scale (Blackburn, Cameron, & Deary, 1990).

3.7 Ethics

Ethical approval for these studies was granted by the University of Oxford Central University Research Ethics Committee and informed consent was obtained from each subject prior to participation.

3.8 Discussion: General

3.8.1 Efficacy of mood induction procedures

These results support the findings of previous studies demonstrating that both self-referential statements (Velten, 1968) and music (Pignatiello, Camp, & Rasar, 1986) are effective methods used to induce sad and happy mood states (Gerrards-Hesse, Spies, & Hesse, 1994; Martin, 1990; Westermann, Spies, Stahl, & Hesse, 1996).

The POMS contains subscales pertaining to different negative and positive mood states and as such provides information about the specificity of the sad or happy induced mood state. Across all three experiments, self-reported depression-dejection subscale scores were greater following sad compared with neutral MIPs. Although the effects of the sad MIP became less prominent following the tasks compared with immediately following the sad MIP, participants were still more depressed following the sad compared with neutral MIP both immediately after the MIPs and after the tasks. Scores on the vigor-activity subscale were lower following the sad compared with neutral MIPs in Experiments one and two, although this effect was reduced following the tasks compared with immediately after the sad MIP. These results are in keeping with Russell's dimensional theory of affect (1980) which suggests that sad and happy are at bipolar opposites of the dimension pleasure-displeasure.

There were also changes in fatigue-inertia subscale scores demonstrating that participants reported greater fatigue after the sad compared with neutral MIPs (in all three Experiments), an effect that was sustained after performing the tasks (in Experiments one and two, only). This may also be in keeping with Russell's theory which placed the affect term 'depression' between moderate and low (i.e. sleepiness) levels of arousal.

There was no change in tension-anxiety or anger-hostility subscale scores following the sad compared with neutral MIPs in all three experiments, nor in confusion-bewilderment subscale

scores in Experiments one and two. That these results were consistent across experiments confirms the notion that the combination of music and self-referential statements used to induce sad mood states in these experiments leads to a specific change in depression-dejected but not tension-anxiety or anger-hostility mood. This is in keeping with the findings from a meta-analysis of 16 types of MIPs which found that only music and self-referential statements induce depressed mood per se (Martin, 1990).

In addition to demonstrating the efficacy of the MIPs, regression analyses supported the results of previous studies showing that participants with increased levels of current depressive symptoms reported greater changes in negative affect following a sad MIP (Bisson & Sears, 2007; Blackburn, et al., 1990). Differences between the results from the regression analyses presented here and those of the meta-regression analyses (see Chapter 2: Sad Mood Induction: A Systematic Review), and a subsequent experiment (see Chapter 5: Attentional Blink) will be addressed in the General Discussion (see Chapter 6: General Discussion and Future Directions).

3.8.2 Emotional stimuli and reasoning

LeDoux (1998) writes that *"cognition is not as logical as it was once thought and emotions are not always so illogical"* (pp. 35). In support of this, the results from these experiments demonstrate that participants required less information to make a decision in emotional compared with classic beads (no face: Experiment 1) and neutral face (Experiments two and three) trials. This effect did not lead to erroneous decision making. This main effect of face emotion is in keeping with the findings of Dudley et al. (1997a) who demonstrate a 'jumping to conclusions' bias to emotional but not neutral word stimuli. Furthermore, these results support the notion that even rapidly presented (and potentially not consciously perceived) task-irrelevant (angry and smiling) facial expressions of emotion can influence subsequent behaviour (Winkielman, et al., 2005).

However, Ledoux (1998) also argues that *“emotional responses can occur without the involvement of the higher processing systems of the brain, systems believed to be involved in thinking, reasoning, and consciousness”* (pp.161). The experiments presented in this thesis provide evidence against the automaticity of emotion processing, and its independence from cognitive processing. This effect of face emotion was dependent upon task difficulty such that as perceived probability shifted towards certainty (i.e. in the high 85:15 compared with the low 60:40 probability condition) participants required less information to make a decision when presented with emotional stimuli. This is consistent with the suggestion that the processing of task-irrelevant stimuli is limited by processing capacity, thus demonstrating an interaction between selective attention, emotion, and cognition (Pessoa, 2008). Although the previously drawn beads were presented at the bottom of the screen to reduce working memory task demands (as in Dudley, et al., 1997b), there remains demands on working memory that were modulated by the proportion of beads in the jar. Specifically the beads must be attended to and held active in working memory to enable an individual to operate on them mentally (Damasio, 1994). In the less even and less cognitively demanding condition, there are more resources available for processing the task-irrelevant emotional stimuli which consequently influence decision making. In contrast in the more even and therefore more cognitively demanding condition, there are fewer resources available therefore emotional stimuli are not processed and do not therefore influence decision making. These findings suggest that emotional stimuli are not processed completely automatically (as has been suggested by LeDoux, 1989; LeDoux, 1998; Öhman, et al., 2000; Vuilleumier, et al., 2003; Winkielman & Berridge, 2004; Winkielman, et al., 2005), rather are dependent upon selective attention and capacity limitations and as such interact with cognitive processing (Pessoa, 2008).

3.8.3 Mood and reasoning

The aim of Experiment one was to investigate differences in reasoning following sad compared with happy MIPs, with a predicted increase (sad) and decrease (happy) in the number of beads drawn before deciding. Results demonstrated no differences between the sad and happy MIPs. Instead participants drew fewer beads before deciding following the emotional (sad and happy) compared with neutral MIPs and amount of mood change was related to the number of beads drawn after the emotional mood induction. These results were not, however, replicated in Experiment two. In both Experiments one and two the neutral MIPs always preceded emotional MIPs therefore any effect of Mood could have been a simple order effect. Experiment three was designed to specifically investigate the potential order effect on the number of beads drawn before deciding in each mood state as the sad MIP always preceded the neutral MIP. A statistical comparison of the data obtained in Experiments two and three demonstrated that any effect of Mood was attributable to an order effect. Participants consistently required less information to make a decision following the second MIP, independent of the valence of that MIP (whether sad as in Experiment two or neutral as in Experiment three). That there were no differences in the number of beads drawn before deciding following the sad and neutral MIPs is in keeping with previously reported results comparing task performance in depressed patients and healthy control participants (Dudley, et al., 1997a, 1997b).

If the effect of MIPs on mood state had remained stable from immediately after the MIPs until after the tasks, the results may have provided evidence for the hypothesised effects following sad and happy MIPs. Using this task to investigate effects in a population of currently depressed or highly dysphoric individuals, who are likely to experience much greater levels of depressed mood than healthy participants following sad mood induction, may lead to different results.

3.8.4 The interaction of mood state and emotional stimuli

In previous studies exploring the interaction of psychological state (primarily with deluded patients but also using a depressed patient control group) and emotional stimuli, emotional trials comprised both negative and positive stimuli (Dudley, et al., 1997a; Young & Bentall, 1997). In contrast, the experiments presented here allow a comparison of reasoning performance in trials with negative or positive stimuli. Experiments one and two demonstrated a negative information processing bias on the angry compared with smiling face trials following the sad MIP. In Experiment two this finding was extended to the fearful face trials, and was therefore consistent across negative face stimuli, but was not present for the mood-congruent sad face trials.

3.8.5 Methodological considerations

Although this series of experiments found no reliable effect of induced mood on inductive reasoning towards mood-congruent sad stimuli, it is acknowledged that various avenues remain to be explored. Adaptations may include altering the duration of the facial expressions of emotion, or using task-relevant self-referent word stimuli (as in Garety, 1991; Warman & Martin, 2006; Young & Bentall, 1997).

Information processing biases towards mood-congruent sad stimuli might depend upon supraliminal presentation and therefore conscious perception and elaboration of the emotional stimulus (cf. Williams, Watts, MacLeod, & Mathews, 1997). Studies using the dot-probe paradigm, for example, suggest that negative attention biases occur when emotional stimuli are presented for $\geq 1,000$ ms durations and are thus available for conscious, strategic processing (Mogg, Bradley, & Williams, 1995). In one study there was an information processing bias to mood-congruent sad but not angry face stimuli when those stimuli were presented for 1,000ms (Gotlib, et al., 2004). In another, a shift of attention towards depression-related words only occurred during the long (500ms and 1000ms) but not short

(14ms) duration of presentation following depressed compared with neutral mood induction (Bradley, Mogg, & Lee, 1997). Similar results were reported in a study using an exogenous cueing paradigm; a bias towards negative stimuli was observed in dysphoric participants when the stimuli were presented for long (1,500ms and trend at 500ms) but not short (250ms) durations (Koster, De Raedt, Goeleven, Franck, & Crombez, 2005). In the novel emotional variant of the Beads Tasks used here, facial expressions were presented for 17ms and are therefore comparable with the short duration condition timing of the dot-probe paradigm. Despite this, a recent meta-analytic review of 29 studies using the emotional stroop and dot-probe paradigms found no effect of stimulus presentation time (500ms and 1,000ms) on mood-congruent attention biases in depressed patients compared to non-depressed participants (Peckham, McHugh, & Otto, 2010). To further investigate the effects of the duration of negative and mood-congruent stimuli on the presence (or absence) of information processing biases, future adaptations of the Beads Tasks could include trials with variable presentation times of the facial expressions of emotion.

Rapid presentation (17ms) of emotional stimuli may have precluded awareness in the experiments presented in this thesis. If longer presentation times were used to elicit awareness, one might hypothesise that participants would request less information and make more errors when reasoning about emotional and specifically mood-congruent material. This is because depression-related biases have been hypothesised to occur when there is conscious awareness eliciting elaborative processing of stimuli (Williams, et al., 1997). Conscious awareness occurs when stimuli have been selectively attended. Selective attention and working memory are support processes for reasoning (Damasio, 1994). Consequently if participants are attending to emotional stimuli at the same time as performing a reasoning task, this may lead to erroneous reasoning.

Although the stimuli were presented rapidly (17ms) in order to reduce conscious perception, a measure of perceptual thresholds was not obtained in Experiments one and two and therefore the certainty that these stimuli were not consciously perceived by participants cannot be determined. Cheesman & Merikle (1986) have proposed two methods that could be used to distinguish the threshold for conscious perception: subjective and objective. Subjective thresholds can be determined on the basis on an individual's phenomenological experience, whereas objective thresholds are obtained according to above chance performance on a two-alternative forced choice task, for example. In experiment three, subjective thresholds for conscious perception of the rapidly presented facial expressions of emotion were determined by asking participants directly if they noticed these stimuli. Only four of the fourteen participants in Experiment three reported seeing the faces, suggesting that participants are largely unaware of their presence. This method was used as it was considered a parsimonious way of probing awareness of the facial expressions of emotion. This measure of subjective awareness highlights that there are individual differences in conscious awareness of rapidly presented stimuli. An alternative, objective method would be to have asked participants to complete a two-alternative forced choice (2AFC) identification task following performance of the Beads Tasks. In each trial of the task, participants would be presented with a facial expression of emotion (17ms) followed by a scrambled neutral face (17ms) followed by a 2AFC to identify the previously presented facial expression of emotion as angry or happy, for example. Correct responses below chance performance would be considered to reflect perception without awareness of perception (Merikle, et al., 2001). Another method would be for the 2AFC identification screen to have the previously presented facial expression of emotion and another randomly selected facial expression. Participants would be required to identify which of the two faces was previously presented. Limitations could be enforced such that only the facial expressions with the same emotion as that which was rapidly presented (e.g. angry) would be presented as the alternative (e.g. angry) during the 2AFC screen.

Whereas the former objective method would assess the threshold of perception of emotion, the latter would assess the threshold of perception of face identification. The results obtained from an objective examination of awareness could be used to group participants into those who were and those who were not consciously aware of the facial expressions of emotion. Subsequently participants in the former group could be excluded from further analysis.

Although MIPs are used to successfully induce a mood state that provides an analogue to the negative mood state experienced by patients with clinical depression, the severity of the induced mood may inevitably be quantitatively lower than that of a currently depressed patient. Therefore researchers might consider using this paradigm to investigate inductive reasoning in currently depressed patients. See Chapter 6: General Discussion and Future Directions for considerations regarding the use of analogue samples to draw conclusions about and generalise findings to individuals diagnosed with clinical depression.

Other adaptations include the draws to certainty version of the Beads Task wherein after each bead is presented participants are asked how certain they are that the beads are being drawn from a particular jar (Young & Bentall, 1997). The certainty version of the Beads Task can be used to determine the number of draws participants require to reach a high level of certainty. Using this version in a sample of currently depressed patients might enable conclusions about the likelihood of depressed individuals engaging in more systematic, elaborative processing of (emotional) information (Blanchette & Richards, 2010), as indexed by a greater number of beads required before reaching a high level of certainty. Furthermore, this task can be adapted so that participants are provided with disconfirmatory evidence half way through. Here the measure of certainty would provide an index of the amount of disconfirmatory information required to establish a new belief.

3.8.6 Implications

Researchers have used the Beads Task in patients with Schizophrenia Spectrum Disorders to test the assumption that reasoning biases contribute to delusion formation: in which a delusion is defined as a fixed and idiosyncratic false belief (Garety, 1991). Deluded (typically Schizophrenic and paranoid) patients request less and thus limit the amount of information gathered before making a decision (Garety, Dudley, et al., 1997b; 1991). The use of this paradigm has not, however, been extended to investigate reasoning biases in depressed patients per se (rather than as a psychiatric control group).

Implications for investigating the influence of mood state and emotional information on inductive reasoning extend beyond the necessity of intact reasoning capacity for successful every day and occupational functioning. Inductive reasoning is a process used when individuals generate hypotheses, formulate theories, and discover relationships, and is evoked when therapists try to model depression when using techniques such as Cognitive Behavioural Therapy (Padesky, 1994). Beck's (1989) cognitive model of depression argues that when depressed patients make negative evaluations of themselves, they are, within their own frame of reference, making an objective judgement. Importantly, it is not necessarily that the patient's appraisal of reality is distorted, rather their system of making inferences and drawing conclusions. Accordingly, cognitive behavioural therapists use inductive reasoning to help patients understand that the negative automatic thoughts and beliefs that they hold to be true are actually derived from imperfect processes (i.e. cognitive distortions) and are thus distinguishable from the truth. Specifically, therapists facilitate the gathering of evidence to test and weaken maladaptive false beliefs whilst either a) activating and strengthening pre-existing or b) establishing new more adaptive schemas (Padesky, 1994). Therefore, if researchers are able to demonstrate an influence and interaction of induced mood and

emotional stimuli on inductive reasoning, this may have implications for and applications within the context of Cognitive Behavioural Therapy.

3.9 Conclusions and future directions

This series of experiments demonstrated that a combination of music and self-referential statements can be used to successfully induce sad and happy mood states in healthy participants. Development of an existing task, designed to probe inductive reasoning, included emotional trials. Participants consistently required less information before making a decision and thus showed a 'jumping to conclusions' bias when that information was preceded by rapidly presented, task-irrelevant emotional compared with neutral stimuli. That this effect was specific to the less difficult conditions suggests that the processing of emotional stimuli is influenced by top-down selective attention mechanisms and capacity limitations. Mood state did not reliably alter the amount of information participants required to make a decision. There was evidence for a negative information processing bias such that participants requested less information on angry and fearful compared with smiling face trials following a sad MIP. This bias did not extend to mood-congruent sad face trials. Suggestions are made for future studies employing the Beads Task to investigate information processing biases to consider varying the presentation time of the facial expressions, use self-referential stimuli, conduct draws to certainty trials and/or use a sample of currently clinically depressed patients. Overall, the results support an interaction between cognition and affect at the level of emotional stimuli but not mood state and some evidence for a negative information processing bias for individuals in a sad mood state.

Chapter 4 Introduction to Functional Imaging and Neuronal Correlates of Cognitive Processes

4.1 Abstract

Functional imaging techniques are used to investigate the organisation and patterns of brain activity to facilitate an understanding of normal human perception, cognition, emotion, and behaviour, as well as elucidating possible pathophysiological mechanisms underlying various psychiatric disorders, such as Major Depression.

Magnetoencephalography is a functional imaging technique that measures the timing of neuronal processes directly with a temporal resolution in the order of milliseconds, and a potential for spatial resolution of two-to-three millimetres for sources in the cerebral cortex. In this thesis, magnetoencephalography was used to investigate the interaction of attention, mood, and emotion.

This chapter aims to introduce the use of electromagnetism to measure neuronal activity and to provide a summary of the functional significance of patterns of such activity produced after the presentation of a stimulus. These patterns are time-locked, stimulus-evoked components (or epochs) known as event related (electric) potentials and event related (magnetic) fields that are measured using electroencephalography and magnetoencephalography, respectively.

4.2 An introduction to functional imaging

4.2.1 Functional imaging

Functional neuroimaging techniques are used to investigate the functional organisation and distributed patterns of brain activity at the macroscopic level: the level of interactions between neuronal networks rather than at the single neuron level (Muller-Gartner, 1998; Stern & Silbersweig, 2001).

The use of such techniques is based on the assumption that affective, cognitive, somatic, and autonomic processes are the result of dynamically interacting cell assemblies responding to sensory stimuli. Similarly, it is argued that emotions represent psychological *and* physiological states (Dolan, 2002), therefore must, by definition, have a neuronal substrate. These techniques thus have the potential to increase our understanding of normal human perception, cognition, emotion, and behaviour, as well as elucidating possible pathophysiological mechanisms underlying various psychiatric disorders, such as Major Depression (MD). The introduction of neuroimaging techniques to the study of psychiatric disorders has enabled investigation of the biological mechanisms underpinning these disorders (Abou-Saleh, 2006; Insel, 2007).

4.2.2 Electromagnetism

Magnetoencephalography (MEG) and electroencephalography (EEG) are the only functional imaging techniques that directly measure the timing of neuronal processes at the appropriate temporal resolution (in the order of milliseconds; Parra, Kalitzin, & da Silva, 2004), and with the potential for spatial discrimination of two-to-three millimetres for sources in the cerebral cortex (Hamalainen, Hari, Ilmoniemi, Knuutila, & Lounasmaa, 1993); see Figure 4.1. They can thus provide an insight to the real-time dynamics of brain function (Insel, 2007).

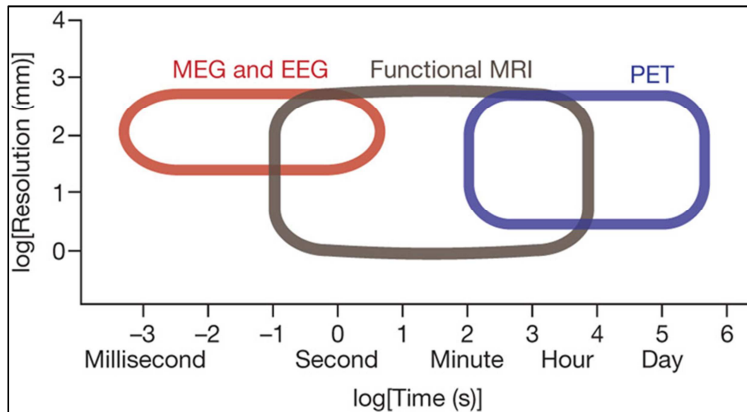


Figure 4.1: Spatial and temporal resolution of imaging modalities

MEG=Magnetoencephalography; EEG=Electroencephalography; fMRI=functional Magnetic Resonance Imaging; PET=Positron Emission Tomography.

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4.2.2.1 What is magnetoencephalography and what does the MEG signal measure?

MEG is a non-invasive method of functional neuroimaging, with the first recording of neuronal activity published by Cohen (1968). MEG measures and records the magnetic fields caused by an amalgamation of postsynaptic potentials generated by several thousand synchronously activated neurons. Neurons are the principal cellular elements underlying the functioning of the brain: they process and transmit information by electrochemical signalling. These electrochemical signals (or action potentials) are carried along the axon of a neuron away from the soma. They trigger synaptic transmission of signals received by the dendrites and soma of the postsynaptic neuron. The influx of postsynaptic (or primary) currents induced by the opening of postsynaptic ion channels and the resultant electrical depolarisation must be compensated for throughout the rest of the neuron by ohmic (or secondary) currents (see Figure 4.2). Whereas MEG is primarily sensitive to the postsynaptic currents, EEG is primarily sensitive to the ohmic currents.

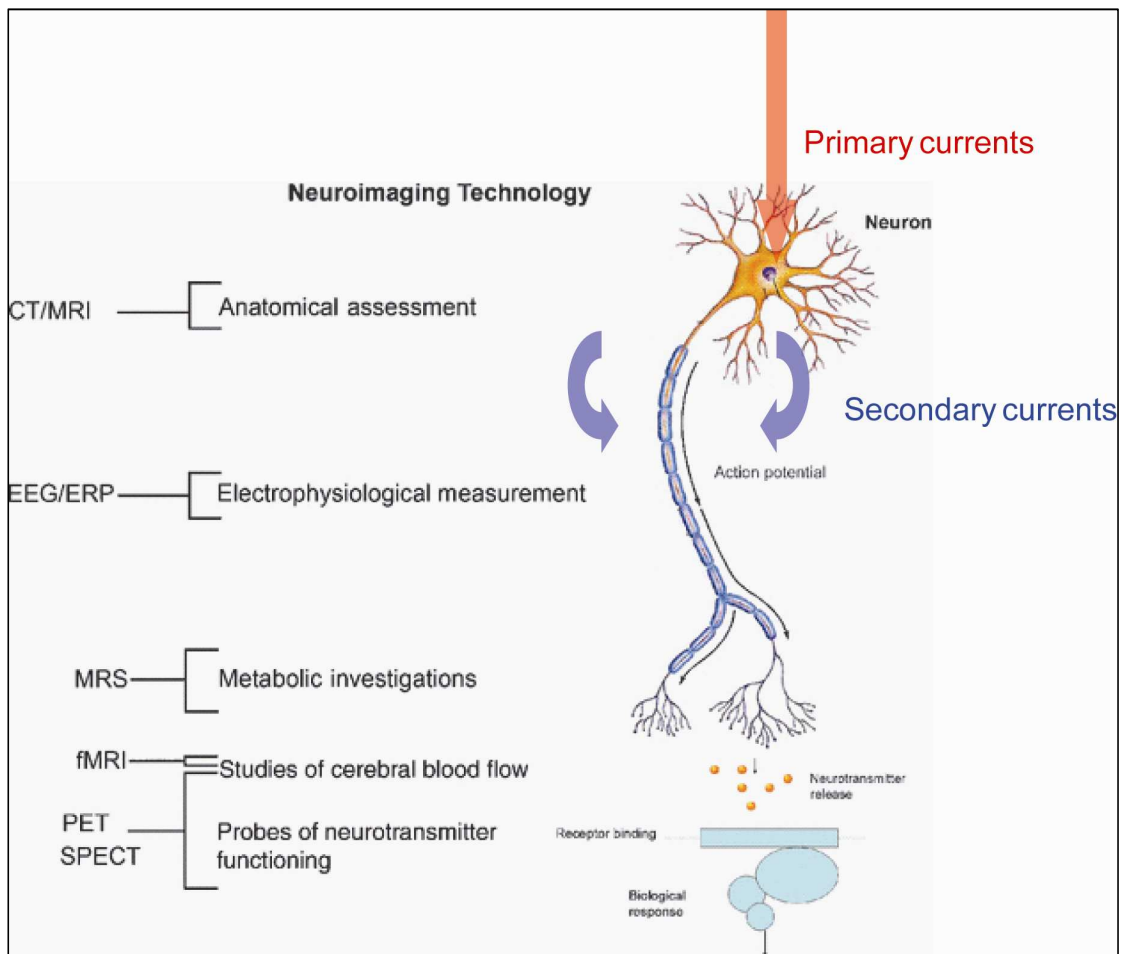


Figure 4.2: Schematic illustration of a neuron and the generation and propagation of an action potential, and the neurobiological processes assessed by neuroimaging modalities

CT=Computed Tomography; MRI=Magnetic Resonance Imaging; EEG/ERP=Electroencephalography/event-related potential; MRS=Magnetic Resonance Spectroscopy; fMRI=functional Magnetic Resonance Imaging; PET=Positron Emission Tomography; SPECT=Single-Photon Emission Computed Tomography.

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It is commonly assumed that the following holds (Hamalainen, et al., 1993; van Putten, 2009):

- MEG signals are primarily composed of activity from cortical pyramidal neurons, which are highly dense constituting 70-80% of all neurons ($\approx 10^5$ per mm^2 of cortex).
- The apical dendrites of pyramidal cells, and therefore the direction of current flow, are aligned perpendicular to the cortical surface thus enable extracranial recording of postsynaptic currents by MEG detectors.
- Current dipoles of individual pyramidal neurons are not strong enough to result in a bio-magnetic signal that can be reliably measured at the surface detector level; rather MEG measures and records signals generated by thousands of synchronously active neurons.

The cerebral magnetic fields produced by the brain are relatively weak. Man-made disturbances (such as power lines and traffic) and naturally occurring geomagnetic fluctuations can interfere with the detection of these cerebral magnetic fields and result in a low signal-to-noise ratio; see Figure 4.3. Accordingly their measurement requires the use of a) physical techniques to reduce the interference caused by external magnetic fields that are several orders of magnitude greater (e.g. housing the MEG scanner in a magnetically shielded room) and b) sensitive instrumentation for detecting these magnetic fields (e.g. superconducting quantum interference device or SQUIDs (Zimmerman, Thiene, & Harding, 1970)).

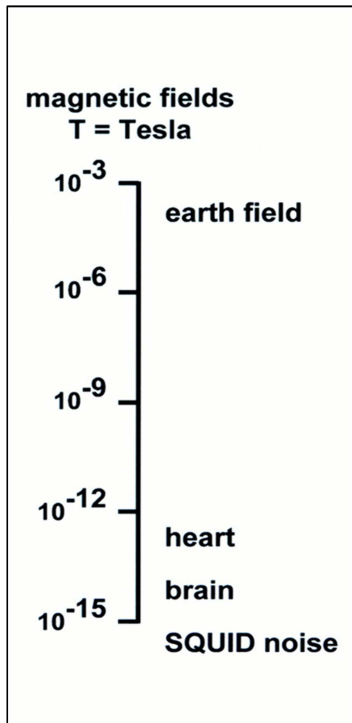


Figure 4.3: The magnetic fields of the brain measured by MEG are ≈seven orders of magnitude smaller than the magnetic field of the earth

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SQUIDs are coupled to the magnetic field through flux transformers containing a pick-up coil that gathers the external flux. The configuration of these pick-up coils determines their sensitivity to the magnetic field. Magnetometers are comprised of a single pick-up coil which measures the magnetic field itself from both proximate and distant sources. Gradiometers are comprised of a pick-up coil and a compensation coil which measures the spatial gradient of a magnetic field. Gradiometers have reduced sensitivity to distant sources as they are manifested as nearly uniform magnetic fields. The MEG system used in the experiment presented in Chapter 5: The Attentional Blink has 102 recording sites containing triple sensor elements of one magnetometer and two gradiometers. Accordingly the 306 MEG-channels combine the focal sensitivity of 204 planar gradiometers and the more widespread sensitivity of 102 magnetometers.

4.2.3 Magnetoencephalography versus electroencephalography

There are a few important differences between MEG and EEG which, in part, contribute to a superior ability of MEG to provide adequate solutions to the forward¹ and inverse² problems.

- MEG can measure frequencies between 0.5 and 150Hz, whereas EEG is limited to 0.5- to-35Hz, yet neuronal sources in the brain can generate frequencies greater than 35Hz (van Putten, 2009).
- The spatial resolution of MEG (0.5-2cm) is greater than that of EEG (1-3cm) (Babiloni, Pizzella, Gratta, Ferretti, & Romani, 2009).
- Pyramidal neurons generate intracellular magnetic fields (measured by MEG, compared with the ohmic currents that are primarily measured by EEG) that penetrate the skull and scalp without distortion and with little attenuation. This facilitates estimation of the location of the primary current source (Wheless et al., 2004); i.e. providing a solution to the inverse problem.
- In EEG, solutions to the forward problem depend upon accurate models for the conductivity of the skull, scalp, and brain. An implicit advantage of MEG is that it requires less model assumptions than EEG, which is important because every model assumption could be incorrect or inaccurate and thus lead to an erroneous solution.
- Finally, MEG does not require a designated reference channel as in EEG, which may impact upon interpretation of the data.

¹ The forward problem is that of predicting observations (in this case, magnetic fields) from a theoretical model (the head) with a given set of parameters (conductivities of the skull, scalp, and brain). MEG forward modelling might assume some parameters to be both known and fixed e.g. the geometry of the head, conductivity of tissues, and sensor locations.

² The inverse problem requires observations (in this case, the externally measured magnetic fields) to estimate the values of some parameters (the spatial and temporal distribution of the underlying magnetic fields). In general, this problem does not have one unique solution. A solution requires the generation of mathematical algorithms that depend upon several assumptions, for example the organisation of brain tissue.

4.2.4 Electromagnetism versus functional magnetic resonance imaging

There are multiple reasons why MEG provides alternative measures of brain activity compared with the blood oxygen level-dependent (BOLD) response measured using functional Magnetic Resonance Imaging (fMRI).

- MEG provides a direct measure of neuronal activity whereas fMRI provides an indirect measure (see Figure 4.4).
- Related to the above is that the BOLD signal, an indirect signal of haemoglobin oxygenation, is sensitive to cerebral blood flow, cerebral blood volume, and cerebral metabolic rate of oxygen. Therefore the BOLD signal may be susceptible to confounds including vascular and physiological factors (Haller & Bartsch, 2009).
- All fMRI measurements are relative or based upon comparisons with reference states (Gusnard & Raichle, 2001). In contrast, because of its high temporal resolution the MEG baseline is individually determined within the same examination, e.g. pre-stimulus.
- MEG has superior temporal resolution in the order of milliseconds (Hamalainen, et al., 1993). In contrast, the peak BOLD response does not occur until ~five seconds after the neuronal response to the stimulus begins (Amaro & Barker, 2006). Accordingly, stimuli have to be presented with a minimum interval so that the BOLD signal associated with these stimuli can be distinguished from each other.

Researchers are currently confirming the relationship between BOLD and neuronal activity. One recent study using multi-modal imaging has demonstrated an electrophysiological correlate for the haemodynamic BOLD response measured with fMRI (Zumer, Brookes, Stevenson, Francis, & Morris, 2010).

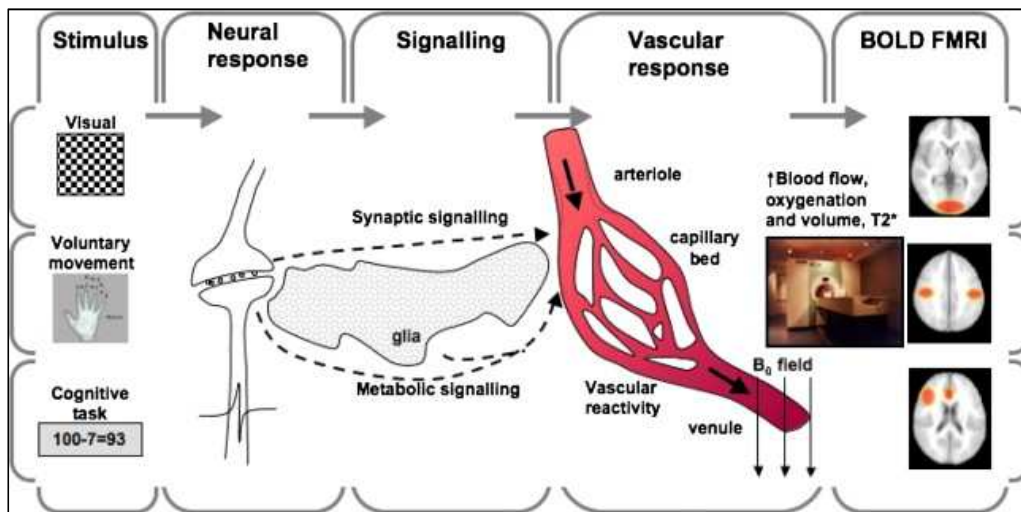


Figure 4.4: Schematic illustration of the generation of the blood oxygen level-dependent (BOLD) signal

Haemoglobin, in capillary red blood cells, delivers oxygen to neurons. When there is increased neuronal activity, there is an increased demand for oxygen in those regions of increased activity. This increased activity leading to increased blood flow exceeds the increased consumption of oxygenated haemoglobin, thus resulting in an increase in the ratio of oxy- to deoxy-haemoglobin. There is a difference in the magnetic properties of haemoglobin when oxygenated (diamagnetic) and deoxygenated (paramagnetic). The ratio of oxy- to deoxy-generated haemoglobin leads to small differences in the magnetic resonance signal. It is the measurement of this difference in blood oxygenation (hence blood oxygenation level-dependent [BOLD] imaging) that is used to make indirect inferences about the level of neuronal activity. Where neuronal activity leads to decreased magnetic susceptibility, there is an increased BOLD signal, which has to be deconvolved with the haemodynamic response function to relate it to the modelled neuronal response.

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4.3 An introduction to evoked responses

The aim of this section is to present a brief review of the spatiotemporal patterns of neuronal activity, produced after the presentation of a stimulus, that are associated with various cognitive processes. These patterns known as event related potentials (ERPs) and event related fields (ERFs) are time-locked components (or epochs) measured with EEG and MEG, respectively.

An ERP/ERF component that is of particular importance in the study of selective attention is the P300 or M300. This is a deflection³ in the EEG or MEG waveform with a latency between 200ms and 500ms (or later) post-stimulus onset.

4.3.1 P300

Early seminal studies demonstrated that the P300 component had a larger peak amplitude to meaningful and unexpected (Chapman & Bragdon, 1964), improbable (Sutton, Braren, Zubin, & John, 1965), and visually attended (Haider, Spong, & Lindsley, 1964) stimuli. Since then, however, researchers have demonstrated that the P300 is not a unitary phenomenon, rather has multiple subcomponents. These subcomponents are defined by the latency and spatial distribution of their peak amplitudes as well their associated cognitive function (Squires, Squires, & Hillyard, 1975). The P3a is elicited by infrequent stimuli, and occurs between 220 and 280ms post-stimulus onset with a spatial distribution over frontal-central regions (Squires, et al., 1975). The P3b or canonical P300 is elicited when participants are instructed to attend to stimuli, occurs between 200 and 500ms (or later), and has a spatial distribution over temporal and parietal regions (Polich, 2007). It was hypothesised, and subsequent experiments supported, that the functional significance of the P300 is the updating and storage of information in working memory (Donchin, 1981; Karis, Fabiani, & Donchin, 1984). It has also been suggested that P300 amplitude is an index of availability of information processing resources and resource allocation (for reviews on the functional significance of P300 see Kok, 2001; Polich, 2007); see Figure 4.5.

³ In the EEG literature, there are multiple ERP components that are defined by the latency and polarity of the maximum amplitude of the EEG waveform (for an overview of ERPs see Hillyard & Kutas, 2002; Sur & Sinha, 2009). In the MEG literature the notion of polarity is somewhat arbitrary but the EEG latency nomenclature has been adopted.

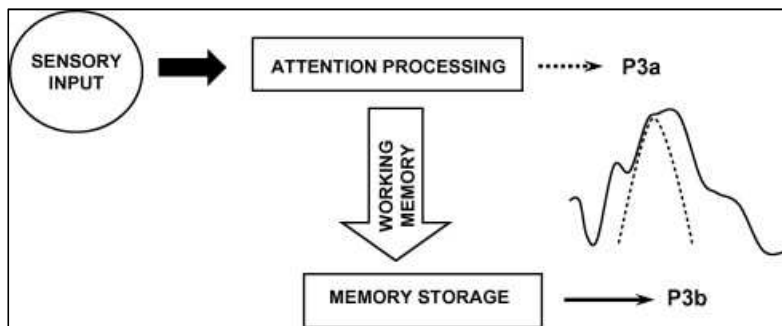


Figure 4.5: Schematic model of cognitive P300 activity. Sensory input is processed, with frontal lobe activation from attention-driven working memory changes producing P3a and temporal/parietal lobe activation from memory updating operations producing P3b

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4.3.2 Other event related potential/event related field components

Stimuli presented at an attended location in the visual field elicit enlarged P100 (deflection 80-130ms post-stimulus onset) and N100 (deflection 90-200ms post-stimulus onset) components that have been localised to the extrastriate visual cortex (the results of these studies are summarised in a review by Hillyard & Anllo-Vento, 1998). The N200 occurs between 180ms and 325ms post-stimulus onset. It is evoked when participants selectively respond to stimuli, and in response to deviation in the form or context of a stimulus (Patel & Azzam, 2005). The N400 is a deflection that begins at about 200ms post-stimulus onset and has a peak at about 400ms over central-parietal regions. The N400 is elicited in response to semantically deviant words and has a larger amplitude to strong compared with moderately semantically incongruent words (Kutas & Hillyard, 1980).

A discussion of the modulation of these components, specifically the P300/M300, as a function of the emotional salience of the stimuli and an individual's mood state will be provided in Chapter 5: The Attentional Blink.

Chapter 5 The Attentional Blink

“...the probability of a particular class of events being selected is increased by certain properties of the events and by certain states of the organism.”

Donald Broadbent, 1958; pp.297

5.1 Abstract

The Rapid Serial Visual Presentation paradigm is one method used to investigate the processing of information under conditions of varying attentional load. Participants were required to identify two rapidly presented (33ms) words embedded in a stream of five-letter consonant string distractor items. The difficulty of identifying the second word was modulated by either a short (more difficult) or long (less difficult) interval of three or nine distractor items between the first (T1) and second (T2) words, respectively. An emotional version of this task was developed such that participants were presented with a neutral word (T1) followed by a neutral, negative, or positive word (T2). In addition, the influence of mood state on attentional processing was explored. A combination of music and self-referential statements were used to induce neutral, sad, and happy mood states prior to the tasks. Finally, attentional processing biases were examined through the interaction of mood state and the emotional salience of T2.

Magnetoencephalography was used to investigate the neuronal correlates of visual attentional processing whilst participants performed the tasks. The principal event related field component of interest in Rapid Serial Visual Presentation paradigms is the M300; believed to reflect selective attention and the updating of working memory. Previous studies have shown that this component is modulated by the emotional salience and relevance of stimuli, as well as being reduced in depressed patients. Such modulations may be used to quantify the neuronal correlates of biases in selective attention.

5.2 Introduction

5.2.1 Attention

Our visual environment presents us with a continuous flow of information. However, capacity limitations dictate that only a subset of this information can be processed more extensively to a level that is available for conscious awareness. A mechanism known as selective attention is used to distinguish and prioritize target from non-target information for further processing. Consequently, there is competition among information to become a target for further processing. This competition is biased by our current (mood) state and task-relevant mechanisms as well as the properties of information such as its emotional salience.

Rapid serial visual presentation (RSVP) paradigms (Eriksen & Spencer, 1969) are one method used to study the focus of attention over time (rather than space) by imposing limitations on information processing resources. Participants are briefly presented with a stream of visual stimuli (targets and distractors) in the same spatial location, and are required to detect or identify¹ one or more of these targets. One phenomenon that has been identified using RSVP paradigms is the attentional blink (AB)²: a phrase that was coined by Raymond et al. (1992) but had been documented previously (Broadbent & Broadbent, 1987). The AB occurs when participants fail to detect or identify the second of two target stimuli.

¹ Note that researchers may ask participants to detect and/or identify targets. Accordingly these terms will be used interchangeably throughout this thesis. The term identify will always be used with reference to the MEG experiment presented here because participants were asked to identify T1 and T2.

² The attentional blink was named as such because it is analogous to an eye blink. When there is a stream of incoming information, there is an attentional response to a target stimulus (and the item immediately following the target). This attentional response entails the opening of a gating mechanism through which there is detection of the target defining features which facilitates identification. When there is confusion in identifying and matching the features of the stimulus to the target template (i.e. when both the target and the post target e.g. distractor item are attended) the gate closes and locks, and will not re-open until identification is complete. According to the analogy, the locking of the gate is like the closing of an eyelid.

5.2.2 Behavioural studies of the attentional blink phenomenon

In a series of experiments, Raymond et al. (1992) reported that the post-target (T1) deficit of detecting a second target (T2):

- Occurred up to 450ms post-T1 and had a maximal effect between 180ms and 270ms; see Figure 5.1,
- Only occurred when participants were asked to detect both T1 and T2 (dual task) and not when asked to ignore T1 (single task). Only the focus of attention and not the stimuli vary between the single and dual task conditions. Consequently the AB is believed to reflect post-perceptual suppression of processing and is thus caused by attentional, and not perceptual, mechanisms,
- Did not occur when a blank interval of at least 90ms immediately followed T1 and preceded T2,
- Occurred when a distractor item then a blank interval followed T1 and preceded T2, and
- Occurred when participants were asked to either detect or identify T1 (Shapiro, Raymond, & Arnell, 1994).

The importance of the post-T1 distractor item in eliciting the AB effect has since been corroborated (Di Lollo, Kawahara, Shahab Ghorashi, & Enns, 2005). In addition Chun & Potter (1995) also showed that the magnitude of the AB effect was reduced with increasing dissimilarity between T1 and the distractor immediately following T1 (greater reduction when the distractor was a symbol compared with a digit).

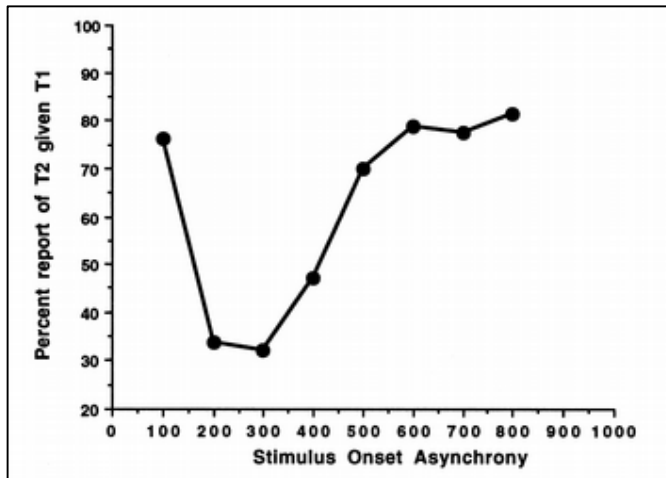


Figure 5.1: The attentional blink effect: percentage report of the second target (T2) given correct report of the first target (T1) as a function of T1-T2 stimulus onset asynchrony (SOA)

This figure demonstrates that the relationship between the accurate detection or identification of T2 and the T1-T2 SOA follows a U-shaped function such that there is lag-1 sparing: accurate reporting when T2 immediately follows T1. There is then a severe drop-off in accuracy, followed by increasing accuracy with increasing T1-T2 SOA until ≈ 500 ms, which thus represents the temporal limit for the redeployment of attention from one target stimulus to another.

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5.2.3 Theories and models of the attentional blink

A number of theories and models have been proposed to account for the AB effect (for a recent in-depth review see Dux & Marois, 2009). For a summary of each of the theories of the AB effect see Appendix 1.8. Proponents of filter-based theories have argued that the AB effect is caused by a) confusion of features between the T1 and post-T1 distractor item at the stage of identifying the target that leads to *perceptual inhibition* of other items in the stimulus stream (Raymond, et al., 1992) and b) enhanced processing of the post-T1 distractor item leading to *inhibition of enhanced processing* of other items in the stimulus stream (C. N. L. Olivers & Meeter, 2008). Proponents of interference or bottleneck models suggest that the AB is caused by *capacity limitations of the information processing system* such that T1 (and the post-T1 distractor item) consumes processing resources resulting in reduced resources for T2 (Shapiro, et al., 1994; Shapiro, Schmitz, Martens, Hommel, & Schnitzler, 2006). These two

categories of models are not, however, mutually exclusive: researchers have proposed models encompassing both concepts. The temporary loss of control model supposes that during the processing of T1 there is *reduced capacity to enable top-down control of the input filter mechanism* (used to match stimuli to templates) resulting in reduced detection of the remaining items in the stimulus stream (Di Lollo, et al., 2005). A dual-task model suggests that selective attention, acting as an input filter to determine which stimuli receive further processing, is necessary due to capacity limitations (Chun & Potter, 1995).

The aim of the next section is to review the results of studies using various neuroimaging techniques (including functional magnetic resonance imaging: fMRI, electroencephalography: EEG, and magnetoencephalography: MEG) to explore the neuronal correlates of visual temporal attention. This will culminate in a discussion of the implications of these results for theories and models of the AB effect.

5.2.4 Evidence from neuroimaging

MEG and EEG have unparalleled temporal resolution and are therefore ideally suited to using RSVP paradigms to investigate the AB effect. However, fMRI has superior spatial resolution and can therefore be used to identify the brain regions correlated with the AB effect.

5.2.4.1 Functional magnetic resonance imaging investigations

Researchers have acknowledged the slow haemodynamic recovery as a problem with using fMRI to investigate the neuronal correlates of temporal attention and the AB effect. In trying to overcome this obstacle, researchers have developed novel ways of using fMRI for such investigations. In one of the earliest fMRI studies, only T1 was presented following the rationale that the AB effect is caused by the processing demands of T1 (Marois, Chun, & Gore, 2000). In a subsequent study, the same group of researchers developed an RSVP paradigm with face (T1) and scene (T2) stimuli as targets, which are known to elicit activation in distinct neuronal regions, thus replacing temporal with spatial separation (Marois, Yi, & Chun, 2004).

Similar methods have since been used by other groups (Johnston, Shapiro, Vogels, & Roberts, 2007; Shapiro, Johnston, Vogels, Zaman, & Roberts, 2007; Slagter, Johnstone, Beets, & Davidson, 2010). Yet others have considered summed activation to the first and second targets (Kranczioch, Debener, Schwarzbach, Goebel, & Engel, 2005; Marcantoni, Lepage, Beaudoin, Bourgouin, & Richer, 2003) alongside grouping participants into those who showed the AB effect and those who did not (Feinstein, Stein, Castillo, & Paulus, 2004).

Collectively these studies provided evidence of increased activity in a network of frontal and parietal areas when targets were consciously perceived compared with when there was an AB effect. There was greater activity in prefrontal cortical regions (Feinstein, et al., 2004; Marois, et al., 2004; Slagter, et al., 2010), lateral frontal cortex (Kranczioch, et al., 2005; Slagter, et al., 2010), superior and inferior frontal gyrus (Feinstein, et al., 2004; Kranczioch, et al., 2005), anterior cingulate cortex (Feinstein, et al., 2004; Marois, et al., 2004), parietal lobe (Kranczioch, et al., 2005; Slagter, et al., 2010), and fusiform gyrus (Kranczioch, et al., 2005) when there was no AB effect (i.e. when participants made correct compared with incorrect or missed responses). In contrast, when there was an AB effect, there was increased activity in occipitotemporal areas including parahippocampal gyrus (Johnston, et al., 2007; Kranczioch, et al., 2005; Shapiro, et al., 2007). There was also increased activity in lateral frontal, inferotemporal, and posterior parietal cortices and cerebellum in the short compared with long T1-T2 SOA condition; the former is known to be associated with the AB effect (Marcantoni, et al., 2003). It is, however, important to note that participants were not required to make a behavioural response to the stimulus stream so the researchers could not therefore determine whether activity reflected the AB effect or not (Marcantoni, et al., 2003). Instead neuronal responses were measured using conditions in which the AB effect was known to occur; i.e. in a dual task with a short SOA. In another study, although participants were divided into those who demonstrated the AB effect and those who did not according to task

performance during the scan, imaging data were not analysed according to behavioural responses (Feinstein, et al., 2004).

That there was activity in occipital regions when stimuli (i.e. T2) were not consciously perceived suggests perceptual processing of both T1 and T2. This supports the notion that the AB effect is caused by a post-perceptual, attentional mechanism (for example Raymond, et al., 1992). Studies using fMRI have made an important contribution to our understanding of the neuronal correlates of the AB effect with fine spatial resolution. However, one major limitation is the difficulty in distinguishing neuronal activity to each stimulus due to relatively poor temporal resolution. This distinction is necessary to provide evidence for the theories of AB. Based on the resource sharing hypothesis (Shapiro, et al., 2006), researchers used fMRI to test the prediction of covariation of T1- and T2-related activity in AB relative to no AB trials (Slagter, et al., 2010). They used T1 and T2 stimuli known to activate distinct neuronal regions. Results showed no trial-to-trial variation in the activity of these two regions as a function of behaviour (AB or no AB effect). In contrast to fMRI, using imaging methods with fine temporal resolution such as EEG and MEG has made the investigation of both T1- and T2-related activity possible. Such research has furthered our understanding of the causal mechanisms and theories of the AB effect.

5.2.4.2 Electroencephalography and magnetoencephalography investigations

A large number of studies using psychophysical methods have demonstrated that the AB effect is likely to be an attentional and not a perceptual phenomenon. Studies using EEG/MEG have begun to elucidate the electro-/magneto-physiological correlates and mechanisms of this effect. A brief review of the spatiotemporal patterns of neuronal activity associated with cognitive processes is presented in Chapter 4: Introduction to Functional Imaging and Neuronal Correlates of Cognitive Processes. The P300/M300³ is a component that is of

³ The M300 is the magnetic counterpart (identified in studies using MEG) of the P300 (identified in studies using EEG).

particular importance in the study of selective attentional processes as it has been linked to the process of updating and storage of information in working memory (Donchin, 1981; Karis, Fabiani, & Donchin, 1984). Accordingly researchers hypothesised reduced or absent P300 to T2 items that are subsequently incorrectly identified or missed in dual task conditions.

Pioneering studies showed P300 suppression during the AB period (dual task, short SOA) suggesting impairments in T2 processing at the stage of visual selective attention and consolidation in working memory. There were no differences in P100, N100, or N400 amplitude suggesting intact perceptual and semantic processing (Vogel & Luck, 2002; Vogel, Luck, & Shapiro, 1998). In these early studies although ERPs were time-locked to stimulus presentation they were independent of T2 response. ERPs did not therefore reflect the AB effect per se, rather conditions in which the AB effect is known to occur. Nevertheless participants did perform the tasks during the EEG recording, unlike one fMRI study in which tasks were performed before, and therefore outside of the scanner (Marcantoni, et al., 2003). In more recent EEG/MEG studies researchers have explored the neuronal correlates of the AB effect analysing event related potentials (ERPs)/event related fields (ERPs) averaged according to behavioural response. Results confirmed the AB effect as a post-perceptual phenomenon: ERPs reflecting perceptual processing (P100 and N100 up to 200ms post-T2 onset over occipitotemporal regions) and semantic processing (N400 at 348ms over inferior frontal regions) were unaffected, whether T2 was subsequently blinked or correct (Sergent, Baillet, & Dehaene, 2005). Suppression of P300/M300 occurred when T2 was blinked, whereas there was a T2-related P300/M300 at the short (and long) SOA when T2 was consciously perceived (Kranczioch, Debener, & Engel, 2003; Sergent, et al., 2005; Sessa, Luria, Verleger, & Dell'Acqua, 2007; Shapiro, et al., 2006). Multiple studies have shown that the divergence of waveforms when T2 was subsequently consciously perceived or not began earlier than the P300 with reduced left-lateralised negativity around 270ms post-T2 onset (N200) over posterior-occipital regions when T2 was blinked (Sergent, et al., 2005). This was concomitant with increased T1-

related P300 over posterior central midline regions (Kranzloch, Debener, Maye, & Engel, 2007).

With regard to the potential cause of the AB effect, an early study (Vogel & Luck, 2002) whose findings have since been corroborated (Sessa, et al., 2007) provided evidence to support the bottleneck or two-stage models of the AB effect (Chun & Potter, 1995). Researchers tested the prediction that a perceptual representation of T2 can last (until it would otherwise decay) until T1 has been consolidated (thus allowing consolidation of T2 into working memory) if there is no post-T2 item and therefore no AB effect rather delayed processing of T2 (Giesbrecht & Di Lollo, 1998). These studies found that T2-related P300 was delayed by $\approx 100\text{ms}$ in the short (i.e. the time window in which the AB effect occurs) but not long SOA (Vogel & Luck, 2002), in the dual but not the single task (Sessa, et al., 2007). Furthermore another study found that the peak amplitude of both the T1- and T2-related P300 was earlier in a group of individuals who did not demonstrate the AB effect (non-blinkers) compared with those who did (blinkers) (Martens, Munneke, Smid, & Johnson, 2006). Further support for these two-stage, bottleneck models comes from studies showing that a greater T1-related P300 was associated with reduced T2-related P300 and a greater AB effect (Kranzloch, et al., 2007; Martens, Elmallah, London, & Johnson, 2006; McArthur, Budd, & Michie, 1999; Sergent, et al., 2005). In contrast to those studies supporting the two-stage, bottleneck models, an MEG study demonstrated individual differences in the allocation of attentional resources to T1 on the AB effect (Shapiro, et al., 2006). Specifically there was a positive correlation between T1-related M300 peak amplitude and the magnitude of the AB effect. The authors suggested this result argued against *“an immutable structural processing bottleneck”* (pp. 166) and for a resource sharing model (see Figure 5.2).

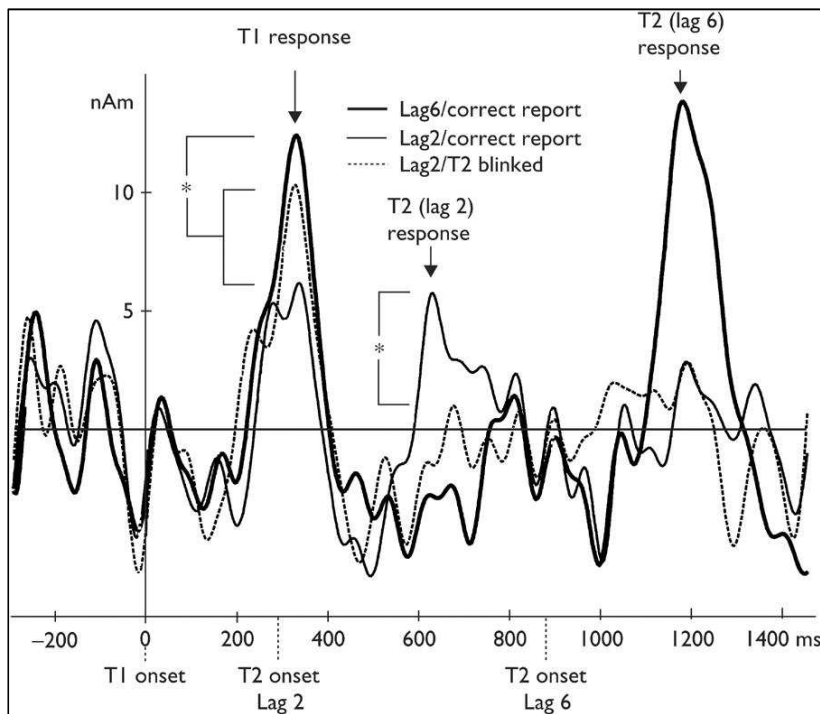


Figure 5.2: T1- and T2-related M300 amplitude as a function of T1-T2 SOA and response

Target-related activation on long T1-T2 SOA trials (lag 6) in which both targets were reported (bold line); short T1-T2 SOA trials (lag 2) in which both targets were reported (non-bold) and short T1-T2 SOA (lag 2) in which T2 was not reported i.e. an AB occurred (dashed). Waveforms represent sources with strongest target-related responses averaged across all participants and target letters. There is a 'trade-off' between T1- and T2-related activity in lag 2 conditions: whereas T2 activation is higher for successful T2 reports ($Z=-1.9$; $p<0.05$, one-tailed), T1 activation shows a non-significant trend towards the opposite tendency. When T1 activation at lag 2 (averaged over correct and incorrect T2 reports) was compared with lag 6 (correct T2 report only), there was a reliable difference in T1 activation ($Z=-2.3$; $p<0.01$, one-tailed).

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Further evidence against two-stage, bottleneck models comes from studies demonstrating that when no AB effect occurred there was earlier T1-related M300 and later T2-related M300 (Kessler et al., 2005a, 2005b). These two-stage, bottleneck models would predict delayed T1-related P300 and therefore delayed T2-related processing thus leading to the AB effect when T1 was masked. Instead the authors suggested that T1-masking terminates the processing of T1 and interferes with preparation for processing T2 (Kessler, et al., 2005b), hence the longer T1-to-T2 peak-to-peak interval.

In summary, these studies support previously reported findings from behavioural experiments that the AB effect reflects a post-perceptual phenomenon. In the dual task the P100 and N100 waveforms (which represent perceptual processing of stimuli) and, to a lesser extent, the P200 waveforms are largely unaffected by the attentional blink (Kranczioch, et al., 2003; Sergent, et al., 2005; Vogel, et al., 1998). The P300/M300, representing the updating of working memory, is absent or significantly reduced when T2 is blinked (Kranczioch, et al., 2003; Kranczioch, et al., 2007; Martens, Elmallah, et al., 2006; Shapiro, et al., 2006).

5.2.5 Overcoming the attentional blink

Many theoretical accounts suggest that the AB effect reflects an overinvestment of limited attentional resources on processing T1 at the expense of processing T2. The deployment of resources by attentional mechanisms can be influenced by the properties of the stimulus and an individual's goals and interests (see Chapter 1: General Introduction). In a series of pioneering experiments, it was found that the AB effect was attenuated when the T2 stimulus was a personally salient word: i.e. one's own name (Shapiro, Caldwell, & Sorensen, 1997). This led to a multitude of experiments aimed at exploring the influence of emotional stimuli on the AB effect.

Emotional word stimuli

Attenuation of the AB effect (or AB sparing) has been reported when **T2** was an emotional as opposed to a neutral stimulus. In contrast, an exaggeration of the AB effect has been shown when **T1** or distractor stimuli had an emotional valence.

Attenuation of the attentional blink by emotional T2 stimuli

Studies have shown enhanced T2 accuracy (or AB sparing) for emotional compared with neutral (Anderson, 2005; Keil & Ihssen, 2004; Keil, Ihssen, & Heim, 2006), negative compared with neutral (Anderson, 2005; Anderson & Phelps, 2001; Ihssen & Keil, 2009; Kihara & Osaka,

2008; Langley et al., 2008; Ogawa & Suzuki, 2004), and positive compared with neutral (Anderson, 2005; Langley, et al., 2008) T2 word stimuli. There is disagreement among researchers about whether AB sparing occurs for all stimuli with emotional valence (Ihssen & Keil, 2009) or is specific to negative compared with positive stimuli (Kihara & Osaka, 2008; Ogawa & Suzuki, 2004). Some report attenuation of the AB effect for both positive and negative T2 stimuli equally and therefore argue that these effects are specific to the arousal value rather than the valence of the stimuli (Anderson, 2005; Keil & Ihssen, 2004). Others have shown attenuation for both pleasant and unpleasant T2 word stimuli, when these stimuli were matched for arousal but not valence ratings (Ihssen & Keil, 2009). There is clear evidence for AB sparing for emotional compared with neutral T2 word stimuli. The potential differential effects for emotional stimuli, and the accompanying dimensions of arousal and valence, are yet to be confirmed.

Exaggeration of the attentional blink by emotional T1 or distractor stimuli

Capture of attentional resources has been explored using emotional T1 or distractor stimuli. Studies have shown a greater AB effect when T1 was a negative compared with neutral word (Kihara & Osaka, 2008). Furthermore, AB sparing to negative T2 stimuli was abolished when T1 was a negative compared with a neutral word. This suggests that negative stimuli (T2) require attentional resources (consumed by a negative T1) for accurate, conscious detection. Others have reported exaggeration of the AB effect for emotional distractor words, and high arousal (i.e. sexual/taboo) but not high valence (i.e. positive and negative) T1 words (Mathewson, Arnell, & Mansfield, 2008). Another group showed reduced T2 accuracy when T1 was a pleasant or unpleasant compared with a neutral word, whether pleasant and unpleasant words were matched for arousal value or not (Ihssen & Keil, 2009).

Mood, affect, and music

The influence of mood, affect, and music have been explored using a variety of methods including studying the AB effect in patients with mood disorders, using mood induction procedures (MIPs), playing music which can influence individuals' mood states (though not intended as a MIP), and exploring individual differences in dispositional affect and personality traits.

One study reported a larger and longer lasting AB effect in participants with relatively severe dysphoria compared with mildly or non-dysphoric participants (Rokke, Arnell, Koch, & Andrews, 2002). Researchers using measures of dispositional affect have shown that positive affect was associated with reduced AB magnitude and negative affect with increased AB magnitude (MacLean & Arnell, 2010; MacLean, Arnell, & Busseri, 2010; Vermeulen, 2010). There have, however, been mixed results from research investigating the effects of negative mood state on the AB phenomenon. Using MIPs one group reported the largest AB effect for participants in an anxious mood state and the smallest for those in a sad mood state (Jefferies, Smilek, Eich, & Enns, 2008).

Both listening to music and performing a mental task (free association) during the RSVP task have been shown to reduce to AB effect; see Figure 5.3 (C. N. L. Olivers & Nieuwenhuis, 2005). Another group of researchers found that playing a piece of music forward but not backwards improved T2 detection accuracy (Ho, Mason, & Spence, 2007). They suggested this effect may be due to the changes in mood state and/or arousal induced by listening to the piece of music.

These results are in keeping with the notion that positive affect broadens the focus of attention and increases cognitive flexibility (Fredrickson, 1998, 2001; Isen, 2000). In contrast depressed individuals demonstrate general impaired attentional mechanisms i.e. the diminished ability to think or concentrate (DSM-IV; 1994).

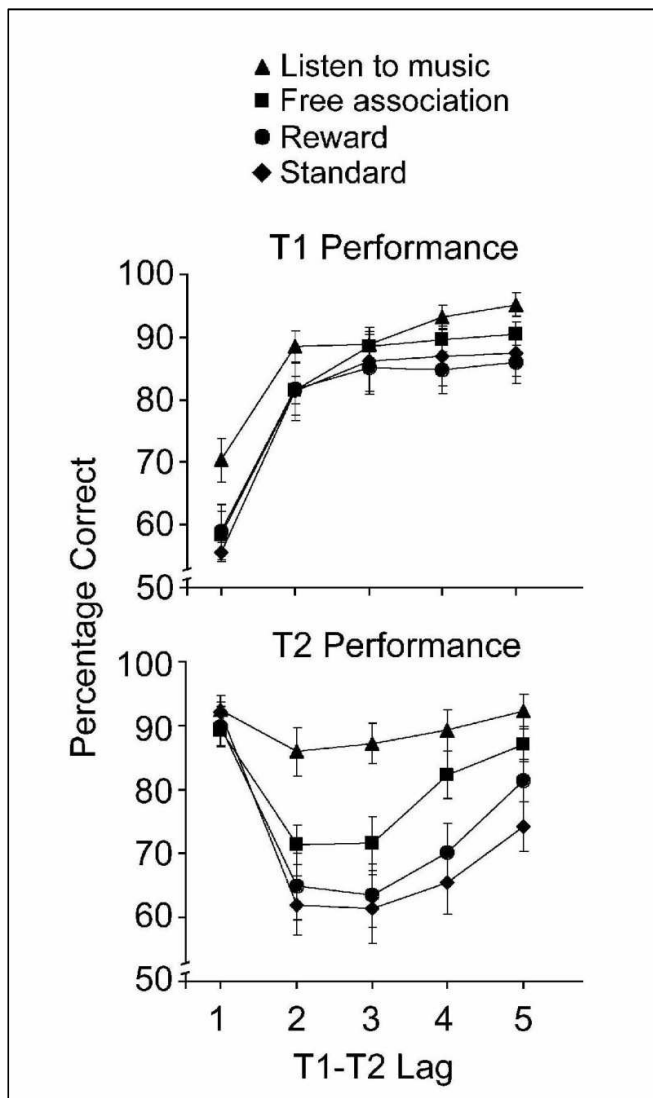


Figure 5.3: Average detection accuracy for the first (T1; top panel) and second (T2; bottom panel) of two target digits in a rapid serial visual stream of letters. Results are presented separately for two control conditions (standard, reward) and experimental conditions in which participants freely associated or listened to music. Error bars denote standard errors of the means

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Mood and emotional stimuli

"If the focussing of attention represents a prioritizing of information processing, then the allocation of resources should be tightly coupled with information of biological or motivational import to the organism" (pp. 258; Anderson, 2005). Accordingly researchers have begun to

explore the influence and interaction of mood state and emotional stimuli on the AB effect. However there have been very few studies investigating the AB effect in depression using mood-congruent negative stimuli.

One recently published study reported impaired identification of a neutral T2 word following presentation of a negative T1 word in relatively dysphoric compared with non-dysphoric individuals (Koster, De Raedt, Verschuere, Tibboel, & De Jong, 2009). Further, T2 word identification was significantly reduced following a negative compared with positive or neutral T1 word in the dysphoric group only; see Figure 5.4. These findings suggested that the attentional deficit (i.e. reduced T2 identification accuracy) in a depressed mood state was caused by a failure to *disengage* attention from mood-congruent (negative T1) stimuli.

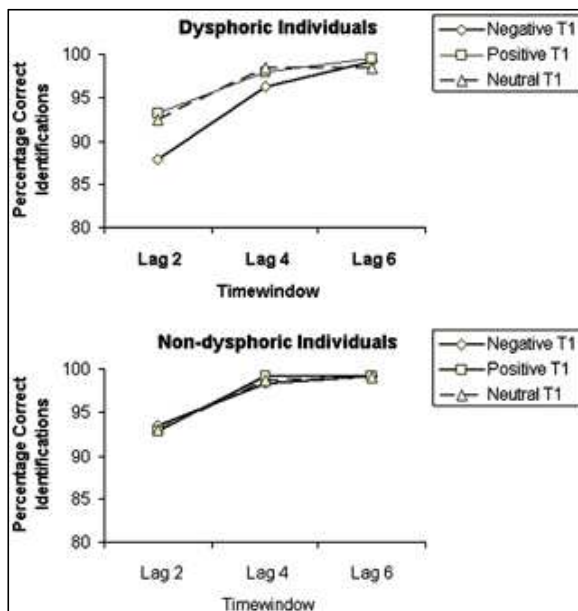


Figure 5.4: Percentage of correct T2 responses in dysphoric (top panel) and non-dysphoric (bottom panel) participants as a function of T1-T2 SOA (x-axis) and T1 valence

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To date, no study has investigated how attentional *capture* by mood-congruent stimuli (i.e. negative or positive words) might attenuate the AB effect (i.e. enhanced T2 accuracy) for participants in a depressed or happy mood state. Nevertheless one recent study did explore

the influence of negative cognitive style (as a potential vulnerability factor for depression) on attenuation of the AB effect when T2 word stimuli were neutral, negative self-referent, or negative non-self-referent words (Romens, MacCoon, Abramson, & Pollak, 2011). Participants with a high compared with moderate or low negative cognitive style identified significantly more T2 negative self-referent words. They also identified more negative self-referent than negative non-self-referent or neutral T2 words.

5.2.6 ERF/ERP components associated with visual emotional word processing

Results from studies presented in the previous sections demonstrated that, behaviourally, individuals showed an attentional bias towards visually presented emotional and mood-congruent word stimuli. The influence of emotion on the ERF/ERP components associated with visual word processing is a relatively new field of research (Kissler, Assadollahi, & Herbert, 2006).

The results of various studies exploring the influence of emotional and neutral word stimuli on ERPs are summarised in Table 5.1. These studies largely show no effects of word valence or arousal on the N100 and P100 components (although see also Bernat, Bunce, & Shevrin, 2001), whereas emotional compared with neutral words elicited larger negativity effects (i.e. N200) $\approx$ 200ms post-stimulus onset (Franken, Gootjes, & Van Strien, 2009; Herbert, Junghofer, & Kissler, 2008; Kissler, Herbert, Peyk, & Junghofer, 2007). Effects on positivity at this latency (i.e. P200) are unclear, with one study showing enhanced positivity to positive compared with negative words (Schapkin, Gusev, & Kuhl, 2000) and another showing the opposite effect (Bernat, et al., 2001). There is evidence for both arousal (enhanced positivity to emotional compared with neutral words) and valence (positive and negative words) effects $\approx$ 300ms post-stimulus onset, although the direction of valence effects is unclear (Bernat, et al., 2001; Franken, et al., 2009; Kissler, et al., 2006; Schapkin, et al., 2000). Finally, there is evidence for

valence effects $\approx 400\text{ms}$ post-stimulus onset with enhanced negativity (i.e. N400) to negative compared with positive (and neutral) word stimuli (De Pascalis, Arwari, D'Antuono, & Cacace, 2009; Herbert, et al., 2008; Kissler, et al., 2006).

First author	Stimulus duration	N100	P100	N200/EPN	P200	P300	N400
(Schapkin, et al., 2000)	150ms	X	-	-	Pos>Neg	Pos>Neu	-
(Bernat, et al., 2001)	40ms	U>P	U>P	-	U>P	U>P	-
(Kissler, et al., 2006)	Review	X	X	-	-	U+P>Neu	U>P
(Kissler, et al., 2007)	333ms	-	-	P>U	-	-	-
	1,000ms	-	-	U+P>Neu	-	-	-
(Herbert, et al., 2008)	333ms	X	X	U+P>Neu	-	-	U>P (U+P=N)
	1,000ms	-	-	-	-	-	-
(De Pascalis, et al., 2009)	450ms	-	-	-	-	-	Neg>Pos+Neu
(Franken, et al., 2009)	$\leq 2,000\text{ms}$	-	-	U+P>Neu	-	U>Neu	-
(Kissler, Herbert, Winkler, & Junghofer, 2009)	680ms	X	X	U+P>Neu	-	-	-

Table 5.1: Results of studies investigating the influence of emotional word stimuli on the amplitude of ERP components, not using a RSVP paradigm

Key: pos=positive, neg=negative, neu=neutral, u=unpleasant, p=pleasant words; > = more activity (whether negativity or positivity) in former, < = more activity in latter; x = no effects, - = effects not explored

N200/EPN = results for studies classifying ERPs with a peak amplitude $\approx 200\text{ms}$ post-stimulus onset as either the N200 component or the early posterior negativity (EPN).

An interesting question that remains to be confirmed is whether the influence of emotional word stimuli on various stages of visual word processing (and therefore ERF/ERP components) is a function of the arousal value (e.g. emotional compared with neutral) or valence specific (e.g. positive compared with negative) aspects of the stimuli. In their review, Kissler et al. (2006) conclude that there is most evidence for arousal but not valence modulations of early ($< 300\text{ms}$) visual word processing, but valence specific modulations during later ($> 300\text{ms}$) stages of processing.

5.2.7 ERF/ERP components associated with mood states

In the 1980s a group of researchers demonstrated significantly reduced P300, but not P200 or N200, amplitudes to visually presented target letter strings in patients with Major Depression (MD) compared with healthy participants (Diner, Holcomb, & Dykman, 1985). In addition, a greater severity of depressive symptoms was associated with reduced P300 amplitude. However others have reported no differences in P300 amplitude in depressed patients compared with healthy participants (Sara et al., 1994). A review of studies exploring the amplitude and latency of the P300 in patients with MD compared with healthy control participants presented variable evidence for a decrease in P300 amplitude (six studies showing a decrease and five showing a negative result) and little evidence for change in P300 latency (one study showing a delay and six showing a negative result) (Roth, Duncan, Pfefferbaum, & Timsit-Berthier, 1986). Despite these inconsistencies, researchers have continued to explore variations in ERP/ERFs in psychiatric populations with the aim to elucidate the information processing deficits underlying the disorder.⁴

There is a lack of research exploring the influence of happy mood states on ERF/ERPs: a search using the keywords 'P300', 'happiness' or 'happy mood' resulted in a negligible amount of relevant articles.

5.2.8 ERF/ERP components associated with visual emotional word processing in induced and naturally occurring mood states

5.2.8.1 P300

A recent review of ERPs notes the P300 component as an index of information processing that is useful for assessing cognitive function and the allocation of attentional resources (Duncan et al., 2009). The P300 is not elicited when stimuli are not attended to, has a smaller amplitude

⁴ Other aims include exploring the neurobiological basis and elucidating diagnostic markers for the disorder, as well as differentiating state and trait abnormalities (Roth, et al., 1986).

when stimuli are presented with shorter ISIs (or SOAs), and is influenced by the salience and relevance of the eliciting stimulus. Indeed it has been noted that *“the P300 appears to reflect the allocation of capacity-limited resources toward motivationally salient environment stimuli”* (pp. 131; Hajcak, MacNamara, & Olvet, 2010).

One study showed larger P300 amplitudes to negative word stimuli among currently depressed but not previously and never depressed individuals (Ilardi, Atchley, Enloe, Kwasny, & Garratt, 2007). Another reported more negative amplitudes to negative than positive word stimuli at 350-600ms post-stimulus onset following a positive, not negative MIP (Pratt & Kelly, 2008).

5.2.8.2 N400

Studies have demonstrated larger N400 amplitudes to mood-incongruent words following induction into a pessimistic or optimistic mood state (Chung et al., 1996). This study was based on the assumption that mood states are associated with expectancies and that violations of these expectancies (i.e. incongruence) elicit differences in ERPs reflecting expectancy, namely N400. In contrast, another EEG study found no differences in N400 amplitude to sentences ending with incongruent positive or congruent negative words for depressed patients or healthy control participants (Klumpp et al., 2010).

5.2.9 Imaging emotion, mood, and the attentional blink

It has been argued that emotional stimuli are preferentially (and potentially automatically) processed (see Chapter 1: General Introduction). This assumption can be explored using RSVP paradigms to engender conditions of limited attentional resources. Very few studies have used the RSVP paradigm to explore the neuronal correlates of the processing of emotional stimuli, and even fewer in the context of different mood states.

A study using fMRI showed increased activity in the rostral anterior cingulate cortex to correctly identified T2 fearful but not neutral faces (De Martino, Strange, & Dolan, 2008). Another study showed exaggeration of the AB effect and attenuation of the AB effect when T1

and T2 were emotional stimuli, respectively (Schwabe et al., 2011). However when both T1 and T2 were emotional, there was a reduction in attenuation of the AB effect. Further incorrect T2 responses were associated with increased activity in the anterior cingulate cortex, right orbitofrontal cortex, and insula, suggesting capture of attentional processing resources by the emotional T1 stimulus.

To date there has only been one published study exploring the neuronal correlates (using EEG) of attenuation of the AB effect as a function of the interaction of psychological state and the emotional salience of T2. T2 stimuli were neutral, emotional (positive and negative), snake, and threat-related spider pictures, and participants were individuals with a spider phobia and healthy volunteers (Trippe, Hewig, Heydel, Hecht, & Miltner, 2007). Behaviourally participants made more correct responses to all emotional (i.e. positive, negative, snake, and spider) compared with neutral pictures (see Figure 5.5). Spider phobic participants identified significantly more spider pictures than control participants. P300s to neutral pictures were smaller than to all other T2 picture categories when participants made correct responses. Spider phobic participants demonstrated larger P300s to T2 spider pictures compared with all other T2 picture categories, and compared with control participants (see Figure 5.6).

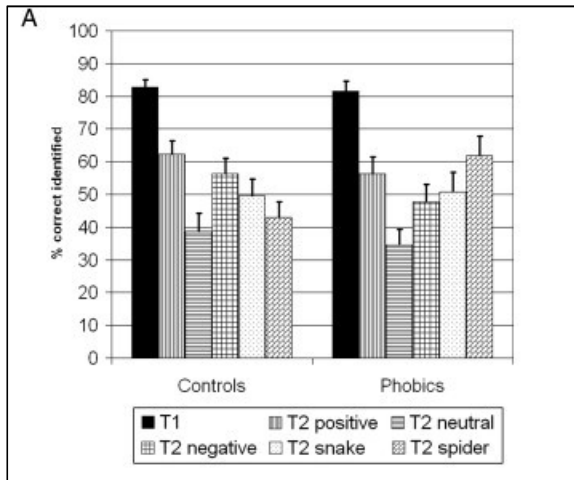


Figure 5.5: Mean percentage and standard error bars of correctly identified T1 and T2 pictures by spider phobic and control participants

Participants made more correct responses to positive than negative pictures ($p=0.01$), which was in turn more than to snake and spider pictures, and all were greater than neutral pictures ($p's<0.001$). Between groups, spider phobic participants identified significantly more spider pictures than control participants ($p=0.02$). Control participants correctly identified fewer spider compared with negative and positive pictures ($p's<0.001$), whereas spider phobic participants identified more spider than other pictures ($p's<0.005$ apart from positive pictures where $p=0.09$).

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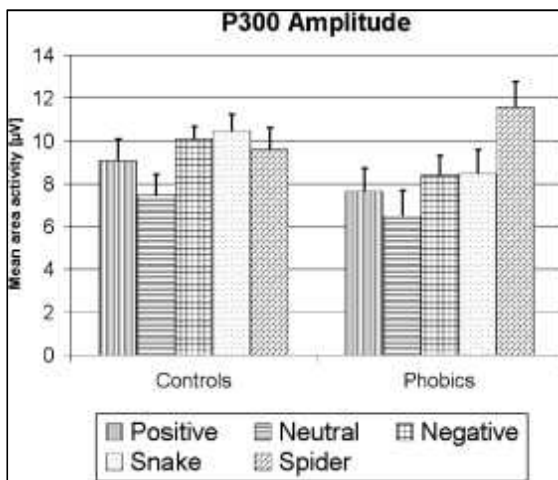


Figure 5.6: Mean P300 amplitudes (and standard error bars) of all T2 picture categories for spider phobic and control participants

Within the control group, P300 was lowest to neutral compared with all other categories ($p's<0.05$ apart from positive T2 where $p=0.073$), whereas within the spider phobic group P300 was greatest to spider compared with all other picture categories ($p's<0.02$) and also reduced P300 to neutral compared with negative, snake, and spider pictures ($p's<0.05$). There were, however, no differences between the control and spider phobic groups for P300s in any category. As controls had higher P300s overall, P300 to neutral T2 pictures was subtracted from all other categories and revealed a larger P300 to T2 spider pictures in spider phobic compared with control participants ($p=0.002$).

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As can be seen from this review of the literature, RSVP paradigms have not to date been widely used to investigate mood-congruent attentional biases in depression. As such the current study is one of few, if not the first to investigate the behavioural and neuronal correlates of attentional processing to emotional stimuli during various transient induced mood states using an RSVP paradigm.

5.3 Aims and hypotheses

The AB does not occur on all trials, suggesting that various factors may influence the allocation of our limited attentional resources. Therefore the aim of this study was to use an RSVP paradigm to investigate attentional control over visual processing of neutral and emotional (negative and positive) words during experimentally induced neutral, sad, and happy mood states.

5.3.1 Behavioural hypotheses

The AB effect occurs when participants make significantly more correct responses in the long compared with short T1-T2 SOA trials.

This experiment was designed to investigate the following hypotheses:

- The AB effect will be reduced when T2 is an emotional (negative and positive) compared with a neutral word, consistent with previously reported findings (Anderson, 2005; Keil & Ihssen, 2004; Keil, et al., 2006).
- The AB effect may be further reduced when T2 is a negative compared with positive word, as suggested by researchers advocating the presence of a negativity bias (Kihara & Osaka, 2008; Ogawa & Suzuki, 2004).
- Participants will demonstrate an exaggerated AB effect following a sad MIP (it has been shown that severe compared with moderate dysphoria is associated with a

larger AB effect; Rokke, et al., 2002). Depression is often associated with general impairments in cognitive and attentional processing (DSM-IV; 1994), as well as more systematic and elaborative processing (Blanchette & Richards, 2010), for example of T1 and distractor stimuli leaving fewer resources available to process T2 in the short SOA condition.

- In contrast, the AB effect will be reduced following a happy MIP due to broadening of attention and increased cognitive flexibility, as suggested by the Broaden and Build Hypothesis (Fredrickson, 1998, 2001) and previous literature (Isen, 2000).
- Biases in information processing will be demonstrated by an interaction of mood and emotion. In accordance with mood-congruent hypotheses (Bower, 1981), participants will make more correct responses when the emotional valence of the T2 word stimulus is congruent with the induced mood state (for example, sad mood and negative words).
- These biases may be specific to the AB effect (i.e. short compared with long T1-T2 SOA) if there is a prioritization of mood-congruent emotional information during conditions of limited availability of processing resources.

5.3.2 Imaging hypotheses

In addition to exploring the behavioural effect of induced mood and emotional target stimuli on the AB effect, MEG was used to record neuronal activity whilst participants performed the tasks. The results of previously published studies discussed above demonstrated that the amplitude (presence) of the P300/M300:

- Indicates the amount of resources allocated to stimulus processing,
- Is modulated by the emotional salience of the stimulus,
- May be reduced for individuals in a depressed mood state, and
- Is modulated by the relevance of the stimulus.

Accordingly, ERFs time-locked to the onset of T1 and T2 stimuli will be used to:

- Examine the neuronal correlates of the AB effect when T2 is correctly or incorrectly identified. This is to provide further support for the hypothesis that early (i.e. P100, N100, N200) T2-related ERFs are present independent of a participant's conscious report of that stimulus (correct or incorrect identification), whereas the later M300, reflecting the selective attention mechanism and updating of working memory, will be reduced or absent when T2 is incorrectly compared with correctly identified.
- Explore the influence of the emotional salience of T2 word stimuli on the neuronal correlates of the AB effect. Specifically, there will be greater T2-related M300 to emotional stimuli, which may facilitate correct identification.
- Explore the influence of mood state on the neuronal correlates of the AB effect. Attenuation of the M300 in a depressed mood state may be associated with impairments in correct identification.
- Investigate the neuronal correlates of information processing biases by examining the interaction of mood state and emotional T2 word stimuli on correct T2 identification.
- Investigate the influence of T1-related M300 on subsequent T2 performance as the potential cause of the AB effect. This is in line with resource sharing models which predict reduced and earlier T1-related M300 when T2 is subsequently correctly identified compared with enhanced and later T1-related M300 when T2 is subsequently incorrectly identified (Shapiro, et al., 2006).

Studies have also shown an influence of expectancy on the amplitude of the M400 component.

Therefore the present study will explore:

- Whether M400 amplitude is larger when participants are presented with emotional T2 words that are incongruent with their mood state.

5.4 Methods

5.4.1 Participants

5.4.1.1 Recruitment

Participants were 24 University of Oxford students and their friends who were approached by advertisement through college common rooms (February – December 2009).⁵ Of these, twelve were assigned to the sad and twelve to the happy mood induction groups in a stratified random manner. Participants were paid £10 per hour as compensation for their time and effort in participating, and travel expenses were reimbursed.

5.4.1.2 Inclusion and exclusion criteria

Eligible participants were between the ages of 18 and 45, able to give free and informed consent, had no history of receiving treatment for any psychiatric or psychological disorder (assessed using the Structured Clinical Interview for DSM-IV-TR Axis 1 Disorders, Research Version, Non-patient Edition. SCID-1/NP (First, Spitzer, M., & Williams, 2002)) or major medical condition, and no contraindications to MEG (as required by standardised MEG protocols). All participants had normal or corrected-to-normal vision and English was their first language.

5.4.2 The emotional rapid serial visual presentation paradigm

5.4.2.1 Pilot data

The methods chosen for the RSVP paradigm were based on extensive behavioural pilot work (four experiments with a total of 53 healthy volunteers); see Appendix 1.10.

⁵ The target number of participants was 24. MEG data were collected for a total of 33 participants because problems occurred during the data acquisition for nine of these participants. Problems included response button failures (N=2), previously unreported (i.e. during screening) contraindications to MEG studies (dental artefacts; N=2), head position indicator failures (N=3), and the stimulus computer aborting the MIP early (N=1).

5.4.2.2 RSVP task stimuli

The attentional blink was examined using an emotional RSVP paradigm (see Figure 5.7). T2 was a neutral, negative, or positive word. Word stimuli were initially selected from those used in other attention paradigms (e.g. Stroop task) and lists of words with emotion ratings. T1 were 119 neutral words, T2 were 50 neutral, 50 negative, and 49 positive words. All T1 and T2 words were of equal frequency, familiarity, and number of letters (assessed using the MRC Psycholinguistic Database; Wilson, 1988). T1 and T2 neutral words did not differ for ratings of meaningfulness (assessed using the MRC Psycholinguistic Database; Wilson, 1988), valence or arousal (assessed using the Affective Norms for English Words database; Bradley & Lang, 2010). T2 negative and positive words differed from T1 and T2 neutral words on these dimensions, and differed from one another on valence but not arousal or meaningfulness ratings. For selection methods, word lists, and analysis of the psycholinguistic properties of the word stimuli see Appendix 1.9.

Targets were distinguished from the distractors by the same physical feature: colour (as in previous studies; Anderson, 2005; De Martino, et al., 2008; Keil & Ihssen, 2004; Kihara & Osaka, 2008). Targets were presented for 33ms in yellow (T1) and green (T2) ink in 24-point Times New Roman font. Distractors were 64 five-letter consonant strings (as in Cornelissen et al., 2009), presented for 50ms in grey ink, followed by a blank black screen (or inter stimulus interval; ISI) presented for 16ms. The onset of T1 and T2 were separated by a blank black screen and three or nine distractors to create the short (247ms) and long (643ms) SOA conditions, respectively.⁶ Immediately after the stimulus stream participants were asked to first identify T2 and then identify T1 from a choice of two words.⁷ Participants were allowed 1,500ms to respond to these two alternative forced choice (2AFC) questions before the

⁶ These SOAs closely follow the methods of similar RSVP paradigms (Sergent, et al., 2005; Shapiro, et al., 2007).

⁷ For determining the order of the questions, see behavioural pilot studies (Appendix 1.10.1 and 1.10.2).

computer automatically began the next trial.⁸ There were a total of eight conditions defined by the *Presence* (present and absent: replaced by a blank black screen) and *Valence* of T2 (neutral, negative, and positive) and the *Latency* or SOA between T1 and T2 (short and long). T1 and T2 were randomly selected for each trial. Across 200 trials each T1 neutral word appeared, on average, 1.68 times per participant. For the 60 T2 neutral, negative, and positive trials, each word appeared, on average, 1.20, 1.20, and 1.22 times, per participant, respectively.

⁸ Another study using an RSVP paradigm reported that participants generally responded within 1 to 2 seconds after a cue appeared (Batterink, Karns, Yamada, & Neville, 2010).

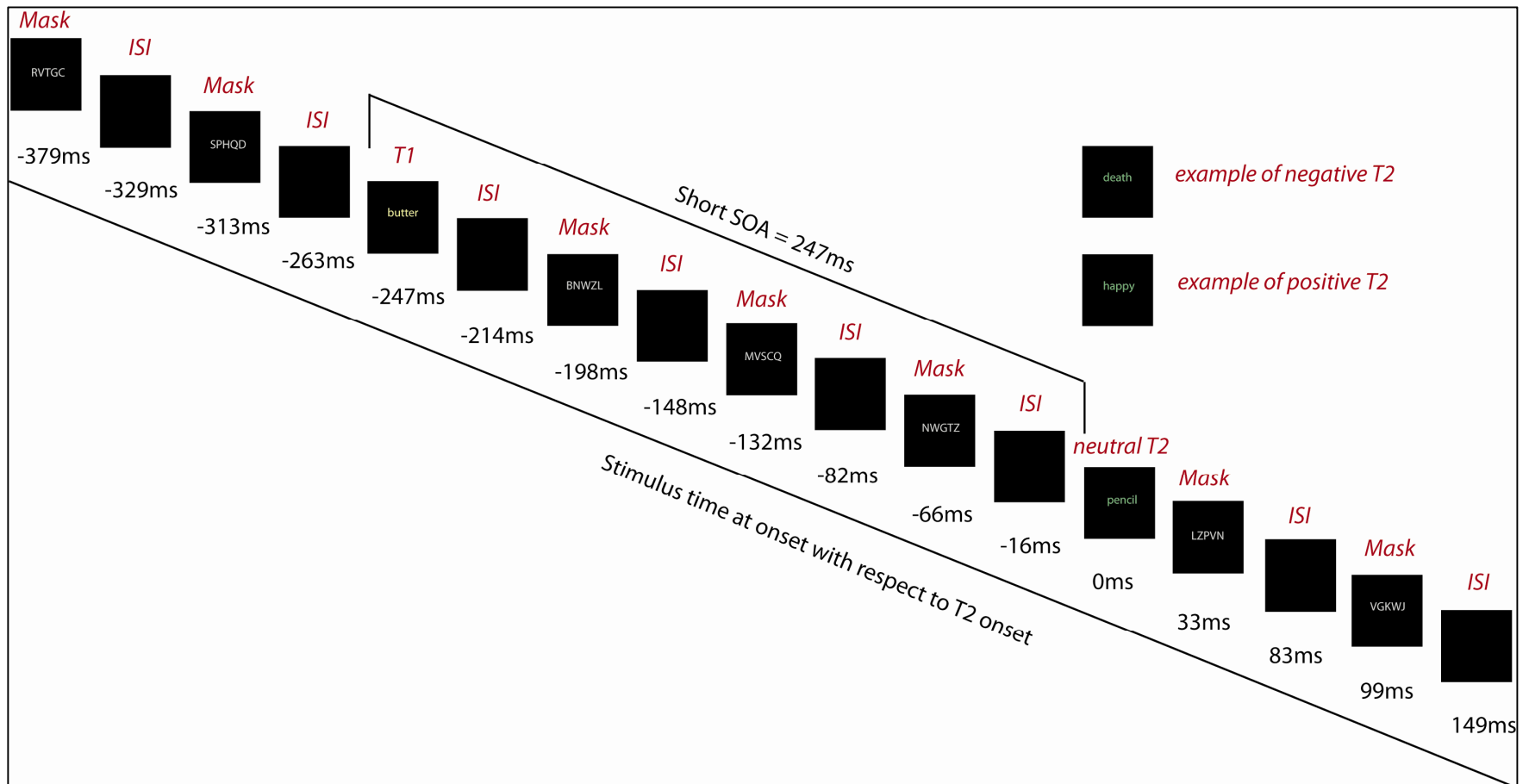


Figure 5.7: An example of the stream of target and distractors presented during the short T1-T2 SOA condition

5.4.3 Mood induction

Neutral, sad, and happy mood states were induced using identical methods to those presented in Chapter 3: Inductive Reasoning. Within the sad and happy MIP groups, the order but not frequency of neutral and valenced MIPs was counterbalanced.

5.4.4 Measures of mood state

5.4.4.1 Depressive mood symptoms

As in Chapter 3: Inductive Reasoning, scores of the severity of depressive symptoms were obtained using the 21-item Beck Depression Inventory Second Edition (BDI-II; Beck, Steer, & Brown, 1996).

5.4.4.2 Mood state ratings

The UWIST Mood Adjective Checklist (UMACL; Matthews, Jones, & Chamberlain, 1990) is a 24-item adjective checklist measure of mood state used to measure three dimensions of mood; energetic-arousal (EA), tension-arousal (TA), and hedonic tone (HT). This was administered to participants at the beginning and end of the experimental procedures to obtain a measure of baseline mood state.

A 100-point visual analogue scale (VAS) was used to measure self-reported mood state following the MIPs and upon completion of the tasks. The VAS ranged from unhappy (0) through neutral (50) to happy (100) with a schematic line drawing of an unhappy or happy facial expression at either end.⁹

5.4.5 MEG data acquisition

MEG is a non-invasive functional imaging technique that measures the timing of neuronal processes directly with a temporal resolution in the order of milliseconds. MEG measures and records the

⁹ Russell's dimensional theory of affect (1980) suggests that emotions vary on two separate dimensions: pleasure-displeasure, and arousal. According to this theory, sad and happy are at bipolar opposites of the dimension pleasure-displeasure. It seems appropriate therefore that a single visual analogue scale (VAS) from unhappy through neutral to happy was used as a measure of self-reported mood state in this experiment. Furthermore this was considered the most efficient way to assess mood state whilst participants were in the scanner. Results from the Beads Tasks, with multiple sub-scales to measure various components of mood state, showed that the sad and happy MIPs increased self-reported depression-dejection and vigor-activity scores, respectively, but did not affect scores on the tension-anxiety, anger-hostility, or confusion-bewilderment subscales.

magnetic fields induced by the post-synaptic current flow within the dendrites of thousands of synchronously active neurons.

5.4.5.1 Image acquisition

MEG data were collected using the Elekta Neuromag® measurement system installed at The Oxford Centre for Human Brain Activity (OHBA), University of Oxford Department of Psychiatry, at the Warneford Hospital, Oxford. The Elekta Neuromag® sensor system offers a dense spatial sampling of the magnetic field emanating from the human brain. The sensors are configured into 306 MEG-channels which combine the focal sensitivity of 204 planar gradiometers and the more widespread sensitivity of 102 magnetometers. Continuous data were recorded for the 306 MEG-channels at a sampling rate of 1,000Hz with a band-pass filter of 0.3-330Hz.

5.4.5.2 Stimulus presentation

The visual and auditory stimuli were generated using a Dell Personal Computer running Presentation™ software (Neurobehavioral Systems, Inc., Albany, CA, <http://nbs.neuro-bs.com>). The audio stimuli were delivered with an MEG-compatible headphone system. Stimuli were projected onto a back projection screen using a Panasonic DLP Based Projector PT-D7700E with an average distance of 150cm and an average viewing angle of 1.91 degrees (for a five letter T1 or T2 word). The delay between the triggers and stimulus presentation was stable and measured as 33ms. This delay was corrected for in the analysis. Jitter of the projected image was less than 1ms with 1280x1024 pixel resolution and 60Hz refresh rate. An optical, multi-digit response device for finger presses was used to record participant responses on line during data acquisition. The delay between the activation of the response device and the external and internal triggers was negligible.

5.4.5.3 Pre-processing and averaging

Pre-processing

Data were filtered using Elekta Neuromag® MaxFilter 2.1. Maxfilter software applies a spatial filter to the data to reduce magnetic interference and artefacts from signals arising outside of the head.

Electrodes were placed above and below the eye to record the electro-oculogram (EOG) in each participant. Eye blinks were identified using a correlation method. A principal component analysis (PCA) was conducted to identify those components corresponding to eye blinks and channels with high amplitude in the magnetometers and gradiometers, separately.

Averaging the MEG waveforms

MEG data were averaged according to behavioural response (T2 correctly and incorrectly identified when T1 correctly identified), T2 word category (neutral, negative, positive), and T1-T2 SOA (short, long) across epochs from -300 to 1000ms post T2 word onset, to create ERFs; see Figure 5.8.

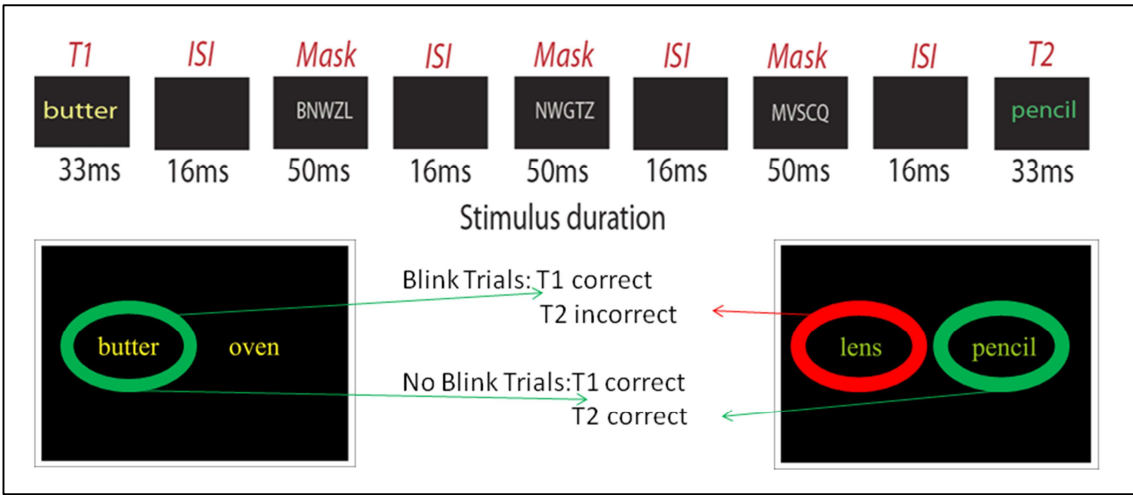


Figure 5.8: Example of trial classification when participants made T1 correct and T2 correct (green) or incorrect (red) responses to a neutral T2 word presented in the short T1-T2 SOA condition

5.4.6 Procedures

Twenty-four participants attended two sessions. The first involved screening for a past history and/or current psychiatric, psychological, or major medical conditions using the SCID-1/NP (First, et al., 2002), a medical screening form, and a check for any contraindications to MEG, such as implanted magnetic medical devices; metal plates, pins, or bolts in the head; and metal fragments in the eyes.

The MEG experiment was conducted in the second session. Depressive symptoms and baseline mood state were assessed using the BDI-II (Beck, et al., 1996) and UMACL (Matthews, et al., 1990), respectively. If any participant recorded a BDI-II equal to or greater than 19 (moderate to severe depressive symptoms range), they would not receive a sad MIP (if that was the condition to which they were allocated), rather would be allocated to the next happy MIP condition. Participants were briefed about the experimental procedures and tasks then were prepared for the MEG scan. Participants removed any items of clothing and jewellery that might affect the MEG scan. Then electrodes were attached to the participant to monitor eye blinks and cardiac cycle (bipolar recording). Participants were then taken into the magnetically shielded MEG room and seated comfortably so that the top of their head was close to the top of the MEG helmet. Using an intercom system, participants were informed when the scan was about to start and asked to keep very still during the scan. Participants could be monitored using the intercom system and video screen. Once in the scanner, participants received the first MIP (neutral/valenced), and then rated their mood state using the 100-point VAS. Following this they completed the RSVP task and rated their mood again using the 100-point VAS. Participants were then given a break and upon returning to the scanner received the second MIP (valenced/neutral), rated their mood, completed the RSVP task, and rated their mood again. Participants then left the scanner room and completed a second UMACL. Following this, participants were debriefed, had any questions regarding the study answered, and had the experiment hypotheses explained to them. Participants who received the sad MIP were given the opportunity to receive the happy MIP before leaving. The experiment proceeded as shown in Figure 5.9.

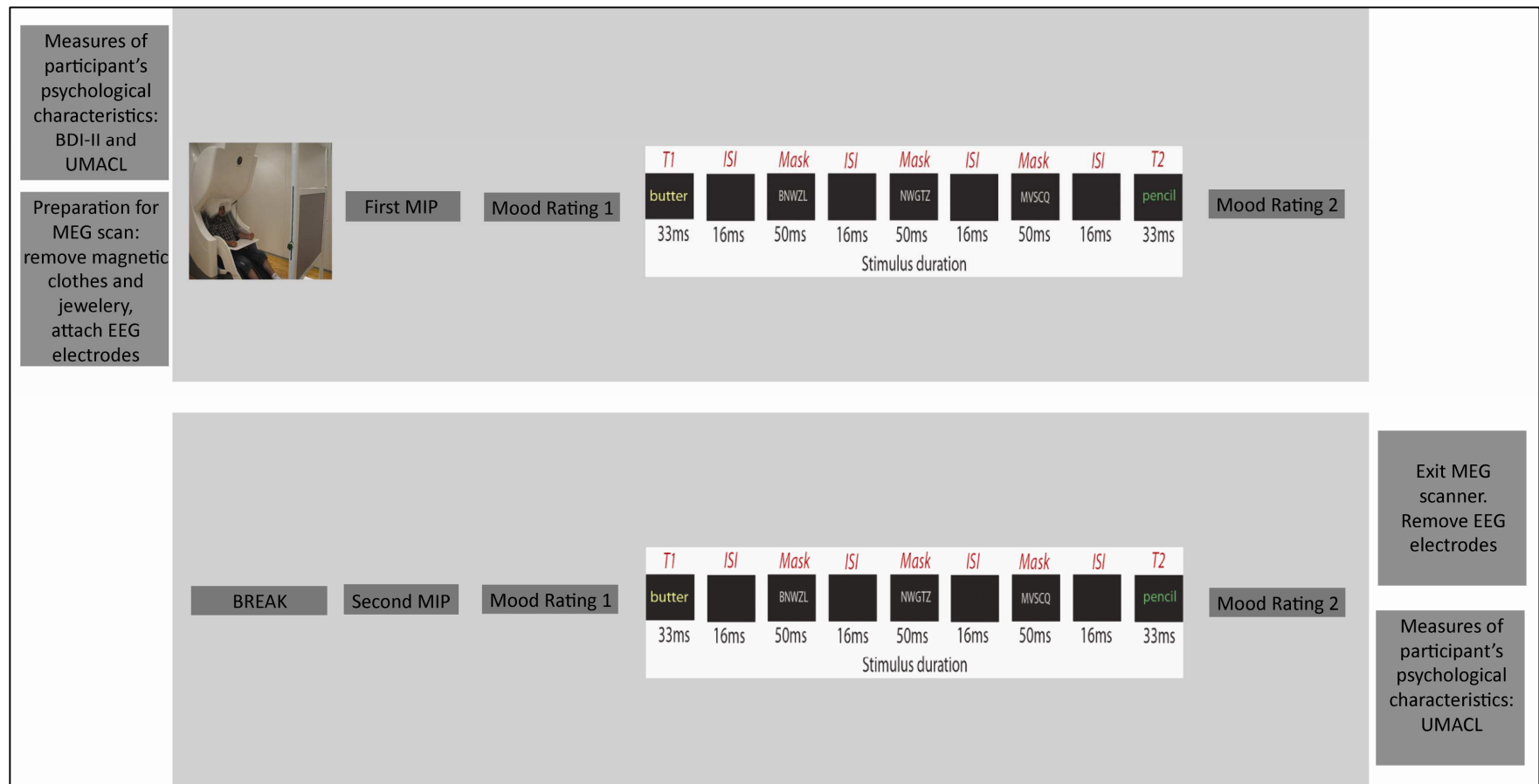


Figure 5.9: Timeline of experimental procedures for the second session: MEG scan

5.4.7 Statistics

5.4.7.1 Mood data

A 100-point VAS was used to measure mood state on four separate occasions: immediately after the MIP/before the tasks (Time 1) and after the tasks (Time 2) following neutral and valenced MIPs (the order of which was counterbalanced across participants). VAS scores were analysed using a repeated measures analysis of variance (ANOVA). Planned comparisons included investigating the assumptions that mood state would:

- Differ following the valenced MIPs for participants in the sad and happy groups,
- Not differ following the neutral MIPs for participants in the sad and happy groups, and
- Remain consistent over time of task (from post-MIP to post-task).

5.4.7.2 Behavioural data

Percentage of correct responses were used to measure performance after the neutral, sad, and happy MIPs in the short and long T1-T2 SOA conditions for the T2 neutral, negative, and positive word trials. The data were analysed with Univariate ANOVAs because there was a single outcome measure (percentage of correct responses). The design of this experiment was not suited to be analysed with methods conventionally used by experimental psychologists including Repeated Measures ANOVAs and Mixed ANOVAs. The design was not Repeated Measures because although participants completed the tasks following a neutral and emotional MIP, the emotional MIP was a between-subjects factors (either sad or happy). A Mixed ANOVA could not be used because although there was both a between (sad or happy MIP) and within (neutral, negative, positive T2 word valence) subjects design, this would not account for data following the neutral MIP.

- To explore whether there were any effects of Mood state, T2 word valence, and T1-T2 SOA on T1 responses, a Univariate ANOVA was conducted on the outcome measure (percentage

of T1 correct responses) with the fixed factors *Mood* (neutral, sad, happy), *T2 word valence* (neutral, negative, positive) and *SOA* (short, long) and the random factor *Participant ID*.

- To establish the presence of the AB effect, the percentage of T2 correct responses was analysed in a Univariate ANOVA with *SOA* (short, long) as a fixed factor and *Participant ID* as a random factor.
- To explore whether T2 word valence influenced the AB effect for participants in a neutral mood state, a Univariate ANOVA was conducted with the outcome measure (percentage of T2 correct responses) and fixed factors *SOA* (short, long) and *T2 word valence* (neutral, negative, positive) and the random factor *Participant ID*.
- To investigate the influence of induced mood state on the AB effect the fixed effects *SOA* (short, long) and *Mood* (sad, happy) and the random factor *Participant ID* were entered into a Univariate ANOVA with the outcome measure (percentage of T2 correct responses) for T2 neutral word trials.
- Finally, to explore the interaction of mood state and T2 word valence on the AB effect, a Univariate ANOVA was conducted on the outcome measure (percentage of T2 correct responses) with the fixed effects *SOA* (short, long), *Mood* (sad, happy), and *T2 word valence* (negative, positive) and the random factor *Participant ID*.

5.4.8 Ethics

Ethical approval for this study was granted by the University of Oxford Central University Research Ethics Committee and the Mid & South Buckinghamshire Research Ethics Committee (08/H0607/69). Informed consent was obtained from each subject prior to participation.

5.5 Results

5.5.1 Participants

There were no significant between-group differences for any of the presumed confounder variables including; age, gender, education, depressive symptoms, and baseline mood state (see Table 5.2).

	Sad group	Happy group	<i>p</i> -value
Age at MEG scan, Mean years (SD)	22 (2.17)	22 (3.57)	0.735
Gender, No. (%)			
Male	8 (66.67)	7 (58.33)	0.673
Female	4 (33.33)	5 (41.67)	
Educational Level, No. (%)			
Undergraduate	8 (66.67)	6 (50.0)	0.408
Postgraduate	4 (33.33)	6 (50.0)	
BDI-II, Mean (SD)	3.58 (3.48)	2.42 (2.54)	0.358
Baseline Mood, Mean (SD)			
UMACL before experiment	63.83 (6.81)	68.27 (5.83)	0.109
UMACL after experiment	59.00 (5.18)	61.20 (7.08)	0.423

Table 5.2: Summary of participant characteristics

UMACL=UWIST Mood Adjective Checklist (Matthews, et al., 1990).

No missing data for Age, Gender, Educational Level, BDI-II. Missing data for UMACL before experiment: happy group N=11, UMACL score after experiment: happy group =10, sad group N=11. Contrast: t-test (or χ^2), two-tailed significance.

5.5.2 Mood data

The following analyses were conducted to establish the efficacy of the MIPs.

5.5.2.1 Individual data

Most participants in the sad and happy MIP groups reported a mood state change in the expected direction (see Table 5.3). Of these, more participants in the sad than happy group report a mood state change of greater than 10-points on the VAS (N=8 and 3 participants, respectively).

Sad Group				Happy Group			
Participant ID	Overall mood change	Mood change after MIP	Mood change after task	Participant ID	Overall mood change	Mood change after MIP	Mood change after task
1	-34.89	-43.78	-26.00	2	-3.00	-9.11	3.11
3	-22.11	-12.67	-31.56	4	4.22	4.89	3.56
6	14.11	8.89	19.33	5	6.89	4.00	9.78
8	Missing	Missing	.67	7	-5.22	-10.89	.44
10	-13.33	-18.44	-8.22	9	15.89	45.11	-13.33
13	-4.11	-14.22	6.00	11	8.11	4.67	11.56
14	-14.11	-18.00	-10.22	12	26.89	21.33	32.44
16	-34.22	-46.22	-22.22	15	-4.11	-2.22	-6.00
19	-8.67	-17.78	.44	17	30.83	45.67	16.00
21	-29.78	-24.44	-35.11	18	-4.89	-5.33	-4.44
22	-10.44	-15.11	-5.78	20	4.11	5.78	2.44
23	-11.56	-9.33	-13.78	24	Missing	22.44	Missing

Table 5.3: Mood change score following valenced compared with neutral MIP for participants in the sad (left) and happy (right) groups

Table shows Valenced MIP VAS score minus neutral MIP VAS score at Time 1: immediately after the MIP (Mood change after MIP), Time 2: after the task (Mood change after task), and across Time 1 and 2: across both post-MIP and post-task measurement (Overall mood change). Values in red indicate participants reporting a mood change in the opposite than expected direction.

One participant (ID 6) in the sad group reported a more positive mood state following the sad compared with neutral MIP, at Time 1, at Time 2, and across Time 1 and 2. Two other participants (ID 8 and 19) reported a slightly more positive mood at Time 2 following the sad compared with neutral MIP. In the happy group, two participants (ID 15 and 18) reported a more negative mood state following the happy compared with neutral MIP, at Time 1, at Time 2, and across Time 1 and 2. There were two other participants (ID 2 and 7) that reported a more negative mood at Time 1 following the happy compared with neutral MIP and one (ID 9) reported a more negative mood at Time 2 following the happy compared with neutral MIP.

5.5.2.2 Group data

Mood ratings were normally distributed for six out of eight measures. Accordingly data were analysed using a parallel-groups repeated-measures ANOVA comparing mean VAS scores at *Time 1* and *Time 2* following *neutral* and *valenced* MIPs. The between-subjects factor was *Group* (sad or happy).

There was a *Mood by Group* interaction [$F_{(1, 20)}=15.43, p=0.001$]. Across time, participants in the sad group were significantly more negative following the sad than neutral MIPs ($t_{(10)}=3.54; p=0.005$).

Participants in the happy group showed a trend towards being more positive following the happy than neutral MIPs ($t_{(10)} = -1.92$; $p = 0.084$). Independent samples t-tests showed that participants in the happy group were significantly more positive than participants in the sad group following the valenced ($t_{(21)} = -5.50$; $p < 0.001$) but not neutral MIPs ($t_{(21)} = -1.43$; $p = 0.169$) across Time 1 and 2 (Figure 5.10).

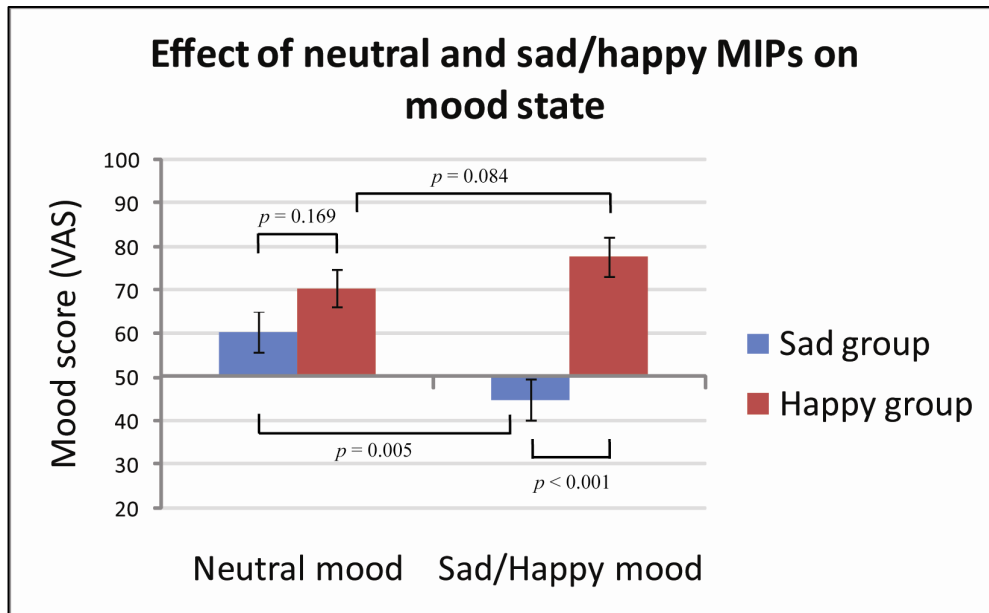


Figure 5.10: Effect of neutral and valenced MIPs on mood state, measured using a 100-point VAS

There was a main effect of *Time* [$F_{(1, 20)} = 10.11$, $p = 0.005$] such that participants were significantly less positive after than before the task, which was qualified by a *Time by Group* interaction [$F_{(1, 20)} = 13.47$, $p = 0.002$]. Paired samples t-tests comparing mood rating before and after the task (across neutral and valenced MIPs) demonstrate that participants in the happy group were significantly less positive following the task than immediately following the MIP/before the task ($t_{(10)} = 3.66$; $p = 0.004$). This effect did not occur for participants in the sad group ($t_{(10)} = -0.69$; $p = 0.504$); see Figure 5.11.

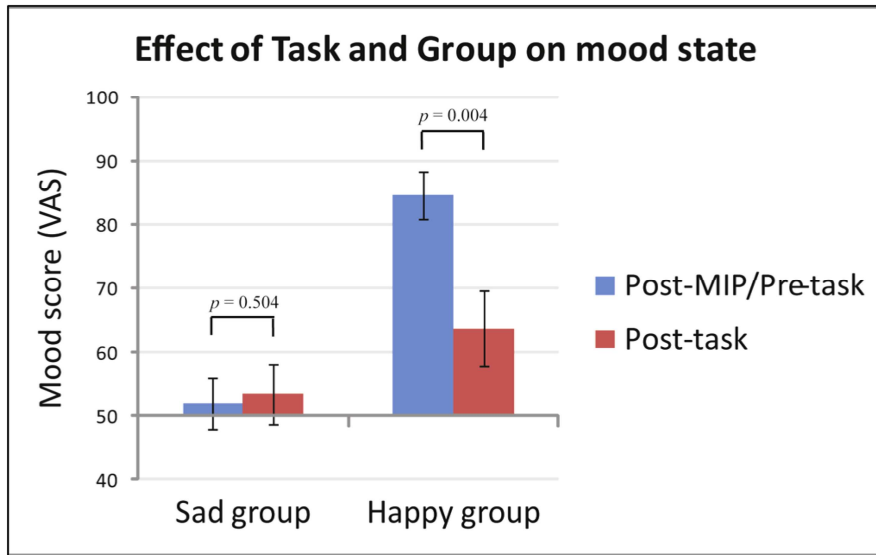


Figure 5.11: Effect of task on mood state for participants in the Sad and Happy groups, measured using a 100-point VAS across the neutral and valenced MIPs

Participants in the happy group showed a trend towards being more positive immediately following the happy compared with neutral MIP ($t_{(11)} = -1.89$; $p = 0.085$) but not following the task ($t_{(10)} = 1.36$; $p = 0.204$). Participants in the sad group reported being significantly more negative immediately following the sad compared with neutral MIP ($t_{(10)} = 4.16$; $p = 0.002$) as well as following the task ($t_{(11)} = 2.26$; $p = 0.045$).

5.5.2.3 Influence of current depressive symptoms

The influence of current depressive symptoms (measured using the BDI-II) on response to valenced (sad and happy) MIPs was examined. Mood change scores were calculated as VAS scores immediately after the valenced MIP minus VAS scores immediately after the neutral MIP. In the sad MIP group, the greater the negative score, the greater the change. In the happy MIP group, the greater the positive score, the greater the change.

Separate linear regression analyses (enter method) were performed for the sad and happy MIP groups with “Mood change” as the dependent variable and “BDI-II” and “Baseline mood state (UMACL)” as independent predictor variables.

This analysis was not significant for the sad MIP group $F_{(2, 10)}=0.303$, $p=0.746$. For the happy MIP group, there was a trend towards significance $F_{(2, 10)}=3.361$, $p=0.087$ which explained 32% of the variance (Adjusted $R^2=0.321$). *BDI-II* had a significant effect on the amount of post-MIP mood change ($\beta=5.303$, $p=0.032$), whereas *Baseline mood state* ($\beta=-0.628$, $p=0.514$) did not. Participants with a higher BDI-II reported the largest changes in mood state following the happy compared with neutral MIP (see Figure 5.12). Although not significant, participants with a lower BDI-II reported the largest changes in mood state following the sad compared with neutral MIP (see Figure 5.13).

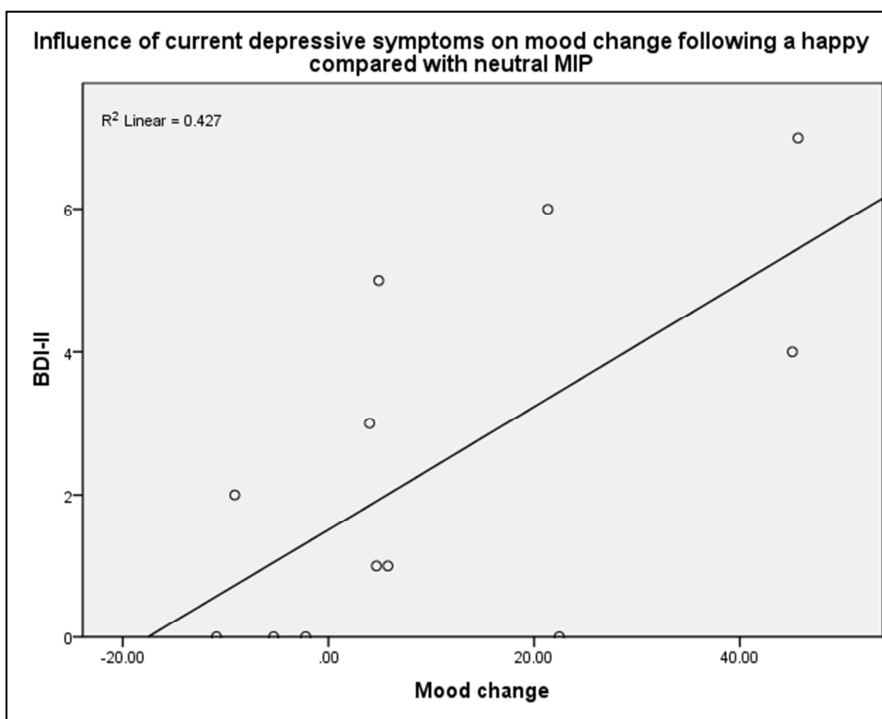


Figure 5.12: Influence of current depressive symptoms on mood change following a happy compared with neutral MIP

Larger positive scores indicate a more positive mood state after the happy compared with neutral MIP.

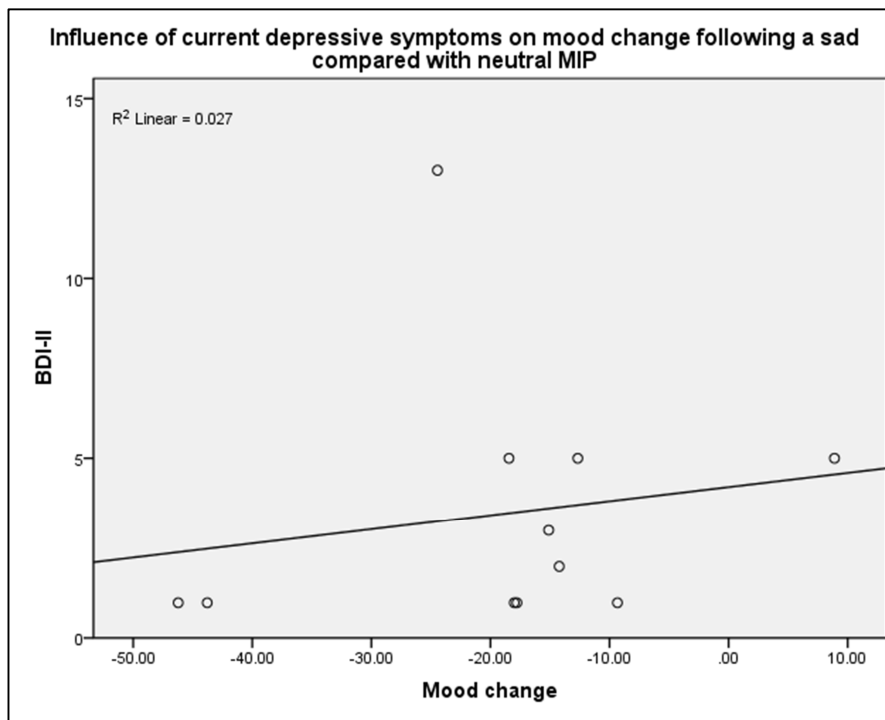


Figure 5.13: Influence of current depressive symptoms on mood change following a sad compared with neutral MIP

Larger negative scores indicate a more negative mood state after the sad compared with neutral MIP.

5.5.3 Behavioural data

The following section presents data exploring the influence of T1-T2 SOA, T2 word valence, and mood state on the AB effect.

In accordance with the literature, T2 responses were only included in the analyses if the preceding T1 was correctly identified. The percentage of T2 correct responses is not necessarily $\geq 50\%$ (i.e. the standard cut-off for above chance performance). This is because the two-alternative forced choice response screen was time limited (1,500ms). Therefore if participants did not make a response within the allocated time this missed response would not contribute to either the correct or incorrect categories. The correct category encompassed responses made when T2 was present and correctly identified. The incorrect category includes responses made when T2 was present and incorrectly identified.

A Univariate ANOVA with the fixed factors *SOA* (short, long), *Mood* (neutral, sad, happy), and *T2 word valence* (neutral, negative, positive) and the random factor *Participant ID* was conducted on the outcome measure total percentage of T2 correct and incorrect responses. There were no significant effects of either *Mood* [$F_{(2,492)}=0.074, p=0.929$] or *T2 word valence* [$F_{(2,492)}=0.277, p=0.758$] on the total percentage of correct and incorrect responses (and by implication the percentage of missed responses). Accordingly, any influence of the factors *Mood* and *T2 word valence* on the AB effect reflects differences in the proportion of correct and incorrect responses, and not differences in participants' propensity to make responses. There was a significant effect of *SOA* reflecting more responses made during the long SOA condition [$F_{(1,492)}=6.741, p=0.010$].

In accordance with the above, *statistical analysis* focussed on differences in the percentage of correct responses in the short and long SOA conditions. Frequency plots for the T1 and T2 correct responses showed that these data were skewed. The data were log transformed to normalise the variance and planned parametric analyses were conducted. For illustrative purposes, the non-log-transformed data (mean and standard deviation) are presented in the tables and figures.

In addition, for *descriptive analysis*, the mean percentage of correct and incorrect responses in the short and long SOA conditions was used to create a measure of the magnitude of the AB effect. AB magnitude was calculated as: (percentage of correct minus incorrect responses in the long SOA condition) minus (percentage of correct minus incorrect responses in the short SOA condition).¹⁰ A greater AB effect is reflected by a larger percentage.

5.5.3.1 T1 performance

To investigate the effect of *Mood*, *T2 word valence*, and *T1-T2 SOA* on the accuracy of T1, the percentage of T1 correct responses were analysed using a Univariate ANOVA with the fixed factors *Mood* (neutral, sad, happy), *T2 word valence* (neutral, negative or positive), and *SOA* (short, long) and the random factor *Participant ID*. There was no influence of *Mood*, *T2 word valence*, or *SOA* on

¹⁰ A similar method has been used previously; where AB magnitude was equal to the difference between T2 accuracy [d'] at short and long SOAs (MacLean, et al., 2010).

the accuracy of T1 responding; see Table 5.4 and Figure 5.14. The significant effect of *Participant ID* reflects individual variability in responding.

Effects	df	F	p-value
Mood	2,21	1.157	0.242
T2 word valence	2, 49.340	0.575	0.566
SOA	1, 24.488	0.001	0.976
Participant ID	23, 29.421	4.727	<0.001

Table 5.4: Results of the Univariate analysis of variance exploring the influence of Mood state, T2 word valence and T1-T2 SOA on the percentage of T1 correct responses

* $p<0.05$; ** $p<0.01$; *** $p<0.001$. df = degrees of freedom, F = F-statistic.

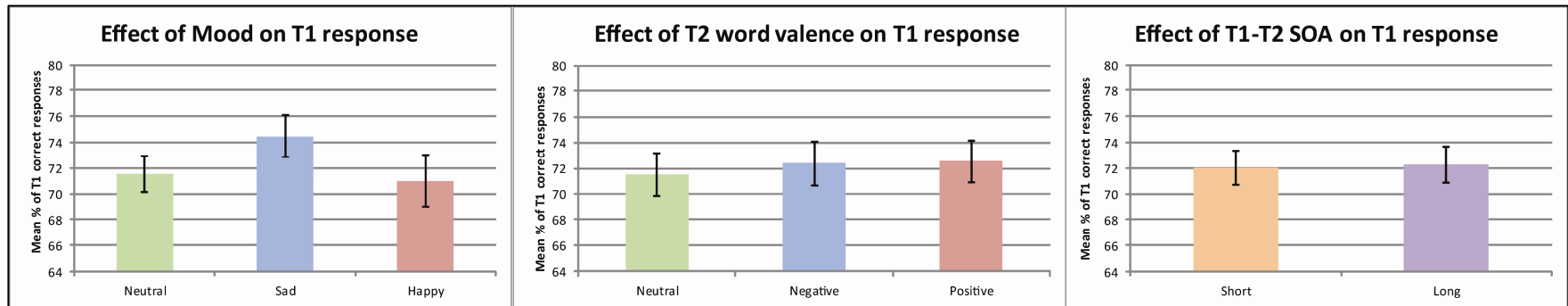


Figure 5.14: Mean percentage of T1 responses and standard error bars following the neutral, sad, and happy MIPs (left); on T2 neutral, negative, and positive trials (middle); and T1-T2 short and long SOA conditions (right)

5.5.3.2 T2 performance

The attentional blink effect

To test the presence of the AB effect, the outcome measure (percentage of T2 correct responses) was analysed in a Univariate ANOVA with *SOA* (short, long) as a fixed factor and *Participant ID* as a random factor.

A main effect of *SOA* [$F_{(1, 24)}=34.648$, $p<0.001$] showed that participants made more correct responses on the long [$M=56.49$; $SD=22.59$] than short [$M=41.42$; $SD=20.31$] *SOA* trials; see Figure 5.15. There was also a main effect of *Participant ID* demonstrating individual variability in responding.

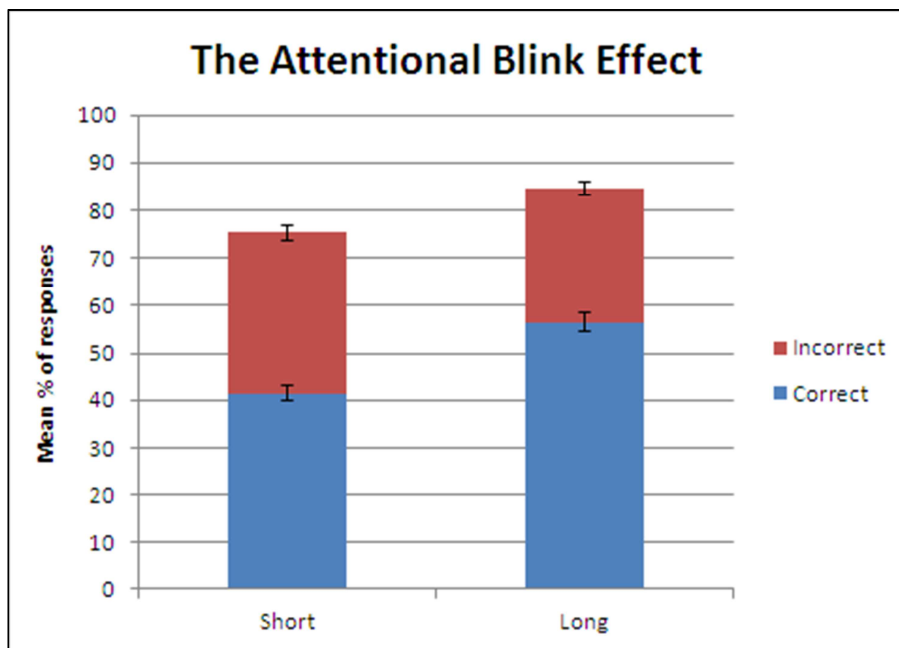


Figure 5.15: Influence of T1-T2 SOA on mean percentage of T2 correct and incorrect responses and standard error bars. T2 was conditional on T1 correct identification

As outlined previously, the percentage of correct and incorrect responses does not necessarily summate to 100% because when participants did not respond within the allotted time (1,500ms) these responses were not counted as either correct or incorrect.

From here on, the influence of *Mood* and *T2 word valence* on the percentage of T2 correct response is demonstrated statistically by an interaction with *SOA*.

Influence of emotional word stimuli on the attentional blink effect

To explore whether T2 word valence influenced the AB effect for participants in a neutral mood state, a Univariate ANOVA was conducted with the outcome measure (percentage of T2 correct responses) and fixed factors *SOA* (short, long) and *T2 word valence* (neutral, negative, positive), and the random factor *Participant ID*.

There was a significant interaction of *SOA by T2 word valence* [$F_{(5, 102)}=11.510$, $p<0.001$]. Participants made more correct responses to negative than neutral T2 words in the short SOA condition, the opposite pattern occurred in the long SOA condition, with positive T2 words intermediate; see Figure 5.16.

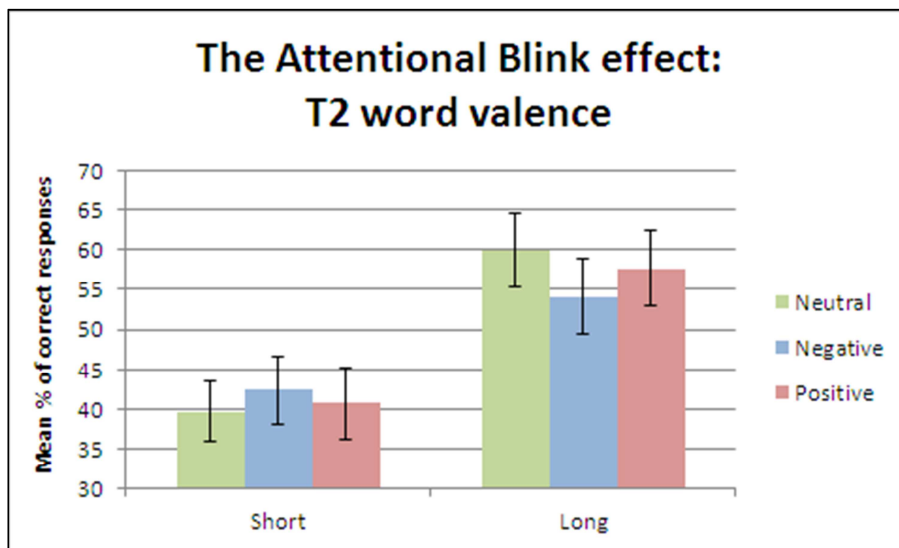


Figure 5.16: Mean percentage of correct responses and standard error bars in the short and long T1-T2 SOA conditions for T2 neutral, negative, and positive trials

Bar heights reflect the values reported in Table 5.4.

The descriptive measure of AB magnitude confirmed that participants demonstrated the smallest AB effect when T2 were negative words and the largest AB effect when they were neutral words, with positive words intermediate; see Table 5.5.

		Neutral	Negative	Positive
	Correct	39.68	42.37	40.69
Short	Incorrect	35.74	33.35	33.60
	Difference (d)	3.94	9.02	7.09
Long	Correct	59.98	54.05	57.66
	Incorrect	24.73	33.17	27.69
	Difference (d)	35.26	20.88	29.97
d long minus d short		31.32	11.86	22.88

Table 5.5: Mean percentage of correct and incorrect responses in the short and long T1-T2 SOA conditions for T2 neutral, negative, and positive trials, and calculations for the magnitude of the AB effect

Magnitude of the AB effect is calculated as (percentage of correct minus incorrect responses in the long SOA condition) minus (percentage of correct minus incorrect responses in the short SOA condition). A greater AB effect will be reflected by a larger percentage.

Influence of mood state on the attentional blink effect

The influence of mood state on the AB effect was explored for T2 neutral word trials using the outcome measure (percentage of T2 correct responses) in a Univariate ANOVA with *SOA* (short, long) and *Mood* (sad, happy) as fixed factors, and *Participant ID* as a random factor.

There was a significant interaction of *SOA by Mood* [$F_{(2, 19)}=11.880, p<0.001$]. Participants made more correct responses at the short SOA following the happy compared with sad MIP and fewer correct responses at the long SOA following the happy compared with sad MIP; see Table 5.6.

These results were confirmed using the descriptive measure of AB magnitude. Participants demonstrated the largest AB magnitude following the sad MIP: a smaller difference in the number of correct and incorrect responses at the short SOA relative to the difference at the long SOA (see Table 5.6). In contrast participants demonstrated the smallest AB magnitude following the happy MIP.

		Sad	Happy
	Correct	40.37	44.21
Short	Incorrect	33.58	29.51
	Difference (d)	6.79	14.70
Long	Correct	56.43	55.78
	Incorrect	27.06	25.45
	Difference (d)	29.37	30.34
d long minus d short		22.58	15.64

Table 5.6: Mean percentage of correct and incorrect responses in the short and long T1-T2 SOA conditions following the sad, and happy MIPs, and calculations for the magnitude of the AB effect

Magnitude of the AB effect is calculated as (percentage of correct minus incorrect responses in the long SOA condition) minus (percentage of correct minus incorrect responses in the short SOA condition). A greater AB effect will be reflected by a larger percentage.

Interaction of mood state and emotional word stimuli on the attentional blink effect

To explore the influence of mood (in-)congruence on the AB effect the outcome measure (percentage of T2 correct responses) was analysed in a Univariate ANOVA with *SOA* (short, long), *Mood* (sad, happy), and *T2 word valence* (negative, positive) as fixed factors and *Participant ID* as a random factor.

There was a significant interaction of *SOA by Mood by T2 word valence* [$F_{(6, 60)}=7.079, p<0.001$]. Participants made more correct responses to mood-congruent positive T2 words in the short SOA and mood-incongruent negative words in the long SOA; see Figure 5.17. Participants made a similar amount of correct responses to mood-congruent negative and mood-incongruent positive words in the short and long SOA conditions following the sad MIP.

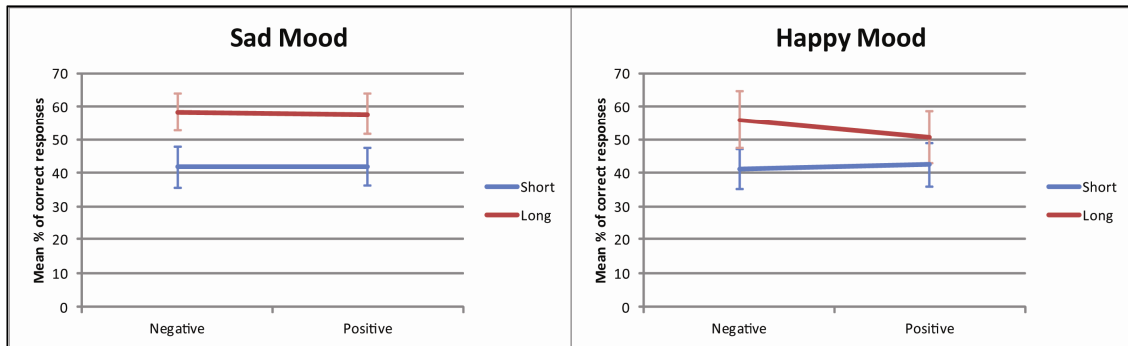


Figure 5.17: Mean percentage of correct responses and standard error bars following the sad (left) and happy (right) MIPs

Correct responses on T2 negative and positive word trials in the short (blue) and long (red) T1-T2 SOA conditions. Line heights reflect the values reported in Table 5.7.

The descriptive measure of AB magnitude confirmed a smaller AB effect to positive than negative words following the happy MIP; see Table 5.7. Participants made more correct and fewer incorrect responses to positive words in the short SOA condition and vice versa in the long SOA condition. Following the sad MIP, the AB effect was smaller to negative than positive words. Participants made a similar amount of correct and incorrect responses to negative and positive words in the short SOA. In the long SOA they made a similar amount of correct responses to negative and positive words but fewer incorrect responses to positive words.

		Sad		Happy	
		Negative	Positive	Negative	Positive
Short	Correct	41.74	41.76	40.97	42.39
	Incorrect	35.57	36.69	33.57	31.97
	Difference (d)	6.17	5.08	7.40	10.42
Long	Correct	58.20	57.65	55.99	50.67
	Incorrect	33.17	27.69	24.63	28.94
	Difference (d)	25.03	29.96	31.35	21.74
d long minus d short		18.85	24.88	23.96	11.32

Table 5.7: Mean percentage of correct and incorrect responses in the short and long T1-T2 SOA conditions following the sad MIP (left column in blue) and happy MIP (right column in red) for T2 negative and positive trials, and calculations for the magnitude of the AB effect

Magnitude of the AB effect is calculated as (percentage of correct minus incorrect responses in the long SOA condition) minus (percentage of correct minus incorrect responses in the short SOA condition). A greater AB effect will be reflected by a larger percentage.

5.5.4 Imaging data

Visual inspection and statistical analysis of the pre-processed MEG data presented in this section was conducted according to the following:

Only those conditions in which there were four or more trials per participant were analysed to optimise the signal-to-noise ratio. Pre-processed, averaged ERFs were filtered using a 30Hz low-pass filter (roll-off 1Hz).

To enable the dissociation of ERFs to T2 stimuli from those to T1 and the stream of distractors, waveforms when T2 was absent were subtracted from waveforms when T2 was present and a) correct and b) incorrect for individual participants. Replications of these effects were explored in a larger sample of participants when T2 absent was not subtracted from the T2-related present and correct/incorrect ERFs.¹¹

Visual inspection of average MEG waveforms (either across all channels or a selection of channels) were conducted using power curves (global root-mean-square):

- Evoked responses for each condition of interest were squared in each gradiometer (channel),
- These squared values were averaged across the 204 gradiometers (or a selection of gradiometers, e.g. those over temporal regions), and
- The square root of the mean was calculated.

¹¹ The number of participants included in the non-subtraction data was 21 for the neutral MIP, neutral T2 trials, as three participants performed poorly and did not have enough trials (>4). The number of participants included in the subtraction data for the neutral MIP, neutral T2 analyses was N=13 short SOA correct and incorrect, N=11 long SOA correct, and N=9 long SOA incorrect. Although all participants had trials when no T2 word was presented (i.e. T2 absent [replaced by a blank black screen]), not all participants had a corresponding T2 absent average ERF. This was due to the nature of the epoching procedure: trials were allocated according to correct and incorrect responses which depended on a participant response. This response was arbitrary for T2 absent trials but participants were not instructed that there would be T2 absent trials to ignore hence some responded, and consequently had a T2 absent average ERF. Some participants did not respond on T2 absent trials hence did not have a T2 absent average ERF.

The spatial distribution of this activity was visualised using local (two gradiometers at each recording site) power maps (local root-mean-square). This was calculated using the same procedure as above but squared values were averaged across the two gradiometers at each recording site. This signal represents a measure of current strength, or neuronal activity, in the region directly below the gradiometers (Braeutigam, Rose, Swithenby, & Ambler, 2004).

Both the global and local power were calculated for individual participants and grand-averages across participants. Differences between conditions in neuronal activity will be referred to as changes in peak, amplitude, and/or signal.

Statistical differences in ERFs between the conditions of interest across participants were analysed using a time-dependent, chi-square based measure $P(t)$; see Figure 5.18 (Braeutigam, et al., 2004).

$$P(t) = \text{probability}(\chi^2) \quad (\chi^2) = -2 \sum_{i=1}^N \ln[f_i(t)]$$

Figure 5.18: Formula for calculating statistical differences using a time-dependent, chi-square based measure

N denotes the number of channels. For each channel, $f_i(t)$ denotes a non-parametric statistical test. $P(t)$ describes significant differences across selected gradiometer channels as a function of time. This test corrects for multiple comparisons at a time point, where that time point may be significant in more than one channel. For each significant interval [$P(t) < 0.05$], the spatial distribution of the significant difference was given by f_i . Correspondence between the spatial distribution of the significant difference and the spatial distribution of ERFs (using grand-average power maps) was explored. However, although $P(t)$ is a method used to detect significant differences in ERFs, these differences do not necessarily translate to changes in activity as represented in the power curves and maps.

Two different non-parametric tests (*f*) were used in the formula above dependent on the nature of the comparison. Wilcoxon and Mann-Whitney U tests were used for within and between MIP group analyses, respectively. The Wilcoxon tests relied upon matched samples whereas the Mann-Whitney U tests did not. Accordingly, the number of participants included in each of the analyses is stated in the results section.

5.5.4.1 Neuronal correlates of the attentional blink effect: T2-related activity

To investigate the AB effect, grand-average power curves (global root-mean-square) when participants made correct and incorrect responses to T2 neutral words following a neutral MIP were compared for the T1-T2 short and long SOA conditions separately. Following this, significant differences were identified using Wilcoxon paired samples tests.

Short SOA

There was significantly greater T2-related amplitude when participants subsequently made correct compared with incorrect responses at 200ms, 400-450ms, and 480-525ms post-T2 onset (see Figure 5.19 and Figure 5.20). There was significantly more activity for incorrect compared with correct responses at 30ms, 110ms, 160ms, and a near 5% significant effect at 240ms. The results of the Wilcoxon analysis are summarised in Table 5.8 and spatial distribution maps are presented in Appendix 1.11. Grand-average power maps (local root-mean-square) for correct and incorrect responses from 10-600ms post-T2 onset are provided in Appendix 1.12 and 1.13, respectively.

These data show a complex pattern of activity. The early effects at 30ms and 110ms may be associated with T1-related processing and therefore used to inform a preliminary analysis of the cause of the AB effect (see Results > Imaging data > Neuronal correlates of the AB effect: T1- and T2-related activity). The effect at 160ms may reflect the N100 elicited to stimuli presented at an attended location (Hillyard & Anllo-Vento, 1998). The near significant effect at

240ms is consistent with previously reported (Sergent, et al., 2005) and replicated (Kranczioch, et al., 2007) data from EEG studies which showed greater N200 for correct responses.

For the purposes of this thesis, analysis will focus on effects observed at about 525ms post-T2 onset. This component is taken to be the M300 and has a spatial distribution over left temporal regions; see Figure 5.21. Previous studies have reported the T2-related P300 to occur around this time (Sergent, et al., 2005) and over left temporal regions (Polich, 2007). Importantly, this pattern was demonstrated in the individual power curves of eleven out of 13 participants. Furthermore the effect was also present in the non-subtraction data (N=21).

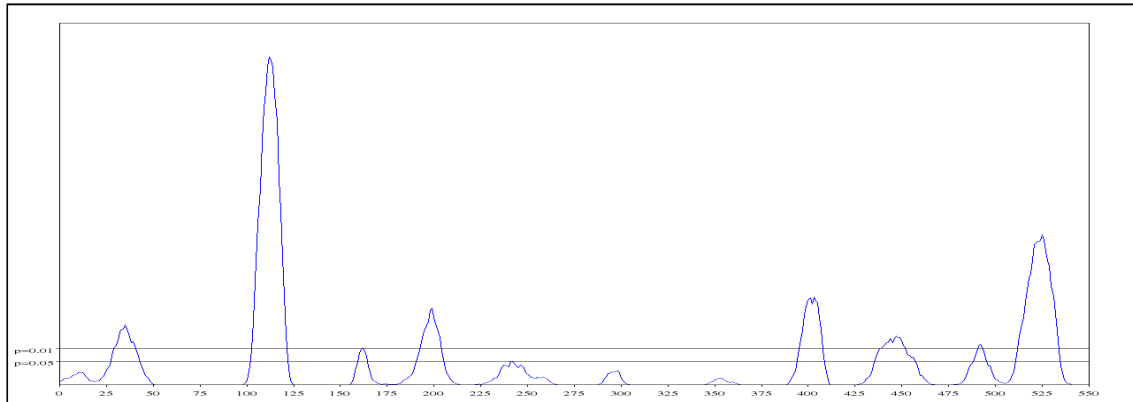


Figure 5.19: Time intervals with significant differences in activity when T2 was correct and incorrect. Neutral MIP, neutral T2 word stimuli, short T1-T2 SOA condition

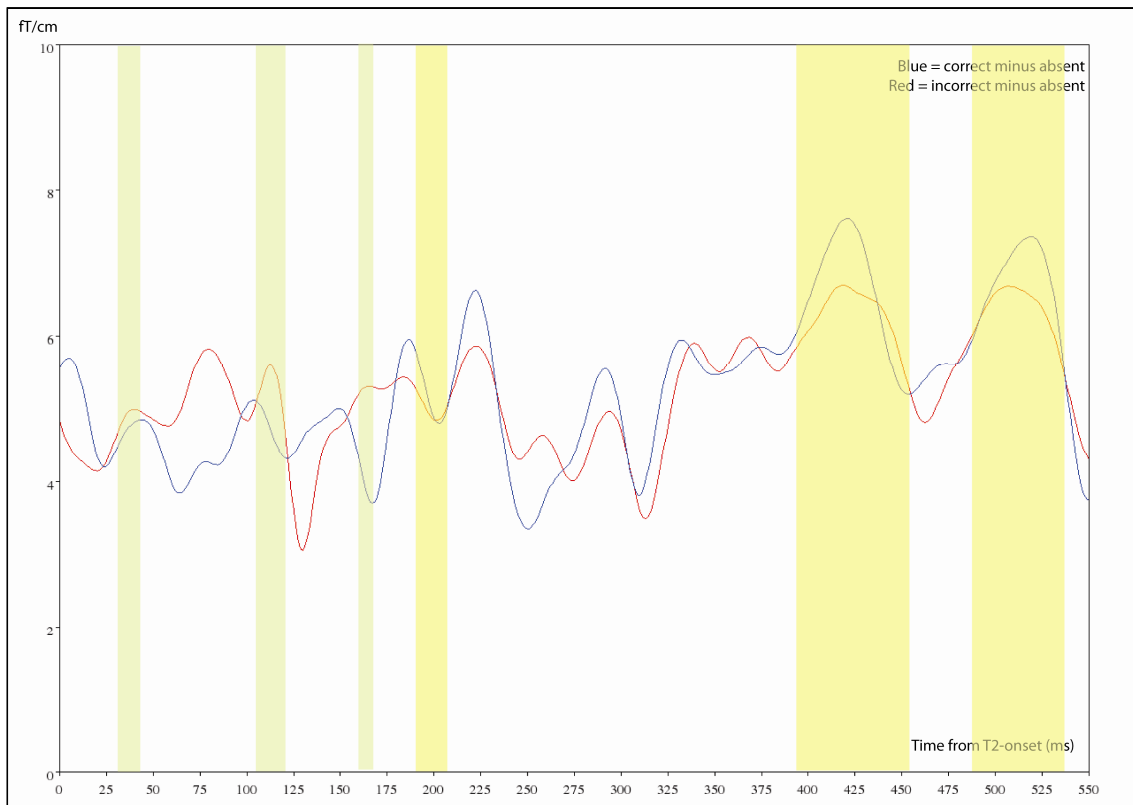


Figure 5.20: Grand-average power curves relative to T2-onset when participants subsequently made correct and incorrect T2 responses in the short T1-T2 SOA condition across all gradiometers. Neutral MIP, neutral T2 word stimuli

Coloured bars indicate time windows identified as demonstrating statistically significant differences between correct and incorrect T2 responses. Yellow bars indicate more activity for correct compared with incorrect responses (200ms, 400-450ms, and 480-525ms); green bars indicate more activity for incorrect compared with correct responses (30ms, 110ms, and 160ms).

Grand averages are for a subset of participants (N=13) with data available for the subtraction.

Time	Sign. level	C versus I amplitude	C versus I latency	Stats map	GM map C		GM map I	Compare maps
30ms	1%	C < I	No diffs	Frontal & R. temporal	Occipital	<	Occipital	X
110ms	1%	C < I	Earlier C v I	Central parietal	Occipital	<	None	X
160ms	Near 1%	C < I	No diffs	L. temporal	L & R temporal and occipital	>	Occipital	L.temporal Correct
200ms	1%	Start of C > I	No diffs	Central frontal	Mid parietal, occipital and L & R temporal	x	L occipital-temporal-parietal	X
400-450ms	1%	C > I	No diffs	Frontal and central parietal	Occipital-parietal-temporal	>	Occipital-parietal and R. temporal	X
480-525ms	1%	C > I	No diffs	L temporal-parietal, central and R. parietal & mid occipital	L. temporal and mid-right occipital	>	Right occipital	L. temporal & occipital Correct

Table 5.8: T2-related activity at the short T1-T2 SOA condition. Regions over which there are significant differences between correct (C) and incorrect (I) responses, and correspondence (Compare maps column) between activity in these regions and that identified in the statistical analysis (Stats map column)

Symbols (=, >, x) summarise the difference between grand-average power maps when T2 was correct minus absent compared with incorrect minus absent: = equivalent activity, > activity greater when correct versus incorrect, < activity greater when incorrect versus correct, x no correspondence and/or different regions.

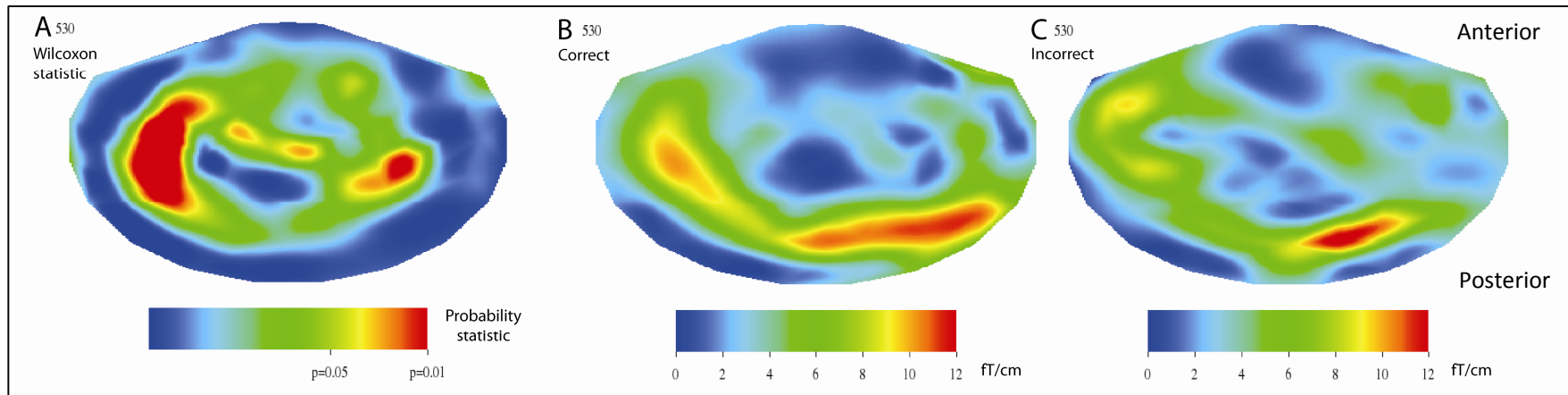


Figure 5.21: Spatial distribution of A) Statistical difference between T2-related activity for correct compared with incorrect responses; and grand-average power maps for T2-related activity when T2 was B) correctly and C) incorrectly identified at 530ms post-T2 onset. Neutral MIP, neutral T2 word stimuli, short T1-T2 SOA condition

Data presented are for a subset of participants (N=13) with data available for the subtraction.

Long SOA

Power curves showed greater and earlier amplitude up to 200ms post-T2 onset when participants subsequently made correct compared with incorrect responses. Only a very early effect at 25ms reached significance. In contrast, at later time points (260ms, 310ms, 400ms, and 530ms) there was significantly increased activity when participants made incorrect compared with correct responses. In the non-subtraction data only the effect at 310ms was replicated.

From here on analysis of the influence of emotional stimuli and mood state when participants made correct responses focuses on effects occurring at about 500ms post-T2 onset in the short SOA condition and up to 200ms post-T2 onset in the long SOA condition. Image analysis was carried out for correct responses only to be in keeping with statistical analysis of the behavioural data.

5.5.4.2 Influence of emotional stimuli ¹²

All analyses described in this section were carried out for the neutral MIP condition.

Short SOA

Wilcoxon analyses were conducted comparing ERFs to positive and negative T2 stimuli when participants made correct responses. There was a significant difference at 525ms. This difference was associated with activity over left temporal regions, and power maps showed activity here when participants made correct responses to negative not positive T2 words; see Figure 5.22. Grand-average power curves over left temporal regions demonstrated greater amplitude to negative compared with positive T2 word stimuli at this time. This pattern occurred in the individual power curves of twelve out of 13 participants. The effect was replicated in the non-subtraction data (N=21).

Long SOA

Wilcoxon analyses revealed no significant differences between ERFs to positive and negative T2 stimuli up to 200ms post-T2 onset when participants made correct responses.

¹² Behavioural data demonstrated that participants made more correct responses to negative compared with positive T2 word trials in the short SOA condition and vice versa in the long SOA condition.

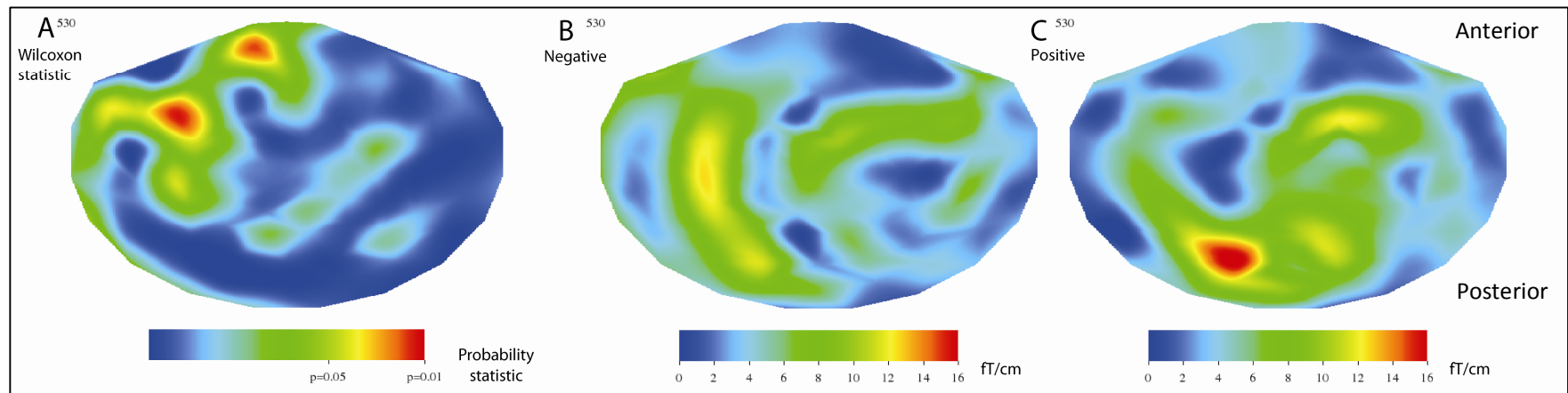


Figure 5.22: Spatial distribution of A) Statistical difference between T2-related activity when participants made correct responses to negative compared with positive T2 words; and grand-average power maps for T2-related activity when T2 was B) negative and C) positive at 530ms post-T2 onset. Neutral MIP, short T1-T2 SOA condition

Data presented are for a subset of participants (N=13) with data available for the subtraction.

5.5.4.3 Influence of mood state ¹³

Short SOA

A between-groups Mann-Witney U test compared ERFs for correct responses following sad and happy MIPs. Although not statistically significant according to the measure P, local statistical maps suggested a trend at 500-510ms post-T2 onset. Grand-average power curves demonstrated greater amplitude at 500-510ms post-T2 onset following the happy compared with sad MIPs. This difference corresponded to more activity over left occipital-temporal and right occipital regions following the happy compared with sad MIPs (see Figure 5.23). Similarly in the non-subtraction data there was greater amplitude at 500ms post-T2 onset following the happy (N=9) compared with sad (N=10) MIP.

¹³ Behavioural data demonstrated that participants made more correct responses at the short SOA following the happy MIP and at the long SOA following the sad MIP.

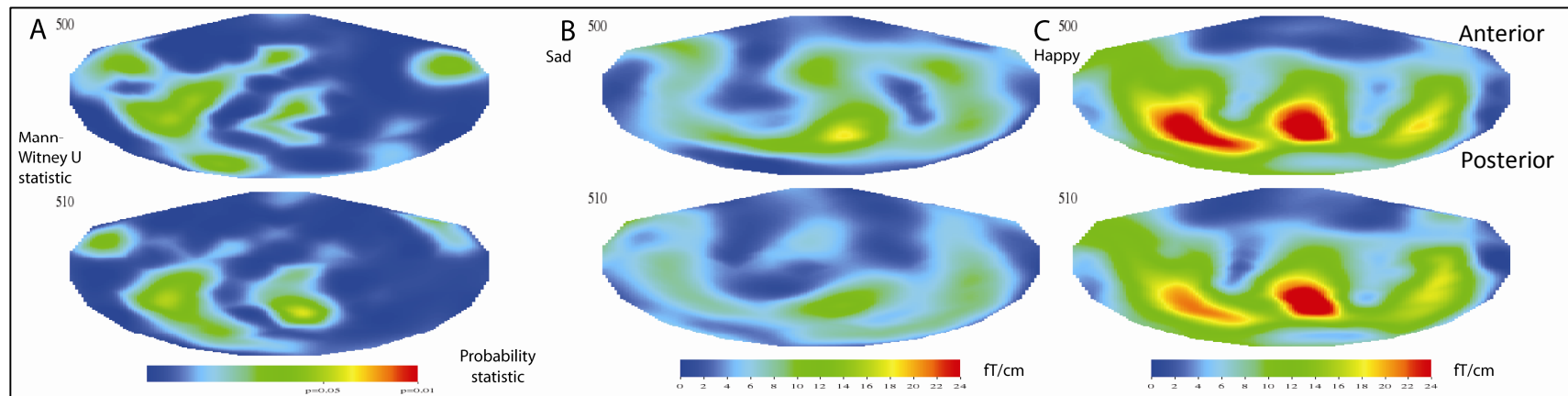


Figure 5.23: Spatial distribution of A) Non-significant statistical difference between T2-related activity when participants made correct responses following a sad compared with happy MIP; and grand-average power maps for T2-related activity following B) sad and C) happy MIPs from 500-510ms post-T2 onset. Neutral T2 word stimuli, short T1-T2 SOA condition

Data presented are for a subset of participants (N=7 sad MIP group, N=5 happy MIP group) with data available for the subtraction.

Long SOA

A between-group Mann-Witney U analysis demonstrated significantly greater amplitude at 200ms post-T2 onset following the sad compared with happy MIP. There was no correspondence between the statistics map (left frontal-parietal-occipital regions) and power maps for correct responses following the sad (right temporal) or happy (central occipital) MIP.

5.5.4.4 Interaction of emotional stimuli and mood state ¹⁴

Short SOA

Mann-Witney U tests were conducted to compare correct responses following the sad and happy MIPs on negative and positive T2 trials, separately. For positive T2 trials there was a significant effect at 490ms post-T2 onset, which was distributed over bilateral temporal-parietal, central parietal, and right frontal regions. Grand-average power curves showed increased amplitude following the happy compared with sad MIPs and the power maps showed that activity was distributed over bilateral temporal-parietal and central parietal regions (see Figure 5.24). For negative T2 trials there was no significant effect at about 500ms (i.e. the M300) but there was an earlier effect at 375ms with grand-average power curves showing increased amplitude following the sad compared with happy MIP. Significant activity over left temporal and central parietal regions was shown in the grand-average power maps following the sad MIP and significant activity over right temporal regions following the happy MIP.

Long SOA

Wilcoxon analyses were conducted to compare correct responses on negative and positive T2 trials for the sad and happy MIP groups separately. Following the happy MIP there was significantly greater amplitude at 200ms (grand-average power curve) when participants subsequently made

¹⁴ Behavioural data demonstrated that participants made more correct responses to mood-congruent stimuli in the short SOA condition and to mood-incongruent stimuli in the long SOA condition following the happy MIP. Following the sad MIP, participants made a similar percentage of correct responses to mood-congruent and mood-incongruent stimuli in the short SOA condition and fewer incorrect responses to mood-incongruent stimuli in the long SOA condition.

correct responses to negative compared with positive T2 stimuli. This significant difference in activity was distributed over left parietal and right occipital regions. Grand-average power maps showed correspondence of activity over the same region to negative but not positive words (see Figure 5.25). This pattern was demonstrated in four out of five participants. The same, although not-significant pattern, was shown in the non-subtraction data (N=9). Following the sad MIP there was greater amplitude at 200ms (grand-average power curve) when participants made correct responses to positive compared with negative T2 stimuli, but this effect did not reach significance. Similarly, this pattern was non-significant in the non-subtraction data (N=10).

A between-group Mann-Witney U test demonstrated significantly greater amplitude at 200ms to negative words following the happy MIP. This was associated with activity over right temporal and right occipital regions. On positive T2 trials, there was significantly greater amplitude at 230ms following the sad MIP which was associated with more activity over left parietal and left temporal regions. There were similar, although non-significant patterns in the non-subtraction data.

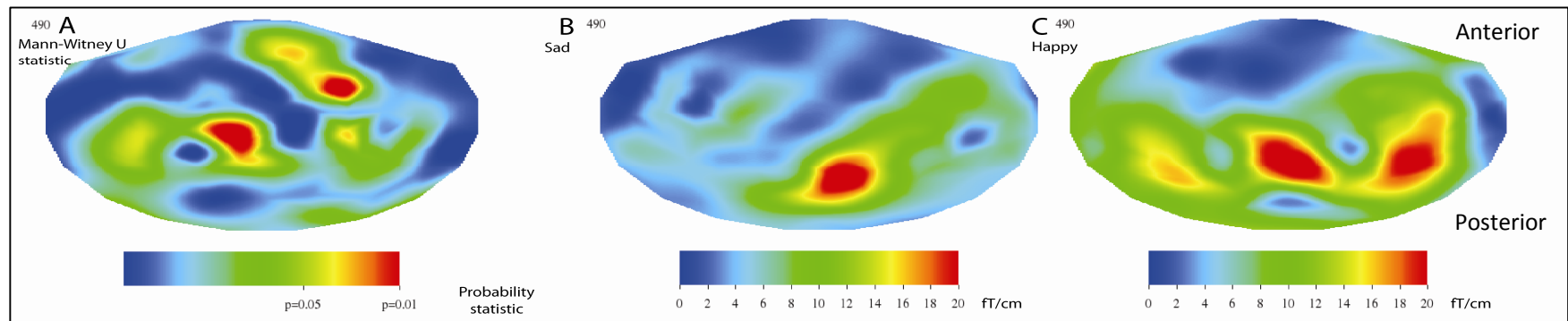


Figure 5.24: Spatial distribution of A) Statistical difference between T2-related activity when participants made correct responses following a sad compared with happy MIP; and grand-average power maps for T2-related activity following B) sad and C) happy MIPs at 490ms post-T2 onset. Positive T2 word stimuli, short T1-T2 SOA condition

Data presented are for a subset of participants (N=7 sad MIP group, N=5 happy MIP group) with data available for the subtraction.

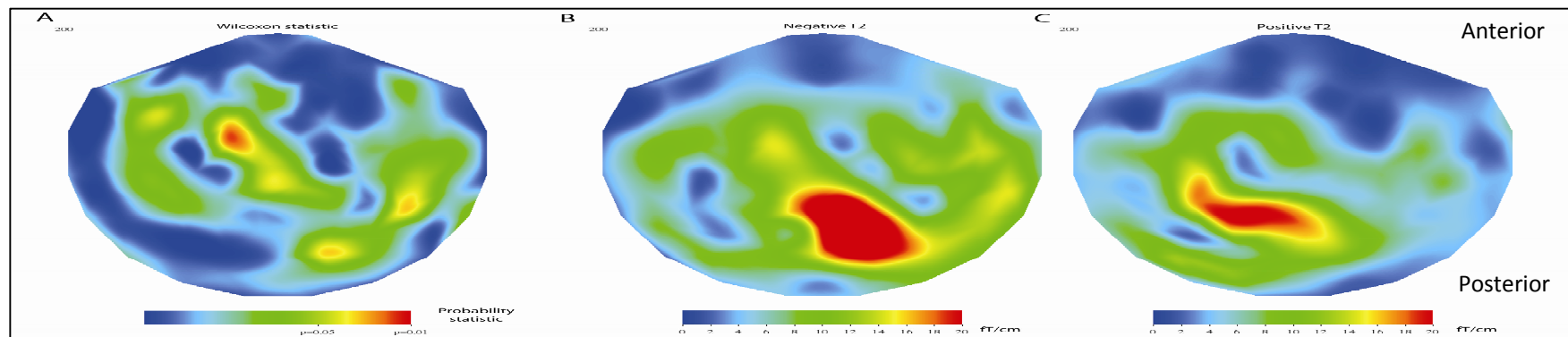


Figure 5.25: Spatial distribution of A) Statistical difference between T2-related activity when participants made correct responses to negative compared with positive T2 word stimuli; and grand-average power maps for T2-related activity when T2 was B) negative and C) positive at 200ms post-T2 onset. Happy MIP, long T1-T2 SOA condition

Data presented are for a subset of participants (N=5 happy MIP group) with data available for the subtraction.

5.5.4.5 Neuronal correlates of the attentional blink effect: T1- and T2-related activity

The primary aim of the image analysis was to explore the influence of emotional stimuli and mood state on the neuronal correlates of the AB effect. It is, however, also possible to investigate potential causes of the AB effect, and such a preliminary investigation is presented here.

Differences in T1-related activity when T2 was correct compared with incorrect were established using a Wilcoxon paired samples test, and grand-average power curves were calculated across all channels; see Figure 5.26. This analysis was carried out for neutral T2 trials in the short SOA condition following the neutral MIP.

There was significantly greater T1-related activity when participants subsequently made incorrect compared with correct T2 responses at 80ms and 490ms post-T1 onset. The pattern at 80ms was demonstrated in the individual power curves of nine out of 13 participants. Ten out of 13 participants demonstrated the effect at 490ms post-T1 onset. In the previous analyses, a potential T2-related M300 component in the short SOA condition was established as activity at about 500ms post-T2 onset. The effect at 490ms post-T1 onset may therefore reflect T1-related M300 activity.¹⁵

In the analysis of T2-related activity in the short SOA condition, there was significantly greater amplitude to incorrect compared with correct responses at 110ms post-T2 onset. This corresponds to 357ms post-T1 onset. There was a significant effect at 310ms post-T1 onset demonstrating an earlier peak when participants subsequently made correct (310ms) compared with incorrect (360ms) T2 responses. All but one participant (N=12) demonstrated this effect.

The regions identified as statistically significant in the Wilcoxon analysis were compared with the grand-average power maps. Results are summarised in Table 5.9 and presented in Figure 5.27 and Figure 5.28.

¹⁵ It was not possible to extract T1-related ERFs independent of ERFs to T2 and the stream of distractors (i.e. the method used to extract T2-related ERFs), as there was no T1 absent condition to calculate such a subtraction.

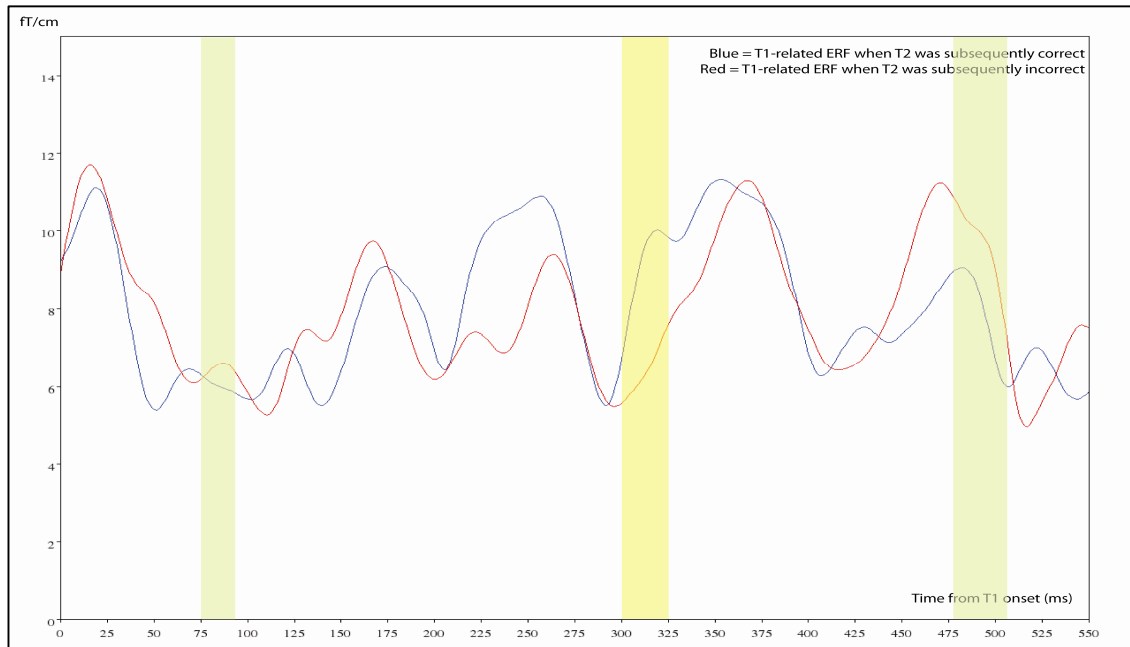


Figure 5.26: Grand-average power curves relative to T1-onset when participants subsequently made correct and incorrect T2 responses in the short T1-T2 SOA condition across all gradiometers.

Neutral MIP, neutral T2 word stimuli

Coloured bars indicate time windows identified as demonstrating statistically significant differences between correct and incorrect T2 responses. Yellow bars indicate more activity for correct compared with incorrect responses (310ms); green bars indicate more activity for incorrect compared with correct responses (80ms and 490ms).

Grand averages are for a subset of participants in the previously reported subtraction analysis of T2-related activity (N=13).

Time post-T1 onset	Time post-T2 onset	Probability statistic	Correct minus absent		Incorrect minus absent	Compare maps
70-90ms	-167ms	Left frontal and left temporal	Bilateral temporal and occipital	=	Bilateral temporal and occipital	Left temporal Correct
310ms	63ms	Parietal	Occipital-parietal	>	Some occipital	Some parietal Correct
490ms	243ms	Parietal and temporal	Occipital	<	Occipital and right temporal	Right temporal Incorrect

Table 5.9: T1-related activity. Regions over which there are significant differences when participants subsequently made correct and incorrect responses to T2 (probability statistic column), and activity associated with these responses (grand-average power maps for correct|incorrect minus absent columns)

Symbols (=, >, x) summarise the difference between grand-average (GM) power maps to T1 when T2 was correct minus absent compared with incorrect minus absent: = equivalent activity, > activity greater when correct versus incorrect, x no correspondence and/or different regions.

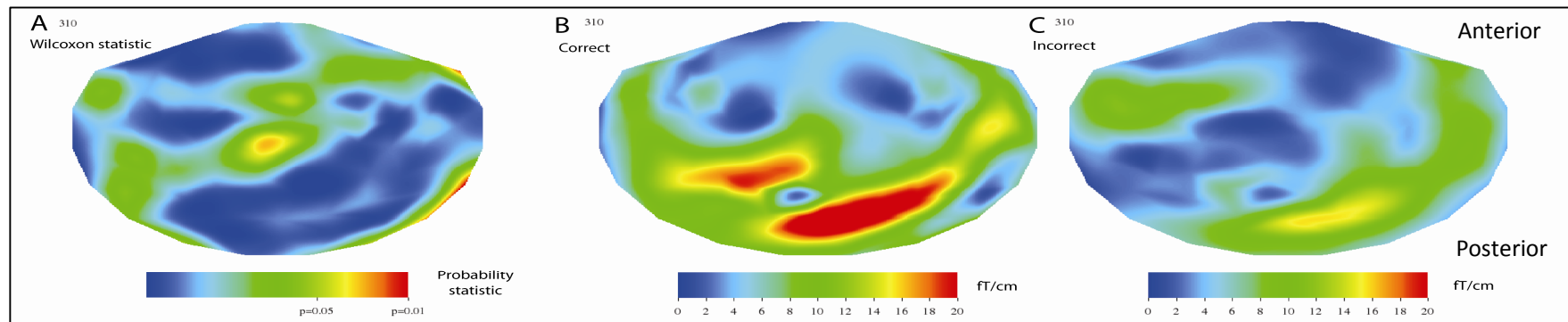


Figure 5.27: Spatial distribution of A) Statistical difference between T1-related activity when participants subsequently made correct and incorrect T2 responses; and grand-average power maps for T1-related activity when T2 was subsequently B) correctly and C) incorrectly identified at 310ms post-T1 onset. Neutral MIP, neutral T2 word stimuli, short T1-T2 SOA condition

Data presented are for a subset of participants in the previously reported subtraction analysis of T2-related activity (N=13).

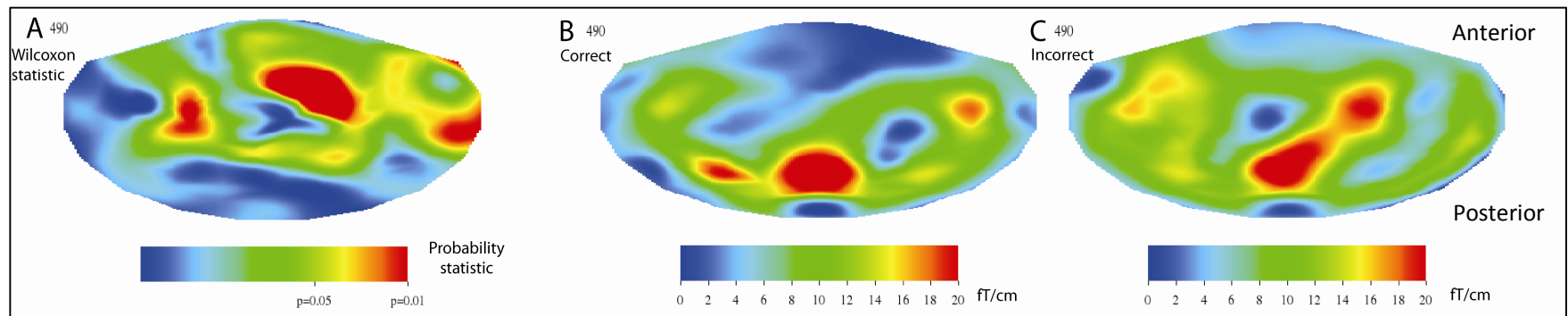


Figure 5.28: Spatial distribution of A) Statistical difference between T1-related activity when participants subsequently made correct and incorrect T2 responses; and grand-average power maps for T1-related activity when T2 was subsequently B) correctly and C) incorrectly identified at 490ms post-T1 onset. Neutral MIP, neutral T2 word stimuli, short T1-T2 SOA condition

Data presented are for a subset of participants in the previously reported subtraction analysis of T2-related activity (N=13).

5.6 Discussion

5.6.1 Mood data

Sad and happy MIPs changed mood in the expected direction. There were no between-group differences in mood state following the neutral MIP. Following the sad compared with neutral MIP, participants reported being significantly more negative both post-MIP and post-task. In contrast, participants only showed a trend towards being more positive following the happy compared with neutral MIP. This result may have occurred because four participants became negative following the happy MIP. Further, participants in the happy but not sad group reported being significantly more negative following the task across both neutral and valenced MIPs. This result may reflect mood state change over time (i.e. reduced effectiveness of the happy MIP) due to task difficulty or the (isolated) nature of the scanning environment.¹⁶ In addition differences in the effectiveness of the sad and happy MIPs may have been due to a technical programming error. The music for the happy MIP only lasted for the duration of the piece of music (6 minutes, 1 second) and did not loop to last for the duration of the presentation of self-referential statements (8 minutes, 20 seconds). Mood state data were analysed for a subsequent experiment that is not reported in this thesis but which followed the same experimental set-up (i.e. induced mood followed by a cognitive task performed in the MEG scanner) but with the error corrected. Data from that experiment showed a significant difference in self-reported mood state following the happy compared with neutral

¹⁶ Participants did, however, report a more positive and negative mood state following the happy and sad MIPs, respectively. It was important that this comparison reached significance for the subsequent behavioural and MEG data analyses in which between group differences of the influence of T2 negative and positive word stimuli on the AB effect were compared.

In addition, that there was no difference between mood state ratings following the neutral MIP for participants in the sad and happy groups was important for the subsequent behavioural and MEG data analyses of the AB effect, and in which the influence of T2 negative and positive word stimuli on the AB effect, following a neutral MIP, were compared.

That there was only a trend towards a difference in mood state following the neutral and happy MIPs but there was a significant difference in mood state following the neutral and sad MIPs was not, therefore, important for some of the subsequent behavioural and MEG data comparisons.

MIPs, whereas only a trend towards significance was shown in the current experiment, thus suggesting that the duration of music may have influenced these results.

A regression analysis demonstrated that participants with increased levels of current depressive symptoms reported greater changes in positive affect following a happy MIP. To date very few studies have considered predictors of response to MIPs and those that have focussed on negative not positive MIPs (Blackburn, Cameron, & Deary, 1990; McHugh & Wierzbicki, 1998; Rexford & Wierzbicki, 1989; Scherrer & Dobson, 2009). Accordingly it is difficult to relate this finding to the previous literature. Although not significant, participants with decreased levels of current depressive symptoms reported greater changes in negative mood following a sad MIP. This pattern of results is in keeping with the results from the meta-regression analysis (see Chapter 2: Sad Mood Induction: A Systematic Review) but different from those presented in Chapter 3: Inductive Reasoning, and will therefore be addressed in Chapter 6: General Discussion and Future Directions.

5.6.2 Behavioural data

Analysis of the behavioural data confirmed the presence of the AB effect. Specifically, participants made more correct responses in the short than long T1-T2 SOA condition.

5.6.2.1 Emotional stimuli and the attentional blink

This study aimed to explore the prioritization of emotional stimuli, following the neutral MIP, under conditions requiring selective attention due to limited availability of processing resources (i.e. short compared with long SOA). Results supported attenuation of the AB effect by emotional compared with neutral T2 stimuli (Anderson, 2005; Keil & Ihssen, 2004; Keil, et al., 2006), and further attenuation by negative compared with positive T2 stimuli (Kihara & Osaka, 2008; Ogawa & Suzuki, 2004). Analysis of the RSVP word stimuli included in the Affective Norms for English Words (ANEW) database (Bradley & Lang, 2010) showed that the T2 negative and positive word stimuli varied only for valence not arousal ratings. These results

suggest that emotion words do overcome the AB effect. However, this effect was greater for negatively valenced words and therefore supports the notion that the valence rather than arousal value of stimuli is associated with attenuation of the AB effect (Kihara, Kawahara, & Takeda, 2008; Ogawa & Suzuki, 2004). Prioritization of processing negative stimuli is in keeping with the idea of a negativity bias (for a review see Baumeister, Bratslavsky, Finkenauer, & Vohs, 2001).

In conclusion, there is clear evidence for AB sparing for emotional compared with neutral T2 word stimuli but a greater effect for negative compared with positive words.

5.6.2.2 Mood state and the attentional blink

Another aim of this study was to explore the influence of induced mood state on attentional processing.

The largest AB effect was observed following the sad MIP, replicating previously reported findings (MacLean & Arnell, 2010; MacLean, et al., 2010; Rokke, et al., 2002; Vermeulen, 2010). Following the sad compared with happy MIP, participants made fewer correct responses in the short SOA condition and slightly more correct responses in the long SOA condition. It has been hypothesised that negative affect increases focussed attention (MacLean, et al., 2010). Specifically, when fewer resources are available (i.e. in the short SOA condition) and participants engage in more systematic and elaborative information processing (Blanchette & Richards, 2010), distractor (and target: T1) stimuli interfere with the processing of target stimuli (specifically T2). In contrast, when more resources are available (i.e. in the long SOA condition) this type of processing facilitates target identification.

The smallest AB effect was observed following the happy MIP, with more correct responses in the short SOA condition and marginally fewer in the long SOA condition compared with the sad MIP. This result is in accordance with the positive-affect hypothesis (C. N. L. Olivers & Nieuwenhuis, 2006) stating that positive affect increases cognitive flexibility, which in turn

results in a diffuse attentional state. In this state, attention is taken away from the RSVP task and results in reduced interference of distractors on the processing of T1 and T2, to the advantage of successful target processing. This may facilitate performance under conditions of limited processing resources (i.e. short SOA).

5.6.2.3 The interaction of mood state and emotional stimuli on the attentional blink

Overall, the magnitude of the AB effect was smallest when the emotional valence of the T2 word stimulus was congruent with mood state. These effects are interpreted according to the percentage of correct and incorrect responses within (i.e. short SOA condition) and outside (i.e. long SOA condition) the AB window.

Following the happy MIP participants made more correct (and fewer incorrect) responses to mood-congruent positive T2 words in the short SOA condition. This result is in line with the mood-congruent hypotheses (Bower, 1981). In contrast, participants made more correct (and fewer incorrect) responses on mood-incongruent negative T2 trials in the long SOA condition. Very few studies have explored the influence of positive mood states on cognitive processing therefore the findings of the current study do not necessarily relate to those of previously published research. In the context of the literature of the negativity bias (for a review see Baumeister, et al., 2001), the prioritized detection of negative compared with positive information may occur because this detection can prevent negative outcomes, within a relevant time frame (i.e. long SOA condition), that might have greater consequences than those for positive stimuli.

Following the sad MIP, participants made a similar amount of correct (and incorrect) responses to mood-congruent negative and mood-incongruent positive T2 words in the short SOA condition, and made only slightly more correct responses to negative than positive T2 words in the long SOA condition. Although mood-congruent processing was hypothesised following the sad MIP (for example Bower, 1981), such effects may be specific to “*extreme cases of clinical*

mood disorders" (pp. 173; Forgas, 2000). The most obvious difference between negative and positive T2 word trials was that participants made fewer incorrect responses to mood-incongruent positive T2 words in the long SOA condition. Mood-incongruent processing during induced mood states may occur through methods of mood regulation (Forgas, 2000) as these mood states are prone to decay and reversal. Indeed, Teasdale (1988) argued that depressed and non-depressed individuals differ in the degree to which they are motivated to repair their mood state. Specifically those experiencing a high intensity of depressive symptoms may see them as "*beyond the perceived range of efficacy of normal mood repair*" (pp. 254; Teasdale, 1988).

In addition to the arguments presented above, there are various methodological considerations that might impact the absence of the predicted mood-congruent effects following the sad MIP. First, attenuation of the AB effect may be elicited by disorder-specific rather than general negative stimuli (as in Trippe, et al., 2007). Indeed participants with a high negative cognitive style identified significantly more T2 negative self-referent than negative non-self-referent or neutral T2 words (Romens, et al., 2011). Second, it has been argued that cognitive biases in depression occur when there is elaboration of the stimulus (cf. Williams, Watts, MacLeod, & Mathews, 1997). Such elaboration is facilitated in the long SOA condition and may therefore explain why neither mood-congruent nor incongruent stimuli attenuate the AB effect in the short SOA condition. Finally, to elicit mood (in-)congruent processing under conditions of limited attentional resources might require a particular severity of negative mood state that may not be achieved using MIPs in healthy volunteers. For a discussion of the use of MIPs as a model of mood disorders see Chapter 6: General Discussion and Future Directions.

5.6.2.4 Considerations

It is noticeable that the percentage of correct responses in the short SOA condition is consistently below 50%. This does not mean that participants made more incorrect than correct responses because the summation of correct and incorrect responses is not necessarily 100%. Although this was a two-alternative forced choice task, the response screen was time limited (1,500ms). Therefore if participants did not make a response within the allocated time this would not contribute to either the correct or incorrect categories. Means show that participants made more correct than incorrect responses in the short and long SOA conditions. Furthermore the AB effect is defined as a bimodal distribution of conscious reports of target stimuli, i.e. 50% accurate T2 report. Accordingly, some researchers conduct behavioural experiments prior to imaging experiments to determine the SOA required to elicit 50% accurate T2 report in participants (Marois, et al., 2004).

Traditionally, participants have been asked to detect/identify T1 and then T2, which follows the order of stimulus presentation. However, in accordance with results obtained from the behavioural pilot data, participants were asked to identify T2 and then T1 in the experiment presented in this thesis. Other studies using the RSVP paradigm have asked participants to identify T2 and then T1 (Fox, Russo, & Georgiou, 2005). Fox and colleagues found that when asked to identify T1 first participants immediately began preparing their responses and consequently almost all T2 responses were missed (personal correspondence). Whereas when asked to respond to T2 first, it was assumed that holding T1 in memory was not as difficult as preparing a response thus T2 accuracy increased (personal correspondence). Despite the ordering of questions as identify T2 then T1, participants made a comparable percentage of correct T1 responses (70-80%) as reported by researchers using the traditional ordering of questions (for example, Trippe, et al., 2007). Finally, although the order of questions was reversed, the order of stimulus presentation and presumably therefore processing was retained as T1 then T2. Recent research has demonstrated that it is only when T2 immediately

follows T1 (leading to lag-1 sparing) that the order of processing may be reversed i.e. T2 before T1 (C. N. Olivers, Hilkenmeier, & Scharlau, 2011).

5.6.3 Imaging data

5.6.3.1 The attentional blink effect: ERFs

To enable an analysis most consistent with the previous literature, both T1- and T2-related activity were explored for participants following a neutral MIP in neutral T2 word trials.

Short SOA condition

There was a complex pattern of T2-related activity associated with divergence of waveforms when participants subsequently made correct compared with incorrect T2 responses.

An early difference at 110ms post-T2 onset corresponds to a significantly earlier T1-related peak amplitude when participants subsequently made correct (310ms post-T1) compared with incorrect (360ms post-T1) responses and is therefore a potential candidate ERF for future research exploring the cause of the AB effect (as in Shapiro, et al., 2006). Differences in activity at 160ms post-T2 onset may reflect the N100 component that is elicited to stimuli presented at an attended location (Hillyard & Anllo-Vento, 1998). Although previous EEG studies report no differences in the T2-related P100 and N100 components (Vogel & Luck, 2002; Vogel, et al., 1998), these ERPs were not averaged according to participant response rather a condition known to elicit the AB effect (dual task, short SOA). A more recent EEG study, where ERPs were averaged by participant response, reported that divergence of waveforms occurred earlier than the P300/M300; specifically at 270ms post-T2 onset reflecting the N200 component (Sergent, et al., 2005). The MEG data presented here demonstrate a non-significant difference in activity at 240ms post-T2 onset. These effects at 160ms and 240ms post-T2 onset provide support for divergence of waveforms earlier than the P300/M300.

With regard to the M300, there was a divergence of ERF waveforms at about 500ms post-T2 onset when participants made correct and incorrect responses. This is within the classic T2-related P300 time window (for example, Sergent, et al., 2005) and is believed to reflect the updating and storage of information in working memory (Donchin, 1981; Karis, et al., 1984). This difference was associated with activity over left temporal and central-right occipital regions. The canonical P300 has a spatial distribution over temporal regions (Polich, 2007). An fMRI study reported activity to seen stimuli in the anterior temporal cortex (Marois, et al., 2004). It has been suggested that the left hemisphere is more specialized for temporal processing (Nicholls, 1996). Researchers have demonstrated a larger AB effect for stimuli presented in the right visual field, hence processed by the left hemisphere (Hollander, Corballis, & Hamm, 2005). A patient with a complete section of the corpus callosum demonstrated above chance performance when T2 was presented in the left visual field and processed by the left hemisphere compared with chance performance when T2 was presented in the right visual field and processed by the right hemisphere (Ptito, Brisson, Dell'Acqua, Lassonde, & Jolicoeur, 2009). Further support for the specialization of the left hemisphere in visual temporal processing comes from a study which found that repetitive transcranial magnetic stimulation (rTMS) to the left hemisphere resulted in reduced accuracy for T2 stimuli presented in the right visual field compared with sham TMS (Verleger et al., 2010). Whereas there was no difference in performance following rTMS compared with sham for T2 presented in the left visual field and processed by the right hemisphere. The researchers suggested that left parietal rTMS further compromised the reduced capacity of the left hemisphere resulting in a larger AB effect, which is consistent with two-stage, bottleneck accounts of the AB effect (for example Chun & Potter, 1995).

Long SOA condition

Unlike the short condition, there was earlier and larger amplitude up to 200ms post-T2 onset when participants subsequently made correct responses. Although not significant, larger peaks

at 80ms and 115ms may correspond to the P100 component that is elicited and larger to stimuli presented at an attended location and is therefore typically associated with visual *spatial* attention (Hillyard & Anllo-Vento, 1998). Divergence of the waveforms at 160ms and 185ms occur slightly earlier than that reported in an EEG study (Kranczioch, et al., 2003). This EEG study demonstrated enhanced P200 amplitude (at 210ms) when participants made correct responses, which occurred in the long SOA condition only.

When participants made incorrect compared with correct responses there was significantly greater activity at 260ms, 310ms, 400ms, and 530ms post-T2 onset. The decision screen appeared 165ms post-T2 onset therefore these effects may reflect an error related negativity (ERN), which peaks at about 100ms after a participant has made an incorrect response (Yeung, Botvinick, & Cohen, 2004).

Comparing short and long SOA conditions

When more attentional processing resources were available: i.e. in the long SOA condition, there was perceptual (up to 200ms) but not attentional (M300) processing of T2 stimuli that were subsequently correctly identified. In contrast, when fewer attentional resources were available: i.e. in the short SOA condition, there was preferential attentional (M300) processing. That M300 suppression was not observed in the long SOA condition both supports (Sessa, et al., 2007; Vogel, et al., 1998) and refutes (Kranczioch, et al., 2003) the results of previously published EEG studies.

After establishing the neuronal correlates of the AB effect (i.e. M300), modulation of this component by T2 emotional stimuli and mood states was examined.

5.6.3.2 Emotional stimuli and the M300

The influence of the emotional salience of T2 on correct responses was specific to the short SOA condition. There were significantly larger M300 amplitudes when participants made correct responses to negative compared with positive T2 word stimuli (similar results have

been reported for T2 picture stimuli; Trippe, et al., 2007). This supports the conclusion of Kissler et al. (2006) that modulations during later (>300ms) stages of word processing are valence specific.

The larger M300 to negative compared with positive stimuli was associated with activity over the left temporal lobe. An fMRI study using a RSVP paradigm demonstrated increased activity in the left amygdala when participants made correct responses to emotional T2 stimuli in the short SOA condition (Schwabe, et al., 2011). In addition, one of the earliest studies exploring the influence of emotion on the AB effect showed that patients with left not right anteromedial temporal lobectomy including removal of the amygdala no longer showed enhanced perception for negative word stimuli (Anderson & Phelps, 2001). The MEG data presented here was not analysed in source space therefore effects cannot be localised to the amygdala, for example. However, the results of the current study and the lesion study demonstrate the association between the left temporal lobe and enhanced attention to negative word stimuli.

5.6.3.3 Mood state and the M300

In the short SOA condition, there was a trend towards greater M300 amplitude for correct responses following a happy compared with sad MIP. This was associated with more activity over left occipital-temporal and right occipital regions, which corresponds to those regions identified in the analysis of the AB effect (i.e. neutral MIP, neutralT2, short SOA condition). This activity may therefore reflect enhanced updating and storage of information in working memory during conditions of limited attentional resources (i.e. the short SOA condition).

In the long SOA condition, there was significantly more activity at about 200ms when participants made correct responses following the sad compared with happy MIP. A previous EEG study noted an 'initial gain' for seen compared with unseen T2 stimuli up to 300ms post-stimulus onset (Sergent, et al., 2005). Although specific to the short SOA condition in the EEG

study, this may underlie participants' slightly better performance following the sad MIP in the long SOA condition of the current MEG study.

5.6.3.4 The interaction of mood state and emotional stimuli: ERFs

Behaviourally, participants made more correct responses (happy MIP) and fewer incorrect responses (sad MIP) to mood-incongruent stimuli in the long SOA condition. Analysis of MEG data in the long SOA condition demonstrated consistent effects of greater amplitudes to mood-incongruent stimuli at about 200ms post-T2 onset in both the within- and between-group comparisons. This increased amplitude to mood-incongruent T2 word stimuli may reflect an increased N200, occurring at about 180ms post-stimulus onset, evoked in response to a deviation in the context of a stimulus (Patel & Azzam, 2005). At this stage, it is not clear whether this may overlap with the early parts of the M400 complex. It has been argued that mood states are associated with expectancies and that violations of these expectancies (i.e. incongruence) elicit differences in the ERP-related N400 (Chung, et al., 1996).

In the short SOA condition, participants made more correct responses in mood-congruent positive than mood-incongruent negative T2 word trials following the happy MIP. The MEG data showed enhanced M300 to positive words associated with activity over bilateral temporal-parietal and central parietal regions following the happy MIP. The mood-congruent effect for enhanced activity to negative words following the sad MIP did not occur at the time of the M300 component rather earlier at 375ms post-T2 onset. Behaviourally, participants made roughly the same amount of correct responses in mood-congruent negative and mood-incongruent positive T2 word trials.

5.6.4 Implications for theories and models of attention and of the attentional blink effect

The behavioural pilot data showed an increased AB effect with increasing similarity between the targets and distractors which supports the predictions of two-stage models (Chun &

Potter, 1995; C. N. L. Olivers & Meeter, 2008). Further support for one of these two-stage models, the boost and bounce theory (C. N. L. Olivers & Meeter, 2008), comes from behavioural data demonstrating the influence of induced mood on the AB effect. This theory predicts enhancement of processing (a sensory 'boost') when a stimulus is deemed task-relevant (i.e. T1). However there is also a boost of the post-T1 item due to their temporal proximity, and due to a temporal delay of the boost, the post-T1 item receives a larger boost than T1. To prevent the post-T1 distractor item entering the working memory store, there is transient inhibition (or 'bounce') such that all stimuli subsequently presented to the input filter are bounced (i.e. T2). In relation to the behavioural data presented in this thesis, there may be a larger AB effect following a sad compared with happy MIP because individuals in a sad mood state exhibit more systematic and elaborative information processing (Blanchette & Richards, 2010). It follows that elaborative processing may reflect enhanced processing (or boost) of T1 and therefore the post-T1 item, and consequently inhibition (or bounce) of processing subsequent (T2) stimuli. The theory also predicts that the inhibition is transient and performance improves with an increased T1-T2 interval. This can explain the smaller difference in the percentage of correct and incorrect responses at the short condition only following the sad MIP. Furthermore, there was no influence of mood state on T1 accuracy which is in keeping with results from a previous study (Vermeulen, 2010). Those researchers suggested this supported a selection deficit (i.e. boost and bounce theory; C. N. L. Olivers & Meeter, 2008) rather than capacity limited (i.e. two-stage model; Chun & Potter, 1995) model of attentional processing. The rationale behind this argument was that if affect influenced attentional capacity (i.e. positive affect increased and negative affect decreased), then both T1 and T2 accuracy should be altered. Whereas if affect influenced selection, in this case the inhibition of distractors, then only T2 accuracy would be altered. Finally, T2 emotional stimuli led to improved T2 accuracy but did not impair T1 accuracy. Similar results have led researchers (C. N. L. Olivers & Nieuwenhuis, 2005) to suggest that such improvements in

performance are not therefore attributable to fewer resources allocated to T1 processing, as would be suggested by the capacity-limited theories of the AB effect (Shapiro, et al., 1994; Shapiro, et al., 2006). Instead alternative hypotheses were proposed (C. N. L. Olivers & Nieuwenhuis, 2006).

The boost and bounce theory does not assume that the AB effect reflects capacity limitations. In contrast to this, analysis of T1-related ERFs showed a significantly smaller T1-related M300 peak amplitude when participants subsequently made correct compared with incorrect responses to T2. This result is in line with predictions of the resource sharing hypothesis (Shapiro, et al., 2006) and a previous study demonstrating that the AB effect was caused by T1-related processing demands (Marois, et al., 2000). Similarly, the temporary loss of control model attributes the AB effect to the processing of T1 (Di Lollo, et al., 2005). The reduced AB effect to emotional stimuli provides support for this model. The model predicts a top-down, endogenous control mechanism dedicated to detection of T1 in the first instance and T2 in the second. The mechanism is configured to suppress or ignore distractors and prioritize detection of T1. Once T1 is detected the mechanism becomes dedicated to the processing of T1 at the expense of ignoring distractors, and bottom-up (i.e. stimulus-based) exogenous control ensues. In accordance with this prediction therefore, a reduced AB effect to emotional stimuli occurs because these stimuli are more likely than neutral stimuli to capture attention in a bottom-up manner. Also in line with this model is the occurrence of mood-incongruent processing in the long SOA. The model predicts that the deficit in detecting T2 remains until T1 has been fully processed at which stage the top-down, endogenous mechanism regains control. As discussed previously, mood-incongruent processing may occur because of a negativity bias following a happy MIP and mood regulation following a sad MIP. Consequently, the endogenous control mechanism that is present in the long SOA condition may be configured towards the negativity bias/mood regulation in happy/sad mood states.

In summary, the results of this thesis provide support for multiple models, and these models largely share the assumption that the AB effect reflects capacity limitations. However, the influence of mood state on T2- but not T1-related processing supports a theory that does not assume such capacity limitations. Accordingly, this discussion highlights the continuing lack of consensus between researchers regarding the theoretical basis of the AB effect. The MEG data presented in this thesis provide neuronal markers of behavioural effects; consequently theorists should aim to extend models of the AB effect to account for the results of studies using neuroimaging techniques.

5.6.5 Methodological considerations

Researchers have developed novel ways of using fMRI to explore the neuronal correlates of the AB effect. However, fMRI is limited by its poor temporal resolution, therefore there may be problems dissociating activity to T1 and T2 stimuli. Despite the greater temporal resolution afforded by EEG, early investigations using this technique failed to average ERPs according to behavioural response. This meant that conclusions were limited to discussion of ‘conditions under which the AB effect occurred’, rather than the AB effect per se. The use of MEG in the current study and averaging ERFs according to behavioural responses enabled an investigation of the AB effect with the appropriate temporal resolution. Furthermore, inclusion of a T2 absent condition allowed dissociation of ERFs to T2 stimuli from ERFs to T1 and the stream of distractors (as in Sergent, et al., 2005). Alternatively one could employ a method used previously to enable extraction of the P300 component (Vogel, et al., 1998). Specifically, there were frequent and infrequent targets, the latter of which are known to elicit a larger P300 (Sutton, Braren, Zubin, & John, 1965). Therefore the target-related P300 was isolated by subtracting the ERF waveforms of the frequent from the infrequent targets.

5.6.5.1 Improvements

To equate task difficulty and therefore performance across participants, detection thresholds for each participant could be measured prior to the MEG scan using a staircase procedure.¹⁷ In addition, a staircase procedure could be used to provide a more fine grained analysis of the temporal limit of attentional processing and the point at which emotional stimuli and mood state impact upon this limit. Another way to explore this temporal limit without using a staircase procedure would be to include multiple T1-T2 SOAs both within (i.e. <500ms) and outside of the AB time window.

The influence of mood state and emotional stimuli on attentional processing as well as implicit memory could be explored by including a surprise memory test at the end of the experimental procedures. This would enable an exploration of the cause, for example capacity limited attentional processing resources, on mood-related impairments and/or improvements (mood-congruent biases) in the recall of neutral and emotional (positive and negative) stimuli. Similar methods have been used in a previous study (Mathewson, et al., 2008). Here correlation and regression analyses showed that both increased arousal ratings of stimuli and increased recognition memory were associated with decreased T2 accuracy for taboo words.

To further explore the prioritization of emotional stimuli under conditions of limited availability of processing resources, the paradigm could have included a cross-over design with both T1 and T2 being neutral and emotional stimuli. Such a sophisticated experimental design has been used previously (Kihara & Osaka, 2008). This enables an exploration of exaggeration of AB effect with an emotional T1 (i.e. disengagement), attenuation with an emotional T2 (i.e.

¹⁷ The staircase procedure is a method used in psychophysiological experiments to determine a participant's threshold of visual detection and discrimination. In this case, trials would begin with a long T1-T2 SOA (outside of the conventional AB time window i.e. >500ms) and this SOA would continue to decrease in incremental steps until the participant made an incorrect T2 response (but always making a correct T1 response). Once an incorrect T2 response had been made the SOA would increase incrementally until a correct T2 response was made, at which point the SOA would reverse to decreasing incrementally again. After multiple reversals, the SOA would be averaged and taken as the point of visual detection and discrimination, and as such would index the bimodal distribution of conscious reports of target stimuli (T2) for that participant.

engagement), and alteration of this attenuation when both T1 and T2 are emotional (i.e. shifting). Such distinctions between different types of attention orienting including attention shifting, engagement, and disengagement have been suggested previously (Posner & Petersen, 1990).

5.7 Conclusions and future directions

RSVP paradigms have not been widely used to investigate mood and emotion-related attentional processing. Consequently, this study is one of few, if not the first to use the RSVP paradigm to investigate the behavioural and neuronal correlates of attentional processing to emotional stimuli during transient induced mood states.

Behavioural and MEG data provide support for the well-established effect of reduced M300 amplitude associated with the AB phenomenon. Furthermore there is evidence to suggest that this effect is specific to the short not long SOA condition and thus adds to the literature debating the specificity of the P300/M300 to the AB time window. With regard to the potential cause of the AB effect, preliminary results support those researchers advocating the importance of the T1-related M300 with larger amplitudes associated with incorrect T2 responses. Although it was not a primary aim of this study, to further investigate the cause of the AB effect a trial-by-trial analysis could be conducted of the relationship between T1- and T2-related M300 amplitude variations.

The AB effect was modulated by the emotional salience of stimuli and mood state. Following a neutral MIP, the smallest AB effect and largest M300 amplitude (in short SOA condition) occurred when participants made correct responses on negative T2 word trials. The AB effect was smallest following a happy compared with sad MIP, which was concomitant with (non-significantly) increased M300 amplitude in the short SOA condition. In the short SOA condition

participants made more correct responses to mood-congruent positive words following the happy MIP, which was associated with enhanced M300.

Participants made slightly more correct responses in the long SOA condition following the sad compared with happy MIP, which was associated with significantly enhanced amplitude at 200ms post-T2 onset. Behaviourally, mood-incongruent processing occurred at the long SOA condition and therefore outside the AB window. Participants made more correct (happy MIP) and fewer incorrect (sad MIP) responses to mood-incongruent stimuli. Correct responses to mood-incongruent stimuli were accompanied by enhanced activity at 200ms post-T2 onset that may reflect the ERP-related N200 and N400 components.

The MEG image analysis in this thesis was achieved using evoked statistics; however researchers are beginning to use other techniques to explore neuronal communication, through synchronisation for example (Gross et al., 2004; Kranczioch, et al., 2007; Nakatani, Ito, Nikolaev, Gong, & Leeuwen, 2005). Such techniques may be used to explore the cause of the AB effect. It has been hypothesised that pre-T1 alpha band oscillations (8-12Hz) predict behavioural responses (Martin, Enns, & Shapiro, 2011) and anticipatory attention which subsequently influences the AB effect (MacLean & Arnell, 2011). Finally, to enable neuroanatomical localisation, the MEG data could be co-registered with MRI data, which was obtained for all participants.

Chapter 6 General Discussion and Future Directions

The experiments presented in this thesis aimed to explore the influence and interaction of mood state and emotional stimuli with attention mechanisms and cognitive processing. In the following sections the main results will be summarised with respect to the aims of this thesis, considerations regarding the use of analogue strategies such as mood induction will be addressed, and directions for future research suggested.

6.1 Attention and affect

We inhabit an environment in which there is a rich flow of information, yet our information processing resources are capacity-limited. Selective attention determines which subset of this information will receive further, more elaborative processing, and subsequently impact upon task performance. There are two types of attention: active voluntary and passive involuntary (James, 1890). In these experiments, active voluntarily attention was considered in the context of induced mood states. Passive involuntary attention, initiated by the stimulus itself, was considered in the context of emotional stimuli. Passive involuntary attention may be consistent with the idea that such information processing occurs automatically and therefore independently of capacity limitations.

Posner & Snyder (1975) hypothesised three criteria that must be met in order for a process to be described as automatic:

- Without intention, involuntary,
- Without giving rise to conscious awareness, and

- Without producing interference with current mental activity, thus implying that automatic processing is independent of capacity limitations.

6.1.1 Emotional stimuli

There is a current debate as to whether the processing of emotional information occurs under the control of, or independently from, capacity-limited attention mechanisms. Various techniques have been used to measure the automaticity of such emotion processing, and their use in the current experiments is summarised in Table 6.1.

Technique	Beads task	Rapid Serial Visual Presentation (RSVP) paradigm
Stimulus presentation time	17ms	33ms
Backward masking	Scrambled neutral face	Five-letter consonant string
Task difficulty/demands	Proportion of beads in a jar	Short and long T1-T2 interval
Dual/divided attention	Dual task: T1 and T2	

Table 6.1: Methods used to measure the automaticity of emotion processing

Results from the RSVP paradigm suggest that task-relevant emotional stimuli can influence the deployment of attention resources. The processing of emotional, specifically negative word stimuli was prioritized under conditions of limited attention resources. This does not necessarily suggest that the mechanism responsible for the evaluation of the affective significance of a stimulus is automatic. MEG data demonstrated that prioritization corresponded with a component (M300) known to reflect the allocation of resources and selective attention. Further, the influence of task-irrelevant emotional stimuli on cognitive processing in the Beads Task did not occur under conditions of limited processing resources (60:40 probability condition). In accordance with the above mentioned definition of automaticity (Posner & Snyder, 1975), emotional stimuli are not processed automatically if they produce interference with current mental activity. The results presented in this thesis support the notion of prioritized rather than automatic processing of emotional stimuli (Pessoa, 2008).

6.1.2 Mood state

It has been suggested that mood has a general and a specific influence on attention (Derryberry & Tucker, 1994):

- It can broaden or narrow the focus of attention, and
- It directs attention towards particular information that is of importance to the individual's current state.

Traditionally, research has focussed on examining *either* cognitive impairments (i.e. general influence) *or* biases (i.e. specific influence). The systematic review and meta-analysis demonstrated *general* impairments in cognitive processing following a depressed mood induction procedure (MIP) in healthy participants. These impairments occurred in the context of task-neutral stimuli and task-irrelevant mood-congruent stimuli. In contrast, improvements occurred in the context of task-relevant mood-congruent stimuli. In the past, researchers have focussed on investigating negative rather than positive mood states. The experiments presented in this thesis aimed to examine the influence of both sad and happy mood states on cognitive processing and biases.

With regard to cognitive impairments, neither induced sad nor happy mood states altered performance in a task probing inductive reasoning (Beads Task). In contrast, under conditions of limited attention resources in the RSVP task there was impaired and improved performance following sad and happy MIPs, respectively. The reverse was observed when attention processing resources were not limited (i.e. long stimulus onset asynchrony [SOA] condition). These results support the hypothesis that negative affect is associated with systematic and elaborative information processing (Blanchette & Richards, 2010). This causes overinvestment of attention resources on stimulus processing which itself causes interference with the processing of subsequently presented stimuli under conditions of limited attention resources (MacLean, Arnell, & Busseri, 2010). In contrast positive affect is hypothesised to broaden the

focus of attention and increase cognitive flexibility (Fredrickson, 1998, 2001; Isen, 2000). This diffuse attention state is not associated with overinvestment of attention resources on stimulus processing which facilitates performance under conditions of limited processing resources (MacLean, et al., 2010).

6.1.3 Interaction of mood state and emotional stimuli

The biased competition model of selective attention (Desimone & Duncan, 1995) postulates that incoming information relevant to an individual's current state is preferentially processed. In accordance with this model and various theories of depression (Beck, 1989; Bower, 1981), the systematic review and meta-analysis revealed mood-congruent cognitive biases. Results from the experiments presented in this thesis demonstrated variable support for these models and theories. There was some evidence for a negative information processing bias in the Beads Task wherein emotional stimuli were task-irrelevant. Participants required less information when presented with task-irrelevant angry and fearful compared with smiling face trials following a sad MIP. In contrast, there was no evidence of mood-congruent processing to negative task-relevant stimuli in the RSVP paradigm following the sad MIP.

One way to reconcile the behavioural results from these experiments is to consider that the emotional stimuli were either task-irrelevant (Beads Task) or task-relevant (RSVP paradigm). When stimuli were task-irrelevant, mood-congruent processing indicates difficulty disengaging attention. In contrast, the lack of mood-congruent processing to task-relevant stimuli demonstrates an absence of attention engagement or difficulty shifting attention. It has been argued that cognitive biases in depression occur when there is elaboration of the stimulus (Williams, Watts, MacLeod, & Mathews, 1997). Accordingly, the absence of mood-congruent processing may occur when attention resources are otherwise unavailable. As noted previously, in the RSVP paradigm there was impaired T2 detection following a sad MIP in the short SOA condition. This may be attributed to overinvestment of attention resources in

processing T1. Consequently there may not be enough resources available for the elaborative stimulus processing (of negative T2 words) hypothesised to result in mood-congruent biases.

There was evidence to support mood-congruent processing following the happy MIP in the RSVP paradigm. Participants made more correct responses to positive words in the short SOA condition. In contrast participants made more correct responses to mood-incongruent negative words in the long SOA condition (RSVP paradigm) and showed a general emotion bias in the Beads Task.

Another factor influencing the presence of mood-congruent processing might be related to the magnitude of the mood induced. In the RSVP paradigm, when more processing resources were available, participants made more correct (happy MIP) and fewer incorrect (sad MIP) responses to task-relevant mood-incongruent stimuli. It was suggested that this might reflect a negativity bias and mood repair following happy and sad MIPs, respectively. Mood-incongruent processing, as a method of mood repair, is hypothesised to occur when mood states are prone to decay and reversal (e.g. following MIPs) and not in individuals experiencing a high intensity of depressive symptoms (e.g. clinical depression) (Teasdale, 1988). This leads onto a discussion of the effectiveness of MIPs at inducing the intended mood state, and their validity as a model of clinical depression.

6.2 Effectiveness and efficacy of mood induction procedures

A large amount of research investigating psychopathology, such as depression, has been conducted using analogue strategies including experimental manipulations such as MIPs, and in individuals with non-clinical subsyndromal disorders. This field of research has been called 'experimental psychopathology' and given the operational definition of *"laboratory-based research with humans...directly aimed at discovering and explaining the etiology and*

maintenance of psychopathological processes..." (pp. 371; Zvolensky, Lejuez, Stuart, & Curtin, 2001).

6.2.1 Effectiveness of mood induction procedures

Importantly, the systematic review and meta-analysis as well as mood state ratings from the experiments presented in this thesis confirmed the effectiveness of MIPs at inducing mood states. In both the Beads task and RSVP paradigms, the effect of MIPs on mood state was somewhat attenuated at the end of the tasks. Researchers have suggested that the influence of MIPs on mood state lasts for 10-15 minutes (Frost & Green, 1982). Including an incubation period, in which the participant read instructions that encouraged them to think and concentrate on the mood induced by the Velten statements (Velten, 1968), increased the duration of the effects to last for roughly 35 minutes (Sinclair, Mark, Enzle, Borkovec, & Cumblerton, 1994). In the experiments presented in this thesis, a combination of self-referential statements, based on the Velten method, and music was used with the intention of inducing a specific and longer-lasting mood state.

6.2.1.1 Influence of current depressive symptoms

Results from the meta-regression analyses demonstrated that individuals with *lower* scores on measures of current depressive symptoms reported the largest changes in negative affect following the sad compared with neutral MIPs. This result was supported with data from the RSVP paradigm.

In line with this result, it has been shown that relatively non-dysphoric participants, i.e. those with lower BDI-II scores, report more sadness following a negative MIP than more dysphoric participants, with higher BDI-II scores (Wisco & Nolen-Hoeksema, 2009). Such results may occur because more dysphoric participants have more difficulty increasing an already elevated negative mood state; a ceiling effect (Wisco & Nolen-Hoeksema, 2009), hence participants with lower scores of current depressive symptoms demonstrate larger effects of a sad MIP. In

contrast, the relationship between current depressive symptoms and mood change was in the opposite direction in the Beads task. This result is concordant with those from studies demonstrating that higher BDI predicts greater mood change following a sad MIP (Bisson & Sears, 2007; Blackburn, Cameron, & Deary, 1990).

There is some consensus in the literature, and results from the meta-regression analysis and RSVP paradigm, to suggest the direction of the relationship between current depressive symptoms and responsiveness to a sad MIP. However, there have been variable results from multiple studies specifically designed to investigate the effects of a variety of measures on predicting response to a sad MIP. Two of these studies reported no effect of measures of depressive cognitions or behaviours on post- compared with pre-MIP mood state (McHugh & Wierzbicki, 1998; Rexford & Wierzbicki, 1989). Another found that after accounting for pre-MIP mood state scores, BDI was not a significant predictor of post-MIP mood state (Scherrer & Dobson, 2009). Therefore, to further investigate this relationship requires a large scale, dedicated study of the influence of multiple variables on responsiveness to a range of MIPs including neutral, sad, and happy with mood measures taken pre- and post-MIP. This has the potential to provide researchers with guidance about possible measures for pre-screening participants to enable selection of individuals that are more likely to experience the greatest change in mood state. Selecting individuals in this way may have consequences for the influence of induced mood on subsequent task performance. Results from the Beads Tasks showed that greater changes in mood state were associated with greater changes in task performance. If greater changes in mood state result in greater changes in task performance, the results of these studies will have more ecological validity and therefore increased generalizability of findings to individuals diagnosed with clinical depression.

6.2.2 Efficacy of mood induction procedures as a model of clinical depression

One review of methodological issues in experimental psychopathology research includes a critical appraisal of the use of such analogue strategies (Sher & Trull, 1996), these issues are summarised in Table 6.2.

Issue	For	Against
1. Use of MIPs in healthy participants	High internal validity to make causal attributions.	Potentially low external validity difficult to generalise findings to clinical population.
	Target specific psychological processes.	Ethical and practical considerations constrain severity of symptoms to be induced – limited to mild and transient.
2. Use of individuals with non-clinical subsyndromal disorders	Homogeneity of environment (e.g. in students).	Younger and less depressed.
	Lower rates of comorbidity and previous treatment.	

Table 6.2: A critical appraisal of the methodological issues associated with research exploring the psychopathology of depression in studies using analogue strategies; (Sher & Trull, 1996)

There are two main debates concerning the appropriateness of the use of analogue samples to draw conclusions about and generalise findings to individuals diagnosed with clinical depression. These are the continuity debate and the generalizability debate. These debates have largely been applied to studies using scores on continuous measures such as the BDI to identify individuals with mild, moderate, and severe depressive symptoms (i.e. individuals with non-clinical subsyndromal depression). They could, however, equally be applied to research in which MIPs are used to induce transient depressive mood in healthy, student participants.

The continuity debate surrounds the validity of the assumption that depression lies on a continuum and that variations between individuals on this continuum are quantitative, not

qualitative (for example, Coyne & Gotlib, 1983; Gotlib, 1984). Contributing to this debate, researchers have analysed results from the U.S. National Comorbidity Survey conducted between 1990 and 1992 and demonstrated that minor depression (defined as two to four DSM-III-R criterion A symptoms) was on a continuum with major depression (five to six symptoms) as the course, correlates, and impairments were similar (Kessler, Zhao, Blazer, & Swartz, 1997). Specifically, both were recurrent with 72.1% and 72.3% of individuals reporting more than one episode of minor and major depression, respectively; there were no differences between individuals with minor and major depression in racial and ethnic background, education, and region; and 42.0% and 49.7% of individuals with minor and major depression reported at least one indicator of impairment (including interference with life, seeing a doctor or other professional, and taking medication). One review considered the continuity issue in studies using standardised clinical interviews to classify individuals with subsyndromal or clinical depression (Solomon, Haaga, & Arnow, 2001). It was concluded that there was some support for the continuity argument as subsyndromal and clinical depression were both associated with impairments (social and occupational functioning); had similar correlates such as increased future risk of a major depressive episode and family history; and psychiatric and medical comorbidity. Further support for the continuity hypothesis comes from a study demonstrating quantitative rather than qualitative differences between clinically depressed patients and an analogue subsyndromal sample of individuals (BDI score ≥ 9) with similarities in impairments as well as correlations between measures of depression and anxiety (Cox, Enns, Borger, & Parker, 1999). A subsequent study by researchers from the same group reported that individuals with greater levels of current depressive symptoms (BDI score ≥ 21) displayed a profile of depression symptoms that was closer to clinically depressed patients (Cox, Enns, & Larsen, 2001). This led to the recommendation that studies using analogue samples should select individuals with greater current depressive symptoms. Other researchers argue that there are qualitative differences between clinical and analogue samples (Ruscio & Ruscio,

2002; Santor & Coyne, 2001); and reviews of these issues have tended to conclude that the debate has not currently been resolved (Sher & Trull, 1996; Solomon, et al., 2001).

Another related issue, the generalizability debate, concerns the appropriateness of the use of participants sampled from student and general populations, and the representativeness of research findings between analogue samples and clinical populations. One group suggested methodological reasons favouring the use of depressed students (Vredenburg, Flett, & Krames, 1993), which have been highlighted in Table 6.2.

The methods of mood induction used in the experiments presented in this thesis are known to induce depression without anxiety (Martin, 1990). This was intended to be analogous to investigating psychopathology in a subsample of individuals with pure types of a disorder (i.e. depression). This strategy may be problematic because there are substantial rates of comorbidity (the co-occurrence of two or more mental disorder diagnoses in one individual) between Major Depressive Disorder and other mental disorders.¹ Therefore studying a subsample of individuals with pure types of a disorder is unrepresentative and can limit the generalizability of the findings (Sher & Trull, 1996). Studies including a more representative sample (i.e. individuals with and without comorbidities), or MIPs not restricted to inducing depression per se, require statistically controlling for any comorbidities using regression. However, previous studies investigating attention biases in depression have been unable to use such methods to disentangle the influence of depression and anxiety on such biases (Mogg, Bradley, & Williams, 1995). This is especially important when considering the

¹ Results from the National Comorbidity Survey Replication (NCS-R) conducted in the U.S. household population between 1990 and 1992 found overall lifetime and 12 month comorbidity rates of 72.1% and 64.0%, respectively between individuals with Major Depressive Disorder and any other psychiatric disorder, diagnosed according to the DSM-III-R diagnostic criteria. Comorbidity between depression and anxiety was the highest of all disorders with lifetime and 12 month rates of 59.2% and 57.5%, respectively. These results were published by (Kessler et al., 2003). In another paper by the same group, rates of pure depression defined as the absence of any other DSM-III-R anxiety or addictive disorder were 45.5% for individuals with minor depression (two to four criterion A symptoms), 33.6% for individuals with Major Depression and five to six symptoms, and 19.7% for individuals with Major Depression and seven to nine symptoms.

hypothesis that anxiety is associated with pre-attentive biases whereas depression-related biases occur at a post-attentive stage of stimulus processing (Williams, et al., 1997). Accordingly, it was considered pertinent to select methods of mood induction shown to be specific to depression per se.

Despite these limitations and considerations, and the lack of resolution of these debates, it has been noted that *“mild depression in college students, in and of itself, is a legitimate topic for study”* (pp. 476; Coyne & Gotlib, 1983). However, these researchers highlight three points about which researchers should be cautious, and which may be applied to research using MIPs:

- Acceptance of null hypotheses of no differences between depressed and non-depressed mood states, as there may be evidence for this hypothesis in studies using a clinical population.
- Potential susceptibility of participants to demand characteristics.
- Factors associated with severe and mild depression may vary.

This leads onto a discussion of potential confounds in MIPs research.

6.2.3 Potential confounds in research using mood induction procedures

6.2.3.1 Demand characteristics

The methods to assess mood state are often based on self-report and are thus susceptible to demand characteristics: a situation in which participants form an interpretation of the purpose of the experiment and change their behaviour accordingly (for example, rating their mood as more negative following a sad MIP). The meta-analyses of the influence of induced mood on measures of cognitive task performance provided a ‘non-explicit’ or covert measure of the

efficacy of MIPs, in addition to enabling clinically relevant conclusions about depression-related cognitive impairments and biases.

In the past, researchers have attempted to minimise the effects of demand characteristics on mood state by the use of 'implicit' methods of mood induction (as in Neumann, Seibt, & Strack, 2001).² One flaw of using such methods is that the researchers do not take measures of mood before or after the MIP, as they argue that this may draw the participants' attention to the purpose of the procedure. Consequently it is more difficult to attribute any effects on task performance to differences in mood state.

Another possible way of minimising the effects of demand characteristics would be to confirm results obtained using MIPs with those obtained from a study in which participants' mood state was naturally occurring (as in Forgas, 1998). In using such methods, one cannot exclude the possibility that any similarities or differences are not due to some extraneous variable between the two samples.

Other studies may attempt to disguise the purpose of the MIP. For example by asking participants to fill out a pre- and post-MIP questionnaire that is presented as a questionnaire forming part of a larger study conducted by the researcher's colleague (as in Hermans, De Houwer, & Helen, 1996). Other methods include presenting the MIPs and cognitive tasks to participants as separate and unrelated studies (Siemer, 2001).

6.2.3.2 Carry over effects

Another problem associated with MIPs research is the potential for carry over effects. For example, in a within-subjects design where participants are induced into one mood state followed by tasks and then into another mood state followed by tasks, the influence of the first MIP on mood state may carry over and influence mood state following the second MIP.

² Participants were asked to listen to a speech, read aloud in a sad or happy voice, and remember as many sentences as possible. The purpose of the tone of voice for inducing mood was disguised by introducing a simultaneous task: remembering sentences.

Researchers may choose to always include a neutral baseline condition i.e. neutral MIP first. This strategy was employed in Experiments one and two in Chapter 3: Inductive Reasoning. However any effects of mood state on task performance cannot then be dissociated from order effects. There was no effect of baseline mood state on self-reported sad mood state in the meta-regression analyses presented in Chapter 2: Sad Mood Induction: A Systematic Review. This suggests that using a neutral MIP in this way may be superfluous, and a strategy of counter-balancing the order of neutral and emotional MIPs was subsequently adopted. Alternatively, researchers may choose to separate the sad and control (neutral and/or happy) MIPs by time (i.e. a week in-between experimental sessions) or in the same experimental session by using filler tasks (as in Gilboa-Schechtman, Revelle, & Gotlib, 2000).

6.2.3.3 Response bias

One important methodological consideration in designing tasks aimed to assess attentional processing biases is to be aware of the distinction between attentional and response biases (cf. Yiend, 2010). Participants may respond according to their interpretation of the purpose of the experiment and as such generate mood-congruent responses. Using emotionally salient task-irrelevant stimuli (facial expressions) as in the Beads Task is one method employed to disentangle attentional from response biases because only neutral responses (e.g. jar with mostly pink beads) are available (for example Mogg, et al., 1995). In the RSVP paradigm, the emotionally salient stimuli were task-relevant (neutral, negative, or positive T2 words) but response bias was controlled because both word stimuli presented in the two-alternative forced choice question were the same valence (for example gloomy or sad).

6.3 Broader context

Analogue strategies such as MIPs may be used to explore information processing biases in participants with unimpaired attention and cognitive functioning. Such investigations are able

to generate preliminary data that may subsequently be used to justify similar experiments in patients with clinical depression.

It is important to investigate cognitive biases because research has shown that such biases are at the core of vulnerability to depression. Depressive rumination is the process of thinking repetitively about one's negative experiences, thoughts, feelings, emotions, and mood state. Studies have demonstrated an association between rumination and depression, such that a ruminative response style is predictive of a diagnosis (but not duration) of depression and subclinical depression one year later (Nolen-Hoeksema, 2000), just as a diagnosis of depression is predictive of ruminative response style at the time of interview and one year later. According to the differential activation hypothesis (Teasdale, 1988), the simultaneous experience of patterns of negative thinking and depressed mood becomes a learned association during a depressed episode. Therefore, during remission the occurrence of one (e.g. rumination) could lead to the onset of the other (depressed mood) and as such is instrumental in relapse.

Furthermore, psychological treatments for depression have focussed on this ruminative response style. Mindfulness meditation has been developed into a specific form, known as Mindfulness-Based Cognitive Therapy (MBCT), as a prophylactic intervention against relapse into depression (Segal, Williams, & Teasdale, 2002). MBCT is psycho-educational in that the therapist teaches the patient; at first generic skills of attention control (e.g. using a neutral focus such as the breath as an anchor point) leading to intentional attention to moment-by-moment thoughts, feelings, and bodily sensations. The aim is to teach patients to become aware of signs indicating mood deterioration and reactivation of patterns of negative thoughts and feelings associated with depressive relapse, and to process this depression-related information in a different way. MBCT teaches individual's to focus their attention towards present moment-to-moment awareness, which necessarily utilizes processing resources that

would otherwise be used to ruminate (Teasdale, Segal, & Williams, 1995), thus interrupting the relationship between rumination and depression. It may seem paradoxical that MBCT actively encourages individuals to focus their attention on the negative thoughts and feelings that they ruminate about. However, it is the process of cultivating an attitude of open curiosity and being non-judgmental rather than focusing on the content of one's thoughts and feelings that makes MBCT an effective prophylactic intervention against relapse into depression.

The introduction of neuroimaging techniques to the study of psychiatric disorders has enabled investigation of the biological mechanisms underpinning these disorders (Abou-Saleh, 2006; Insel, 2007). The findings from research with patients and using analogue strategies may be used to facilitate an understanding and identification of target regions of the brain (e.g. biomarkers) for treatment with both pharmacological therapeutic substances and neuromodulation techniques, such as deep brain stimulation; DBS (Schnitzler & Gross, 2005).

6.4 Directions for future research

One potential extension of the meta-analysis would be to conduct an analysis of the effect of MIPs on cognitive processing using only those studies that were deemed effective at inducing the intended mood state and/or inducing a higher intensity of depressed mood. Previous research has shown that impairments in various measures of cognitive processing worsen with increasing severity of depression (McDermott & Ebmeier, 2009). Therefore one might hypothesise that impairments in task performance following depressed compared with neutral MIPs may be dependent upon the effectiveness of the depressed MIP at inducing the expected mood state. The results of this extension of the meta-analysis may therefore have enhanced ecological validity and generalizability to a clinical population.

The results of the Beads Task could not confirm that a sad induced mood state influenced inductive reasoning. There was, however, a significant relationship between the success of emotional MIPs and the number of beads drawn before decision after the emotional MIPs: the greater the mood change the fewer beads requested. It was previously noted that researchers using analogue strategies should be cautious about accepting null hypotheses of no differences between depressed and non-depressed mood states, as there may be evidence for the hypothesis in studies using a clinical population (Coyne & Gotlib, 1983). Accordingly, to further explore the influence of mood state on inductive reasoning, the Beads Tasks could be used in patients with MD compared with healthy control participants, and/or with individuals demonstrating relatively high and low levels of dysphoria.

It would be interesting to explore the behavioural and neuronal correlates of attention processing in a sample of clinically depressed patients using the RSVP paradigm. Theories predict that depressed patients demonstrate mood-congruent cognitive biases: they preferentially attend to negative stimuli. Extending the use of this paradigm to a clinical population may confirm the effects of sad mood states on attention processing in general, and enable an exploration of the specificity of mood (in-)congruent processing to clinical populations. Furthermore the RSVP paradigm could be used to investigate attention processing in depressed patients before and after an eight-week MBCT course. MBCT teaches patients to focus their attention on negative thoughts and feelings. It is argued that the process of cultivating an attitude of open curiosity and being non-judgmental towards such negative thoughts and feelings makes MBCT an effective prophylactic intervention against relapse into depression. Accordingly, it would be hypothesised that patients would demonstrate an increase in mood-congruent processing after the MBCT course, yet would be less likely to relapse into depression. The findings of this research might therefore have implications for the mechanisms of action of MBCT. As a step towards this, data have been collected for 13 MBCT teachers to determine the behavioural and neuronal correlates of

attention processing in a sample of expert meditators. If this study yields positive results, the findings could be used to justify a similar investigation in a clinically depressed patient population.

In Chapter 4: Introduction to Functional Imaging and Neuronal Correlates of Cognitive Processes, differences between and reasons for choosing MEG over EEG were outlined. However the methods of MEG data analysis presented in this thesis do not make the most of these differences.

MEG primarily measures the magnetic fields generated by pyramidal neurons which penetrate the skull and scalp with little distortion and attenuation, which facilitates localisation of the primary current (i.e. a solution to the inverse problem) with greater spatial resolution than that afforded by EEG. With respect to this, future directions involve co-registration of MEG with MRI data, which has been collected for all participants, to enable source localisation of the statistically significant effects presented in this thesis.

Participants demonstrated a larger AB effect and reduced M300 amplitude following a sad compared with happy MIP. Research has shown that oscillations in the alpha band determine conscious perception of stimuli in the RSVP paradigm (Hanslmayr, Gross, Klimesch, & Shapiro, 2011), and that mood state alters the amplitude of on-going activity in the alpha band, which subsequently influences the speed of conscious perception of rapidly masked stimuli (Kuhbandner et al., 2009). As MEG can measure a wider range of frequencies (0-150Hz) than EEG (van Putten, 2009), statistical techniques could be used to examine the effect of induced mood states on oscillatory activity in a larger range of frequency bands and the effects of this activity on the cause and correlates of the AB effect.

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A. Criteria for assessing the quality of systematic reviews

1. Was an 'a priori' design provided?

The research question and inclusion criteria should be established before the conduct of the review.

- ☐ Yes
- ☐ No
- ☐ Can't answer
- ☐ Not applicable

2. Was there duplicate study selection and data extraction?

There should be at least two independent data extractors and a consensus procedure for disagreements should be in place.

- ☐ Yes
- ☐ No
- ☐ Can't answer
- ☐ Not applicable

3. Was a comprehensive literature search performed?

At least two electronic sources should be searched. The report must include years and databases used (e.g. Central, EMBASE, and MEDLINE). Key words and/or MESH terms must be stated and where feasible the search strategy should be provided. All searches should be supplemented by consulting current contents, reviews, textbooks, specialized registers, or experts in the particular field of study, and by reviewing the references in the studies found.

- ☐ Yes
- ☐ No
- ☐ Can't answer
- ☐ Not applicable

4. Was the status of publication (i.e. grey literature) used as an inclusion criterion?

The authors should state that they searched for reports regardless of their publication type. The authors should state whether or not they excluded any reports (from the systematic review), based on their publication status, language etc.

- ☐ Yes
- ☐ No
- ☐ Can't answer
- ☐ Not applicable

5. Was a list of studies (included and excluded) provided?

A list of included and excluded studies should be provided.

- ☐ Yes
- ☐ No
- ☐ Can't answer
- ☐ Not applicable

6. Were the characteristics of the included studies provided?

In an aggregated form such as a table, data from the original studies should be provided on the participants, interventions and outcomes. The ranges of characteristics in all the studies analyzed e.g. age, race, sex, relevant socioeconomic data, disease status, duration, severity, or other diseases should be reported.

- ☐ Yes
- ☐ No
- ☐ Can't answer
- ☐ Not applicable

7. Was the scientific quality of the included studies assessed and documented?

‘A priori’ methods of assessment should be provided (e.g., for effectiveness studies if the author(s) chose to include only randomized, double-blind, placebo controlled studies, or allocation concealment as inclusion criteria); for other types of studies alternative items will be relevant.

- ☐ Yes
- ☐ No
- ☐ Can’t answer
- ☐ Not applicable

8. Was the scientific quality of the included studies used appropriately in formulating conclusions?

The results of the methodological rigor and scientific quality should be considered in the analysis and the conclusions of the review, and explicitly stated in formulating recommendations.

- ☐ Yes
- ☐ No
- ☐ Can’t answer
- ☐ Not applicable

9. Were the methods used to combine the findings of studies appropriate?

For the pooled results, a test should be done to ensure the studies were combinable, to assess their homogeneity (i.e. Chi-squared test for homogeneity, I^2). If heterogeneity exists a random effects model should be used and/or the clinical appropriateness of combining should be taken into consideration (i.e. is it sensible to combine?).

- ☐ Yes
- ☐ No
- ☐ Can’t answer
- ☐ Not applicable

10. Was the likelihood of publication bias assessed?

An assessment of publication bias should include a combination of graphical aids (e.g., funnel plot, other available tests) and/or statistical tests (e.g., Egger regression test).

- ☐ Yes
- ☐ No
- ☐ Can’t answer
- ☐ Not applicable

11. Was the conflict of interest stated?

Potential sources of support should be clearly acknowledged in both the systematic review and the included studies.

- ☐ Yes
- ☐ No
- ☐ Can’t answer
- ☐ Not applicable

This is a measurement tool for the ‘assessment of multiple systematic review’ (AMSTAR)

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In relation to the systematic review presented in this thesis:

- The research question and criteria for inclusion were established prior to the search (statement one),
- Two individuals independently screened abstracts for inclusion in the review according to the search criteria (statement two),¹
- Two electronic sources were searched (statement three),
- The status of the publication was considered such that only original peer-reviewed journal articles were included (statement four),
- In contrast to statement five, a list of studies that were included and excluded is not provided as a large number of studies were initially identified (N=501),
- The characteristics of participants (e.g. age and percentage of female participants) in each of the studies are provided in a table (statement six),
- The inclusion of studies based on *a priori* criteria for the assessment of the scientific quality of studies was not applied as few studies using Mood Induction Procedures (MIPs) include blinded randomisation of participants to different MIP groups for example (statement seven), but
- A discussion of the quality of the methodological rigor (e.g. predominant use of participants from student populations) is provided (statement eight),
- Tests of heterogeneity were conducted to assess the appropriateness of combining results across studies (statement nine), and
- The likelihood of publication bias was assessed using graphical aids and statistical tests (statement ten).

¹ If there was disagreement between the two individuals screening the abstract, there was a discussion until an agreement was reached. If any disagreement remained, the third author was consulted.

B. Demographic information of participants included in the studies presented in the systematic review and meta-analyses

ns = not specified in paper

First author	Total number of participants	Mean age (Std. Dev.)	% female	Sample
(Allwood & Bjorhag, 1991)	60	29	65	Students
(Badcock & Allen, 2003)	78	19.35	100	Students
(Beevers & Meyer, 2008)	65	18.68	66.15	Students
(Bisson & Sears, 2007; study 2)	227 198 responders	20.7	100	Students
(B. P. Bradley, Mogg, & Lee, 1997; study 1)	34	21	47.06	Students
(Brand, Verspui, & Oving, 1997)	60	21.6 (2.5)	55	Students
(Ferraro, King, Ronning, Pekarski, & Risan, 2003)	50 younger adults 25 older adults	20.5 66.8	78 56	Students Retired faculty & community
(Forgas, 1998; study 1)	96	Median 19	50	Students
(Forgas, 1998; study 3)	84	Median 19	50	Students
(Gilboa-Schechtman, Revelle, & Gotlib, 2000)	81	ns	ns	Students
(Hermans, De Houwer, & Helen, 1996)	40	ns	57.5	Students
(Hunt & Forand, 2005)	153	19.5	60.13	Students
(Jacoby, Brewin, & Watkins, 2008)	36	22.56 and 22.33 for contextual and control groups, respectively.	ns	ns
(Joormann & Siemer, 2004; study 1) ²	119	25.77	73.11	Students
(Kanayama, Sato, & Ohira, 2008)	80	19.19 (1.1)	81.25	Students
(Kenealy, 1997; study 1a)	24	24.8(Range 19-39)	≈55	Students
(Kenealy, 1997; study 1b)	28	22.9(Range 19-26)	100	Students
(Kenealy, 1997; study 1c)	40	22.6(Range 18-38)	≈50	Students
(Kenealy, 1997; study 2)	24	21.5(Range 20-25)	100	Students
(Kenealy, 1997; study 3)	20	23.3(Range 20-36)	100	Students
(Klauer, Siemer, & Stöber, 1991)	51	ns	ns	Students

² There were many subgroups in this study; therefore the mean age and percentage of female participants presented in this table are derived from grand average calculations across the means for participants in these groups. See Table 1 in the original paper (Joormann & Siemer, 2004) for a breakdown of mean age and number of female participants according to those subgroups.

First author	Total number of participants	Mean age (Std. Dev.)	% female	Sample
(Kliegel et al., 2005)	62	25.07 (4.12)	50	Students
(Knight, Maines, & Robinson, 2002)	119 young adults 78 older adults	Range 18-35 Range 62-90	79.83 67.95	Students Community
(MacLeod & Campbell, 1992)	24	18.4	50	Students
(Moore & Oaksford, 2002)	36	Range 18-25	ns	Students
(Phillips, Smith, & Gilhooly, 2002)	48 younger adults 48 older adults	23.0 67.0	50 50	General public volunteers
(Philpot & Madonna, 1993)	50	Range 18-24	60	Students
(Ruci, Tomes, & Zelenski, 2009)	90	ns	≈60	Students
(Siemer, 2001; study 1)	87	26.3	55.17	Students
(Siemer, 2001; study 2)	38	25.7	83.93	Students
(Smallwood, Fitzgerald, Miles, & Phillips, 2009)	59	21.7 (2.0)	57.63	Students
(Stopa & Waters, 2005)	30	24.4 male, 24.1 female	56.67	Students and non-academic staff
(Svaldi & Mackinger, 2003)	100	21.3 (6.3)	100	ns
(Van der Does, 2002)	48	21.1	68.75	Students
(Varner & Ellis, 1998; study 1)	40	ns	ns	Students
(Varner & Ellis, 1998; study 2)	72	ns	ns	Students
(Weaver & McNeill, 1992; study 1)	24	ns	50	Students
(Weaver & McNeill, 1992; study 2)	32	ns	50	Students
(Wood, Saltzberg, & Goldsamt, 1990; study 1)	31	ns	38.70968	Students? (Advertised around university campus)
(Wood, et al., 1990; study 2)	79	ns	100	Students
(Yeung, Dalglish, Golden, & Schartau, 2006)	45	26.47 (7.92)	73.33	Volunteer panel

C. Results of studies investigating the effects of sad MIPs on cognitive processing, presented in the systematic review

N/A = Not Applicable, RT = Reaction Time, VS = versus.

First author	Task	Stimuli		Results: Mood		Results: Mood congruence		Results: General Impairment
		Task-related	Task-unrelated	Sad vs. Happy ³	Sad vs. Neutral ⁴	Sad vs. Happy ³	Sad vs. Neutral ⁴	Neutral stimuli
(Allwood & Bjorhag, 1991)	Confidence judgments	General knowledge questions	N/A	No main effects of mood	No main effects of mood	N/A	N/A	No effect of MIPs on proportion of correct answers to general knowledge questions
(Badcock & Allen, 2003)	Wason card selection task	-Cheater detection -Truth detection -Social competition -Attachment	N/A	N/A	↑correct in social competition (vs. cheater and truth versions)	N/A		No effect of sad vs. neutral mood on either cheater or truth detection tasks
(Beevers & Meyer, 2008)	Scrambled sentences task	Neutral, negative and positive solutions	N/A	N/A	No main effects of mood	N/A	↑ use of negative solutions (following thought suppression after MIP)	
(Bisson & Sears, 2007; study 2)	Lexical decision task	Neutral, negative and positive words	N/A	N/A	N/A. Sad MIP only: no main effects of mood	N/A	No interaction of mood and word valence	

³ Note that results described here are for the effects of sad MIP relative to happy MIP. For example, increased (↑) errors means more errors following sad compared with happy MIP.

⁴ Note that results described here are for the effects of sad MIP relative to neutral MIP. For example, increased errors (↑) means more errors following sad compared with neutral MIP.

First author	Task	Stimuli		Results: Mood		Results: Mood congruence		Results: General Impairment
		Task-related	Task-unrelated	Sad vs. Happy ³	Sad vs. Neutral ⁴	Sad vs. Happy ³	Sad vs. Neutral ⁴	Neutral stimuli
(B. P. Bradley, et al., 1997; study 1)	Dot-probe	Dot	Neutral, depression-, anxiety- and positive-related words	N/A	ns	N/A	Slower to respond when dot preceded by depression-related words	
(Brand, et al., 1997)	Stroop	Colour of words	Colour words	Slower to make errors	Slower to make errors	N/A	N/A	
(Ferraro, et al., 2003)	Lexical decision task	Sad, happy and pseudo words	N/A	No main effects of mood. Main effect of stimuli: ↓ RT to sad and happy vs. pseudo words. ↓ errors to happy vs. sad and pseudo words	N/A	↓ RT to mood-congruent words after sad and happy MIPs	N/A	Participants were slower and made more errors to pseudo than sad or happy words, but this did not differ between mood states
(Forgas, 1998; study 1)	Attributions	Read an essay for/against nuclear testing – led to believe author had free choice/was coerced into position	N/A	↓ attribution errors (coerced, no effect for freely chosen)	No main effects of mood	N/A	N/A	
(Forgas, 1998; study 3)	Remember and recall essay content	As above but essays about logging native forests	N/A	As above as well as ↑ memory	As above	As above	As above	
(Gilboa-Schechtman, et al., 2000)	Stroop	Colour of words	Neutral, negative and positive words	Slower reaction times	N/A	Slower reaction times when negative words	N/A	No effects of mood state on neutral words reported
(Hermans, et al., 1996)	Picture appraisal	Neutral, negative and positive pictures	N/A	No effect of MIPs. ↓RT if more depressed than less depressed	N/A	No effect of MIPs. ↓RT to negative than positive pictures if more depressed	N/A	No effects of mood state on neutral picture trials reported

First author	Task	Stimuli		Results: Mood		Results: Mood congruence		Results: General Impairment
		Task-related	Task-unrelated	Sad vs. Happy ³	Sad vs. Neutral ⁴	Sad vs. Happy ³	Sad vs. Neutral ⁴	Neutral stimuli
(Hunt & Forand, 2005)	Dysfunctional cognitions	Dysfunctional attitude scale (DAS)	N/A	N/A	N/A. Sad versus No MIP: No effect of mood. ↑ DAS predicted ↑ BDI scores one month later for No MIP > Sad MIP			
(Jacoby, et al., 2008)	Scrambled sentences task	Negative and control sentences	N/A	N/A	N/A. Sad MIP only: No main effects of mood	N/A	N/A. Sad MIP only: Participants who unscrambled sentences with extreme solution were more depressed after task	
(Joormann & Siemer, 2004; study 1)	Memory accessibility	Unpleasant and pleasant descriptions of events	N/A	No main effects of mood on recall	N/A	↓ recall latency for pleasant events for non-dysphoric Participants following happy MIP (congruent) and sad MIP (incongruent) after rumination (sad only).	N/A	
(Kanayama, et al., 2008)	Recognition memory	Negative and positive words	N/A	↑ performance when mood consistent at encoding and retrieval (i.e. sad-sad or hap-hap vs. sad-hap or hap-sad)	N/A	No interaction of mood and word valence	N/A	

First author	Task	Stimuli		Results: Mood		Results: Mood congruence		Results: General Impairment
		Task-related	Task-unrelated	Sad vs. Happy ³	Sad vs. Neutral ⁴	Sad vs. Happy ³	Sad vs. Neutral ⁴	Neutral stimuli
(Kenealy, 1997; study 1a and b)	Immediate and delayed free recall	Map and 22 directions	N/A	No main effects of mood on recall	N/A	↑ forgetting (delayed-immediate) when mood inconsistent at encoding and retrieval (i.e. sad-hap or hap-sad vs. sad-sad or hap-hap)	N/A	
(Kenealy, 1997; study 1c)	As above	As above	As above	↓ delayed free recall	As above	As above	As above	
(Kenealy, 1997; study 2)	Immediate and cued delayed free recall	As above	As above	↓ delayed free recall	As above	↓ delayed free recall if mood at encoding and retrieval is sad-hap (vs. hap-sad)	As above	
(Kenealy, 1997; study 3)	Immediate and delayed free recall (1), then cued free recall then free recall (2+3)	As above	As above	No main effects of mood on recall	As above	As above at delayed free recall (1) but not (2+3)	As above	
(Klauer, et al., 1991)	Pattern recognition	Patterns	N/A	↓ accuracy and effort	↓ accuracy and effort	N/A	N/A	
(Kliegel, et al., 2005)	Prospective memory	Button press	N/A	N/A	-↓ correct Sad MIP mood responders vs. neutral MIP -↓ time accuracy of press in Sad MIP mood responders vs. non-responders	N/A	N/A	

First author	Task	Stimuli		Results: Mood		Results: Mood congruence		Results: General Impairment
		Task-related	Task-unrelated	Sad vs. Happy ³	Sad vs. Neutral ⁴	Sad vs. Happy ³	Sad vs. Neutral ⁴	Neutral stimuli
(Knight, et al., 2002)	Immediate and delayed free recall	Negative and positive trait words	N/A	N/A	No main effects of mood on recall	N/A	↑ free delayed recall for negative words	No effects of mood state on neutral words reported
(MacLeod & Campbell, 1992)	Memory accessibility	Negative and positive descriptions of events	N/A	No main effects of mood on recall latency or perceived future probability of similar events	N/A	-↓ recall latency -↑ perceived future probability	N/A	
(Moore & Oaksford, 2002)	1.Word association 2.Visual learning	1.Cue and target words 2.Target shapes	N/A	1.None 2.↑ RT on day 1 but ↓ RT over days 1-4	1. ↓ RT over days 1-4 2. ↓ RT over days 1-4			
(Phillips, et al., 2002)	Tower of London task	Disks	N/A	No differences reported	-↑ excess moves -↑ under estimation of # moves required	N/A	N/A	
(Philpot & Madonna, 1993)	Immediate and delayed free recall	Abstract nouns (auditory)	N/A	No effect of mood at immediate or delayed free recall	No effect of mood at immediate or delayed free recall	↓ delayed free recall if mood at encoding and retrieval is inconsistent (i.e. sad-hap or hap-sad vs. sad-sad or hap-hap or neutral-neutral)		
(Ruci, et al., 2009)	Immediate free recall and recognition memory	Neutral, negative, and positive words (auditory)	Words semantically associated to task-relevant words (critical lures)	No main effects of mood reported	No main effects of mood reported	-↑ free recall and false recognition of negative critical lures (vice versa for happy MIP and positive critical lures)	N/A	No difference in false recognition, recall, or remember judgements of neutral critical lures across mood states
(Siemer, 2001; study 1)	Appraisal and emotion judgments	Hypothetical emotional scenarios	N/A	N/A	N/A. Sad (versus angry and anxious) MIP: No effect of mood on emotion judgments or RT	N/A	N/A. Sad (versus angry and anxious) MIP: ↑ sadness appraisals	

First author	Task	Stimuli		Results: Mood		Results: Mood congruence		Results: General Impairment
		Task-related	Task-unrelated	Sad vs. Happy ³	Sad vs. Neutral ⁴	Sad vs. Happy ³	Sad vs. Neutral ⁴	Neutral stimuli
(Siemer, 2001; study 2)	As above	As above	As above	No main effects of mood	As above		As above. Also, no effect on sadness appraisals following happy MIP	
(Smallwood, et al., 2009)	Go/NoGo	Symbols	N/A	- ↑ errors of commission - ↓ post-error slowing - ↓ post-correct speeding - ↑ task un-related interference	- ↓ post-correct speeding	N/A	N/A	
(Stopa & Waters, 2005)	Maladaptive schemas	Young schema questionnaire short	N/A	↑ defectiveness (significant) and emotional deprivation (trend) ↓ entitlement	↑ defectiveness and emotional deprivation	N/A	N/A	
(Svaldi & Mackinger, 2003)	Autobiographical memory test	Neutral, negative, and positive cue words	N/A	N/A	N/A	- ↑ recall of negative memories - ↓ recall of positive memories	N/A	No difference in autobiographical memory for neutral words between sad and happy MIPs
(Van der Does, 2002)	Dysfunctional cognitions	Dysfunctional attitude scale	N/A	N/A	N/A. Sad MIP only: ↑ DAS pre versus post MIP; greater for previously than never depressed participants	N/A	N/A	
(Varner & Ellis, 1998; study 1)	Immediate free recall	Negative and writing-organisation words	N/A	N/A	No main effects of mood reported	N/A	↑ immediate free recall of negative vs. writing words (vs. schema MIP)	

First author	Task	Stimuli		Results: Mood		Results: Mood congruence		Results: General Impairment
		Task-related	Task-unrelated	Sad vs. Happy ³	Sad vs. Neutral ⁴	Sad vs. Happy ³	Sad vs. Neutral ⁴	Neutral stimuli
(Varner & Ellis, 1998; study 2)	Delayed free recall	As above	As above	As above	As above	As above	↑ delayed free recall of negative vs. writing words (vs. schema MIP)	
(Weaver & McNeill, 1992; study 1)	Sentence appraisal	Negative and positive sentences	N/A	No main effects of mood	N/A	No interaction effects	N/A	
(Weaver & McNeill, 1992; study 2)	As above	As above	As above	As above	As above	As above	As above	
(Wood, et al., 1990; study 1)	Sentences with missing words	Fill the blank with 'I', 'we', or 'they'	N/A	N/A	↑ self-focus (greater use of 'I')	N/A	N/A	
(Wood, et al., 1990; study 2)	Write thoughts	N/A	N/A	No effect of mood	↑ self-focus (more internal than external focused thoughts)	N/A	N/A	
(Yeung, et al., 2006)	Autobiographical memory test (Wood, et al.)	Neutral, negative, and positive cue words	N/A	Not assessed	↓ autobiographical memory specificity (AMS)	Not assessed. Data were collapsed across neutral, negative and positive cue words		

D. Mood induction Procedures: Instructions and Statements

Neutral MIP instructions

Screen 1: Please read each of the statements silently to yourself.

Screen 2: Go over each statement again and again in your head, and concentrate your full attention on it.

Screen 3: Do you have any questions?

Neutral MIP statements

- 1 There are 60 minutes in one hour.
- 2 A nerve cell fires rapidly.
- 3 Manchester is in the United Kingdom.
- 4 Strawberries are picked in the summer.
- 5 Basket weaving was invented before pottery making.
- 6 Some baseball bats are made from the wood of the ash tree.
- 7 The Shakers invented the circular saw.
- 8 It snows in Scotland.
- 9 Perennials bloom every year.
- 10 Arizona has both deserts and pine-covered mountains.
- 11 You have to take the ferry to get to the island.
- 12 London is the capital of England.
- 13 Elephants carried the supplies.
- 14 The Pacific Ocean has fish.
- 15 Most secondary schools have a choir.
- 16 The rug was made according to an old Indian pattern.
- 17 Some think that electricity is the safest form of power.
- 18 Most oil paintings are done on canvas.
- 19 Many buildings in Washington were made of marble.
- 20 Corn is sometimes called maize.
- 21 An orange is a citrus fruit.
- 22 Some say that ladybirds are good for the garden.
- 23 New York City is in New York State.
- 24 Diamonds really can cut glass.
- 25 Some chimps have been taught to use sign language.

Sad MIP instructions

Screen 1: You are going to hear some music at the same time as reading statements, one at a time, over a period of several minutes.

Both the music and statements represent a certain mood.

Screen 2: Please read each of the statements silently to yourself.

Go over each statement again and again in your head, and concentrate your full attention on it.

Screen 3: Experience each statement as if it were written for you, with the determination and willingness to really believe it.

Always try to respond to the feeling suggested by each statement.

Sad MIP statements

- 1 I feel a little down today.
- 2 My classes are harder than I expected.
- 3 Everyone else seems to be having more fun.
- 4 Sometimes I feel so guilty that I can't sleep.
- 5 I wish I could be myself, but nobody likes me when I am.
- 6 Today is one of those days when everything I do is wrong.
- 7 I doubt that I'll ever make a contribution in the world.
- 8 I feel like my life's in a rut that I'm never going to get out of.
- 9 My mistakes haunt me, I've made too many.
- 10 Life is such a heavy burden.
- 11 I'm tired of trying.
- 12 Even when I give my best effort, it just doesn't seem to be good enough.
- 13 Nobody understands me or even tries to.
- 14 I don't think things are ever going to get better.
- 15 I feel worthless.
- 16 What's the point of trying?
- 17 My parents don't know who I am.
- 18 When I talk no one really listens.
- 19 I feel cheated by life.
- 20 Why should I try when I can't make a difference anyway?
- 21 Sometimes I feel really guilty about the way I've treated my parents.
- 22 Every time I turn around, something else has gone wrong.
- 23 I'm completely alone.
- 24 There is no hope.
- 25 I feel I am being suffocated by the weight of my past mistakes.

Happy MIP instructions

Screen 1: You are going to hear some music at the same time as reading statements, one at a time, over a period of several minutes.

Both the music and statements represent a certain mood.

Screen 2: Please read each of the statements silently to yourself.

Go over each statement again and again in your head, and concentrate your full attention on it.

Screen 3: Experience each statement as if it were written for you, with the determination and willingness to really believe it.

Always try to respond to the feeling suggested by each statement.

Happy MIP statements

- 1 Being in college makes my dreams more possible.
- 2 The world is full of opportunity and I'm taking advantage of it.
- 3 I know if I try I can make things turn out fine.
- 4 I bet things will go well for the rest of the day.
- 5 When I have the right attitude, nothing can depress me.
- 6 Most people like me.
- 7 I've got some good friends.
- 8 I can make things happen.
- 9 My parents brag about me to their friends.
- 10 I know I can get the things I want in life.
- 11 My future is so bright I've got to wear shades.
- 12 I feel creative.
- 13 Nothing can bum me out now.
- 14 Things look totally awesome.
- 15 The relationships I have now are the best I've ever had.
- 16 It doesn't get any better than this.
- 17 I can make any situation turn out right.
- 18 I feel completely aware.
- 19 I'm in charge of my life and I like it that way.
- 20 Life's a blast; I can't remember when I felt so good.
- 21 I'm going to have it all!
- 22 When it comes right down to it, I'm just too cool.
- 23 I know I can do it; I'm going to seize the day!
- 24 I'm energized.
- 25 It's great to be alive!

E. Profile of Mood States questionnaire: Inductive reasoning

The original 65-item Profile of Mood States (POMS; McNair, 1992) questionnaire. Items highlighted in yellow are those included in the shortened (17-item) version of the POMS.

P.O.M.S. (65)

Name _____ Date _____

I.D. No _____ Time 1 2 3 4 5

Below is a list of words that describe feelings people have. Please read each one carefully. Then circle one number, which best describes HOW YOU ARE FEELING RIGHT NOW

0 = not at all; 1 = a little; 2 = moderately; 3 = quite a lot; 4 = extremely

Friendly	0 1 2 3 4	Tense	0 1 2 3 4	Angry	0 1 2 3 4
Worn Out	0 1 2 3 4	Unhappy	0 1 2 3 4	Clear-headed	0 1 2 3 4
Lively	0 1 2 3 4	Confused	0 1 2 3 4	Sorry for things done	0 1 2 3 4
Shaky	0 1 2 3 4	Listless	0 1 2 3 4	Peeved	0 1 2 3 4
Considerate	0 1 2 3 4	Sad	0 1 2 3 4	Active	0 1 2 3 4
On edge	0 1 2 3 4	Grouchy	0 1 2 3 4	Blue	0 1 2 3 4
Energetic	0 1 2 3 4	Panicky	0 1 2 3 4	Hopeless	0 1 2 3 4
Relaxed	0 1 2 3 4	Unworthy	0 1 2 3 4	Spiteful	0 1 2 3 4
Sympathetic	0 1 2 3 4	Uneasy	0 1 2 3 4	Restless	0 1 2 3 4
Unable to concentrate	0 1 2 3 4	Fatigued	0 1 2 3 4	Helpful	0 1 2 3 4
Annoyed	0 1 2 3 4	Discouraged	0 1 2 3 4	Resentful	0 1 2 3 4
Nervous	0 1 2 3 4	Lonely	0 1 2 3 4	Miserable	0 1 2 3 4
Muddled	0 1 2 3 4	Cheerful	0 1 2 3 4	Bitter	0 1 2 3 4
Exhausted	0 1 2 3 4	Anxious	0 1 2 3 4	Ready to fight	0 1 2 3 4
Good natured	0 1 2 3 4	Gloomy	0 1 2 3 4	Desperate	0 1 2 3 4
Sluggish	0 1 2 3 4	Rebellious	0 1 2 3 4	Helpless	0 1 2 3 4
Weary	0 1 2 3 4	Bewildered	0 1 2 3 4	Alert	0 1 2 3 4
Deceived	0 1 2 3 4	Furious	0 1 2 3 4	Efficient	0 1 2 3 4
Trusting	0 1 2 3 4	Full of pep	0 1 2 3 4	Bad-tempered	0 1 2 3 4
Worthless	0 1 2 3 4	Forgetful	0 1 2 3 4	Carefree	0 1 2 3 4
Terrified	0 1 2 3 4	Guilty	0 1 2 3 4	Vigorous	0 1 2 3 4
Uncertain about things	0 1 2 3 4	Bushed	0 1 2 3 4		

F. Participant questionnaire: Inductive reasoning

Debrief questions given to participants at the end of the experimental procedures. The wording in the last section was altered according to participants' MIP group in Experiment one i.e. negative or positive.

Subject ID: _____		Date: _____				
<i>Participant information</i>						
Age: _____						
Gender: _____						
Please circle highest educational qualification attained:						
CSE	HNC	HND	GCSE/O Level	A Level	Degree	Postgraduate
Other: _____						
Please circle ethnic group:						
Asian	Black	Chinese	White	Mixed		

<i>We would like to ask you a few questions about the task.</i>						
1. How did you make your decisions about which jar the beads were drawn from?						
2. Did you notice any difference between the two beads tasks?						
3. Were there any differences in the way that you made your decisions between the two tasks?						
4. Did you have any difficulties distinguishing between the coloured beads?						
5. Using a scale of 1 to 5 where 1 = not very confident at all and 5 = very confident, how confident are you in understanding probabilities?						

<i>We would also like to ask you a few questions about the second (i.e. negative) mood induction procedure.</i>						
1. How did the negative mood induction procedure make you feel?						
2. Do you think that the negative mood induction procedure had an effect on your task performance, and if so, what was the effect?						
3. Do you feel as though there are any lasting effects of the negative mood induction procedure?						

Thank you for your participation!						

G. Power calculation: Inductive reasoning task, Experiment three

This experiment was designed to act as a control experiment using a smaller sample of participants to enable an investigation of the influence of the order of MIPs on task performance; therefore a power calculation was performed. A statistical power analysis programme (G*Power; <http://www.psych.uni-duesseldorf.de/aap/projects/gpower/>) was used to obtain the required sample size for Experiment three comparing the number of beads drawn before deciding in the 85:15 probability condition for neutral and angry face trials, following neutral and sad mood induction, in a within-subjects design. Results from Experiment two were used for the 28 participants in the angry face condition. The power calculation determined that a sample size of 14 in Experiment three would have 81% power ($\alpha = 0.05$, one-tailed) to yield a statistically significant result (see Figure 1).⁵

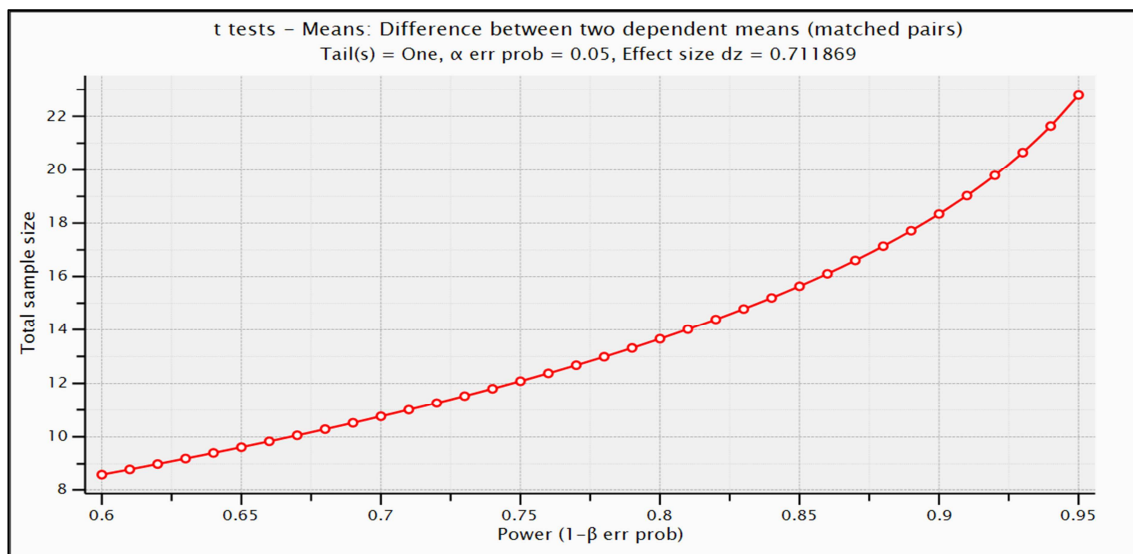


Figure 1: Total sample size as a function of Power that is required to yield statistically significant results in Experiment three.

⁵ Similarly, using results from Experiment one, the power calculation determined that a sample size of ten in Experiment three would have 83% power ($\alpha = 0.05$, two-tailed) to yield a statistically significant result whereas a sample size of 14 gave 95% power.

H. A summary of the theoretical accounts of the attentional blink effect

An initial filter-based theory proposed that the Attentional Blink (AB) effect reflects a gating mechanism regulating the flow of visual information at the post-perceptual stage of processing (Raymond, Shapiro, & Arnell, 1992). The temporary suppression of the visual processing of a second target (T2) occurs because when an item (e.g. a distractor) immediately follows the first target (T1), the *features* (e.g. colour and categorical identity) of both of these items are processed simultaneously. The greater the similarity between these two items, the greater the confusion (of matching the features of targets and distractors e.g. white and letter = target, black and letter = distractor) at the stage of identification. This leads to the gate shutting thus a period of attentional blink impairing the detection and identification of T2. Such theories can explain why the AB effect disappears when a blank interval proceeds T1 as well as accounting for the unimpaired identification of T2 when presented immediately after T1 (which later became known as lag-1 sparing). The same researchers that proposed the initial filter-based model, later presented an alternative interference model given the results of their subsequent experiments demonstrating that AB effect occurred when participants were asked to *either identify or detect T1* (Shapiro, Raymond, & Arnell, 1994). This model supposes that there is a template for targets predicting their entry into visual short term memory. However, the item immediately following T1 (i.e. a distractor) is also likely to enter visual short term memory due to its temporal proximity to the target item. Hence was it suggested that competition between T1 and the first post-T1 distractor at the stage of retrieval reduces capacity available to process T2 thus causing the AB effect. This model can account for the finding that the AB effect disappears when T1 is followed by a blank interval rather than distractor item (Raymond, et al., 1992) as well as the phenomenon of lag-1 sparing. As a result of their findings from an MEG experiment, a similar resource sharing model was proposed according to which the AB effect is

influenced by the amount of attentional processing resources allocated to T1 and therefore subsequently available for T2 (Shapiro, Schmitz, Martens, Hommel, & Schnitzler, 2006). Specifically, individuals that allocate fewer attentional processing resources to T1 have more resources available to enable better at detection/identification of T2. This allocation of resources can be voluntary (i.e. strategic) or involuntary (i.e. influenced by attentional capture by the stimulus). In contrast to the predictions of the capacity-limited models, Di Lollo et al. (2005) conducted a series of experiments showing no AB effect when participants were required to identify three targets presented consecutively but did find an AB effect when the two targets were separated by a distractor item. The authors present a more recent filter-based theory, according to which the AB effect reflects an interruption to a control mechanism that is limited by the number of tasks that can be performed concurrently. A top-down, endogenous control mechanism dedicated to a single task (i.e. detection of T1 in the first instance and T2 in the second) is configured to suppress or ignore distracters and prioritise detection of T1. Once T1 is detected this endogenous control mechanism becomes dedicated to the processing of T1 at the expense of ignoring distracters, and bottom-up (i.e. stimulus-based) exogenous control ensues. Under exogenous control, if the stimulus that immediately proceeds T1 is the same category as T1 (i.e. a target) then it will be processed, as it matches the initial configuration of the endogenous mechanism. If, however, the item does not match (i.e. a distractor) there will be an exogenous change such that the system is no longer configured to detect stimuli that match the T1 category. In this case, the deficit in detecting T2 remains until T1 has been fully processed at which stage the top-down, endogenous mechanism regains control. This theory is able to account for the U-shaped trend in the accuracy of T2-reporting which encompasses lag-1 sparing and recovery at longer lags.

In contrast to the filter-based model proposed by Raymond et al. (1992), subsequent research showed that the AB effect occurred when targets and distractors were distinguished from one another by a single feature (categorical identity e.g. letters and digits), thus suggesting that

confusion of features (e.g. colour and categorical identity) at the stage of identification does not account for the AB effect (Chun & Potter, 1995). Therefore Chun & Potter (1995) proposed an alternative, two-stage or bottleneck, model to account for the AB effect. According to this model, at the first stage the features of stimuli are detected but these initial representations are short-lived. Selective attention is the proposed mechanism that initiates selection of information, that (probably) matches templates for target stimuli, for further processing and consolidation in working memory (stage 2), which is required to enable subsequent report of the target stimuli. Selective attention is necessary due to the limited capacity of stage 2. The timing of this selective attention mechanism allows both T1 and stimuli immediately following T1 (i.e. distractors or T2 at lag 1, hence accounting for lag-1 sparing) to enter stage 2. When it is more difficult to discriminate targets (i.e. T1) from distractors (i.e. post-T1 item), stage 2 takes longer. No other subsequent stimuli can reach stage 2 until the processing and consolidation of T1 and the post-T1 item has been completed. Given the assumption that initial representations in stage 1 are transient, when the duration of stage 2 exceeds the interval between T1 and T2 (stimulus onset asynchrony; SOA) the processing of T2 at stage 2 will be delayed and the longer the delay the more likely that T2 will be lost therefore not processed at stage 2 at all and consequently not available for subsequent report. The boost and bounce theory (Olivers & Meeter, 2008) is an alternative two-stage model and holds many similarities to the initial filter-based theory (Raymond, et al., 1992). As in Chun & Potter's model (1995), the two stages involve sensory processing and working memory. However these stages encompass interacting rather than sequential processes. Further, the model does not assume that the AB reflects any capacity limitations of working memory, although it does acknowledge its existence (limit set at five items). At the stage of sensory processing representations of both perceptual (e.g. colour) and higher-order (e.g. semantic) features/information are activated. Working memory stores these representations and uses a gating mechanism (which also featured in the model by Raymond, et al., 1992) to compare

representations with an attentional set (a predefinition of targets and distractors generated at the time of receiving task instructions). Enhancement of processing (excitatory feedback of gating neurons on sensory neurons 'boosts' sensory representations) occurs when a stimulus is deemed task-relevant i.e. the representation matches the attentional set (e.g. T1), whereas inhibition (inhibitory feedback of gating neurons on sensory neurons 'bounces' sensory representations) preventing access to the working memory store occurs when a stimulus is deemed task-irrelevant i.e. the representation does not match the attentional set (a distractor). When there is a greater difference between the target and distractors there is stronger bottom-up activation (sensory evidence), thus reducing the need for the gating mechanism, therefore reducing the AB effect. Indeed researchers have previously demonstrated that the magnitude of the AB is reduced alongside increasing dissimilarity between target and distractor items (Chun & Potter, 1995; Raymond, et al., 1992). Similarly to the model assumptions of Raymond et al. (1992) and Chun & Potter (1995), the post-T1 item is boosted at the same time as T1 due to their temporal proximity. In contrast, however, this model does not suggest that the post-T1 distractor item causes confusion or increased processing time. Rather there is a temporal delay of the boost such that the post-T1 item receives a larger boost than T1. In order to prevent the post-T1 distractor item entering the working memory store, there is transient inhibition or bounce such that all stimuli subsequently presented to the input filter are bounced. As this inhibition is transient, performance improves with an increased T1-T2 interval. Accordingly, and unlike other some models, the boost and bounce theory incorporates explanations of the AB effect and lag-1 sparing.

I. Selection methods and psycholinguistic properties of rapid serial visual presentation (RSVP) paradigm word stimuli

i. Methods for selecting RSVP paradigm emotional word stimuli

A total of 460 emotional words were identified using the methods outlined in Figure 2. After this any repeated words were removed (N=430). The remaining words were entered into the MRC Psycholinguistic Database (Wilson, 1988). Those that had information available for familiarity, frequency norms, meaningfulness norms, and number of letters were retained (N=110). One word was removed as this was an outlier for frequency norms ('life') and another word was removed as it appeared in both the positive and neutral word lists ('pious'). All words with more than nine letters were removed leaving a total of 99 (50 negative and 49 positive) words. For a list of words see Figure 3.

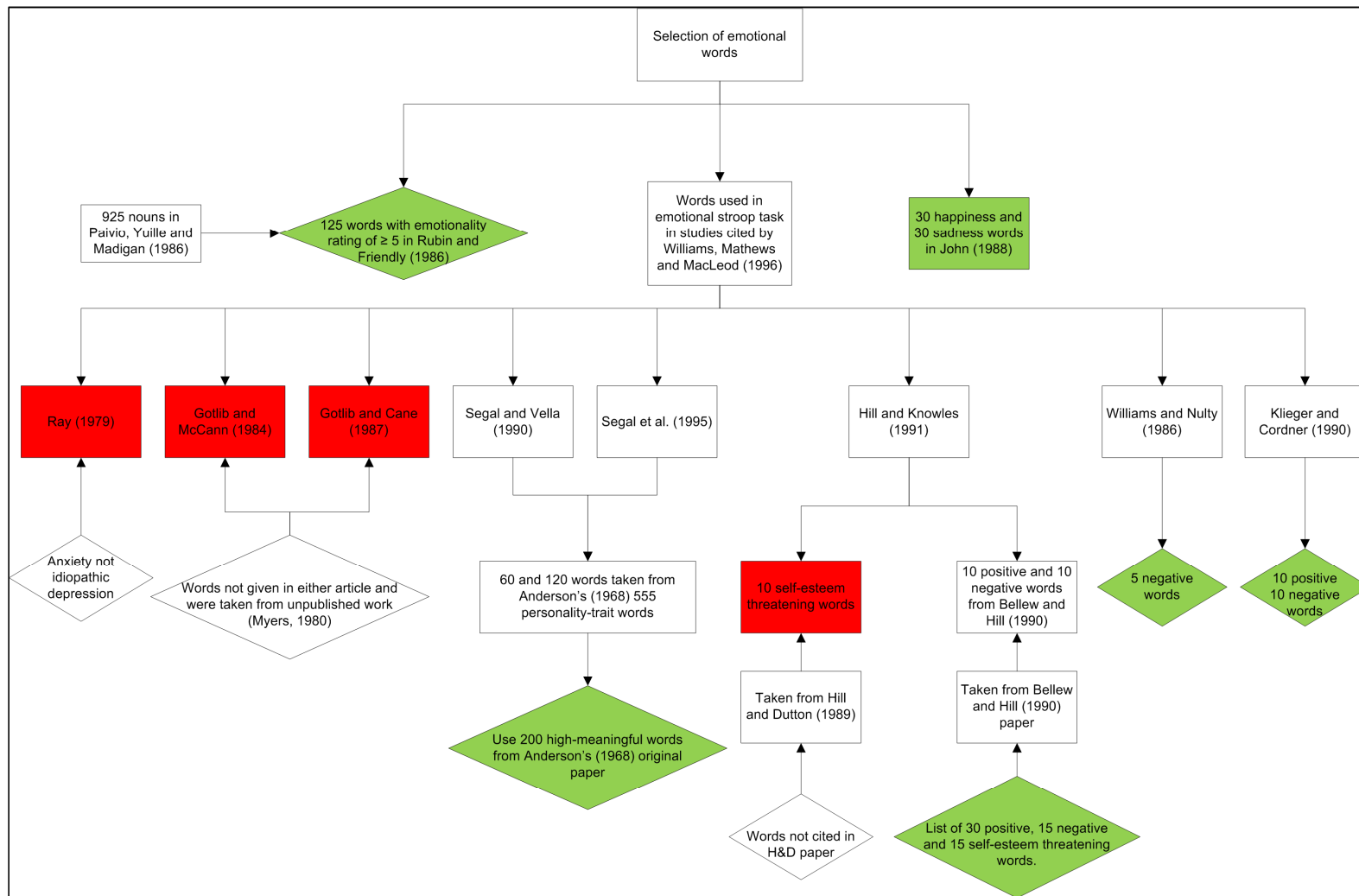


Figure 2: Flow diagram demonstrating selection of emotional words

	Neutral T1		Neutral T2	Negative T2	Positive T2	Distractors	
Academy	Iron	Sugar	Angle	Agony	Alert	RVTGC	FHGDQ
Air	Jacket	Sulphur	Author	Anger	Baby	SPHQD	NHDXS
Apple	Journal	Table	Banker	Ashamed	Belief	BNWZL	ZPVCT
Arm	Keen	Ticket	Barrel	Bad	Bright	MVSCQ	VKTXG
Bacteria	Kerosene	Toast	Basement	Blood	Calm	NWGTZ	MZFQN
Bagpipe	Kettle	Tobacco	Beauty	Clumsy	Charm	LZPVN	SJDCQ
Bard	Knife	Tool	Coin	Cold	Cheerful	VGKWJ	FVXTD
Beaver	Knight	Tree	Cord	Cowardly	Clever	CNMKP	SVFQN
Board	Lad	Tripod	Corner	Crime	Dream	KNBDH	GHSDW
Book	Lawn	Umbrella	Dirt	Cruel	Eager	ZLGTX	ZNVQF
Boulder	Lemon	Vest	Dress	Cry	Fantasy	NWJRH	GPKBH
Bowl	Lemonade	Village	Elephant	Danger	Fate	TZXHV	KTHSZ
Bread	Lime	Vote	Fact	Death	Frank	GQSJB	XKBRM
Building	Lobster	Wheat	Fashion	Deceit	Freedom	ZWJHG	FDMSB
Butter	Mail	Willow	Fox	Despair	Friend	WFPKM	
Car	Maple	Window	Frog	Fault	Generous	QCHZK	
Cat	Meat	Yellow	Gender	Fire	Glory	CKVRF	
Cell	Meeting	Zero	Hairpin	Flood	Happy	TBJKF	
Cellar	Metal	Zone	Hour	Gloom	Hope	LGXNQ	
Chair	Method		Insect	Grave	Intimate	PMVRS	
Chicken	Mosquito		Item	Greedy	Joy	BSGTP	
Cigar	Moss		Jelly	Grief	Justice	QPLBM	
Circle	Mule		Juice	Guilt	Kind	ZNMKL	
Coffee	Nursery		Lens	Hostage	Kiss	SQNVG	
Colony	Onion		Library	Hunger	Lord	XTMHC	
Contract	Oven		Limb	Hurt	Love	BTCGZ	
Corn	Owner		Locker	Lazy	Mother	ZMXVP	
Cost	Oxygen		Magazine	Liar	Neat	NHBLV	
Cotton	Paper		Mast	Mean	Obedient	XNMJV	
Door	Peach		Molecule	Misery	Orderly	SWMBZ	
Dust	Pen		Mucus	Morgue	Passion	MKWGT	
Engine	Plant		Neck	Murder	Peace	VDHPR	
Eternal	Potato		Oyster	Nervous	Peaceful	XJLMT	
Fan	Proxy		Palm	Pain	Polite	SZGJP	
Fork	Pupil		Pencil	Panic	Power	BJDXK	
Form	Quick		Pepper	Punish	Praise	DNKGC	
Fowl	Rapid		Pipe	Rain	Prayer	NLPRB	
Fur	Restore		Plain	Ridicule	Pride	WCNTR	
Gallery	Rod		Pole	Robbery	Proud	CPSMK	
Gist	Seat		Property	Sad	Quiet	PDJQB	
Grass	Shallow		Quarter	Shame	Smile	MHKTJ	
Green	Ship		Recruit	Shriek	Soul	WHZNC	
Hall	Sillet		Research	Solemn	Sunset	HCLPT	
Hammer	Soil		Rock	Tempest	Thrifty	KJWSZ	
Harness	Spinach		Skin	Tense	Tidy	PQBSW	
Heel	Spray		Slipper	Tire	Tolerant	DMPCJ	
Horse	Square		Street	Tragedy	Truth	FVPMW	
Hotel	Steam		Tank	Trouble	Victory	SKJXG	
Infinite	Stone		Tray	Ugly	Woman	FRKQJ	
Ink	String		Uncle	Worse		JPKFM	

Figure 3: List of T1 neutral, T2 neutral, T2 negative, and T2 positive words

ii. MRC Psycholinguistic database

Data for familiarity, frequency, number of letters (≤ 8) and meaningfulness were obtained using the MRC Psycholinguistic Database (Wilson, 1988) and are presented in Table 1. A one-way ANOVA was used to test for differences in each of these measures between the four categories of words (T1 neutral, T2 neutral, T2 negative, and T2 positive). There were no significant differences for number of letters [$F_{(3, 267)}=0.69$, $p=0.559$], familiarity [$F_{(3, 267)}=0.75$, $p=0.526$] or frequency [$F_{(3, 267)}=1.51$, $p=0.214$]. Bonferroni corrected post-hoc tests showed that there were significant differences in meaningfulness [$F_{(3, 267)}=8.89$, $p<0.001$]. T2 neutral words had lower meaningfulness ratings than both T2 negative ($p=0.024$) and T2 positive ($p=0.002$) words. Similarly, T1 neutral words had lower meaningfulness ratings than T2 negative and positive words; $p=0.004$ and $p<0.001$, respectively. Importantly, there were no significant differences in meaningfulness ratings for T1 and T2 neutral words ($p=1.000$) or T2 negative and positive words ($p=1.000$).

	Words (N)	Letters (N)	Frequency	Familiarity	Meanfulness
T1 neutral	119	5.25 (1.40)	52.46 (69.51)	530.69 (68.88)	439.14 (53.57)
T2 neutral	50	5.44 (1.45)	48.90 (76.03)	531.90 (46.97)	438.88 (51.86)
T2 negative	50	5.34 (1.26)	45.04 (59.98)	529.94 (48.87)	469.08 (48.33)
T2 positive	49	5.57 (1.37)	72.84 (80.85)	544.24 (41.14)	476.49 (52.02)

Table 1: Mean and standard deviation of the psycholinguistic properties of T1 and T2 word stimuli

iii. Participant survey

To further validate the meaningfulness ratings for T1 and T2 word stimuli, 21 participants who had been screened as healthy volunteers responded to an online survey (<http://www.kwiksurveys.com/>). All word stimuli were presented in a random order and participants were asked to rate each word on a 5-point scale: very negative (1), slightly negative (2), neutral (3), slightly positive (4), and very positive (5). All participants gave T2

negative words the lowest ratings, T2 positive words the highest ratings, and T1 neutral and T2 neutral words were intermediate (see Figure 4).

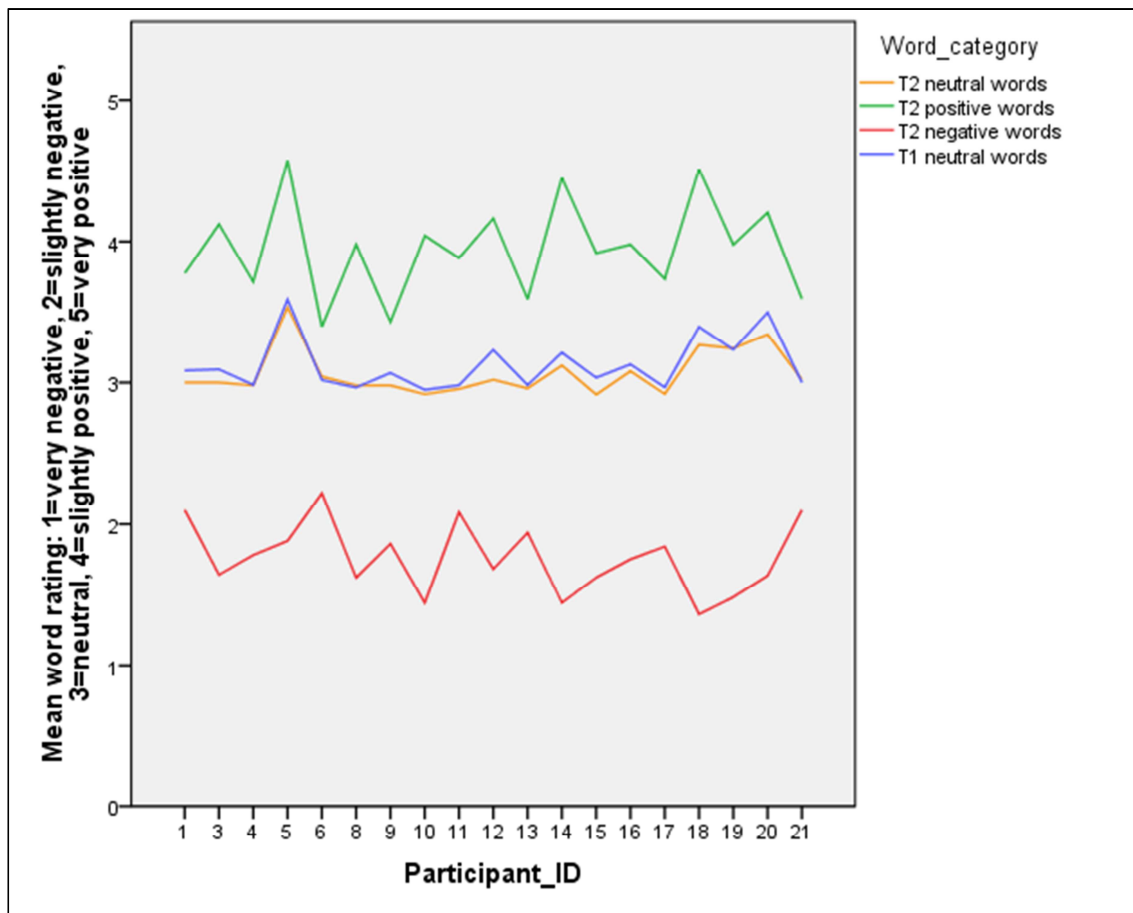


Figure 4: Mean of individual participant responses to words in the different categories

Data from 2 participants were excluded from the analysis as they did not complete more than half of the survey.

A repeated-measures ANOVA was conducted on meaningfulness ratings with participants (N=19) as the within-subjects factor and word category as the between-subjects factor. There was a main effect of Participant ID [$F_{(11.332, 2345.683)}=10.62, p<0.001$], which was qualified by Participant ID * word category effect [$F_{(33.995, 2345.683)}=6.943, p<0.001$]. This demonstrates that different participants gave different ratings across the word categories. However, all participants showed the same pattern of differences in meaningfulness ratings for the four word categories, which was demonstrated by a significant effect of word category [$F_{(3,$

207]=217.769, $p<0.001$]. Bonferroni post-hoc tests revealed that participants rated T2 negative words as significantly more negative than T1 neutral, T2 neutral and T2 positive words; $p's<0.001$ (see Figure 5). T2 positive words were rated as significantly more positive than T1 neutral, T2 neutral, and T2 negative words; $p's<0.001$. There were no differences between T1 neutral and T2 neutral words ($p=1.000$).

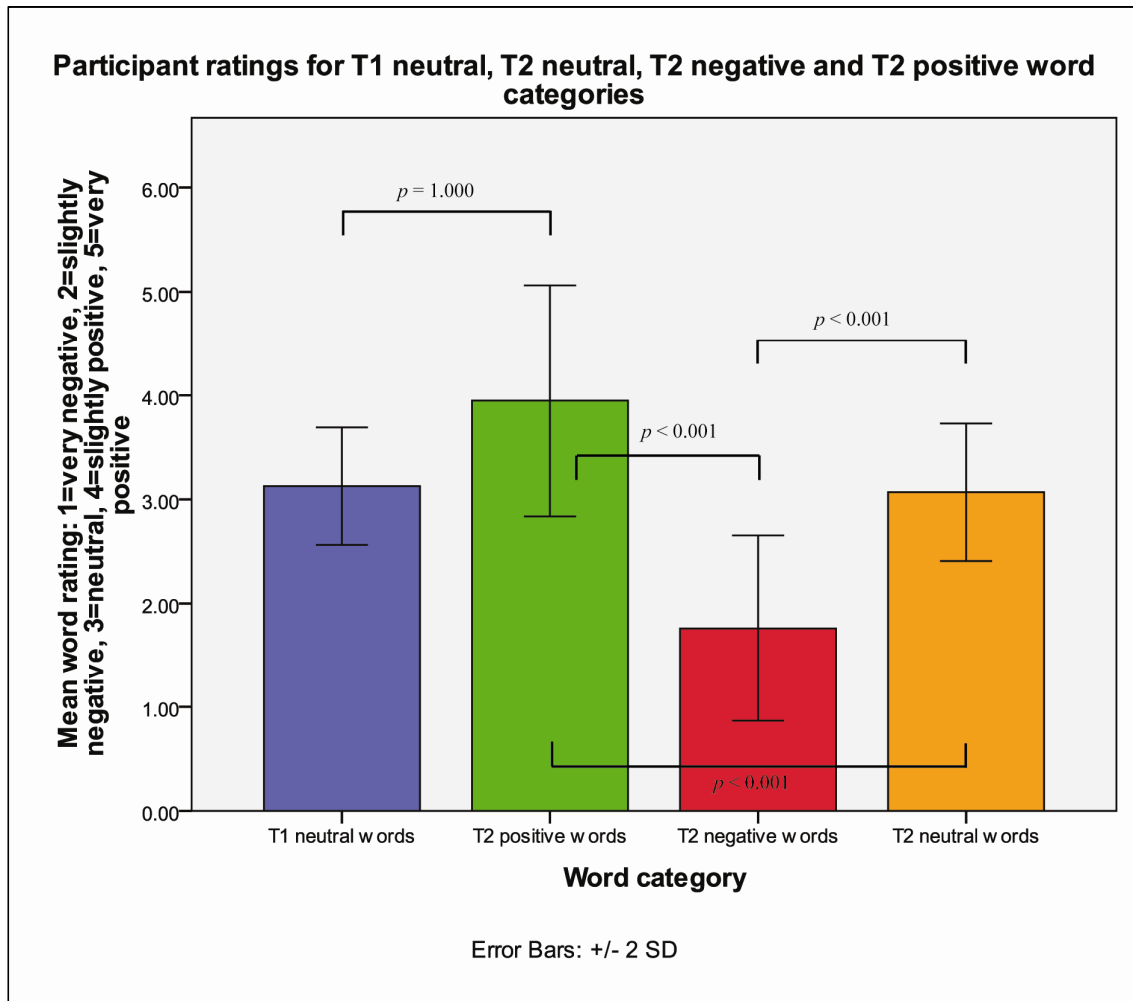


Figure 5: Mean negative-positive ratings for T1 and T2 word categories across 19 participants

Due to some missing values, participant ratings for 90 T1 neutral, 36 T2 neutral, 44 T2 negative and 41 T2 positive words were included in the analysis.

iv. Affective Norms for English Words database

In addition to using the MRC Psycholinguistic Database and participant survey, those T1 and T2 word stimuli with ratings in the Affective Norms for English Words (ANEW; M. M. Bradley & Lang, 2010) database were compared for valence and arousal ratings of the word categories; see Table 2 and Figure 6.

	Valence	Arousal
T1 neutral	5.40 (1.53)	4.20 (2.15)
T2 neutral	5.39 (1.45)	4.21 (2.07)
T2 negative	2.79 (1.61)	5.57 (2.36)
T2 positive	7.32 (1.59)	5.43 (2.47)

Table 2: Mean and standard deviation of the valence and arousal ratings (ANEW database) of T1 and T2 word stimuli

Data were available for 72/119 T1 neutral, 32/50 T2 neutral, 45/50 T2 negative and 41/49 T2 positive words.

A one-way ANOVA was used to test for differences in valence and arousal ratings between the four categories of words stimuli. There were significant differences between these categories for both valence [$F_{(3, 188)}=193.563$, $p<0.001$] and arousal ratings [$F_{(3, 188)}=27.998$, $p<0.001$]. Bonferroni corrected post-hoc tests demonstrated no differences in either valence ($p=1.000$) or arousal ($p=1.000$) ratings between T1 and T2 neutral words. There were differences in valence ($p<0.001$) but not arousal ($p=1.000$) ratings between T2 negative and positive words. T2 negative words were rated more unpleasant than T2 positive words. Finally, both T2 negative and positive words differed from T1 and T2 neutral words for valence and arousal ratings (p 's <0.001).

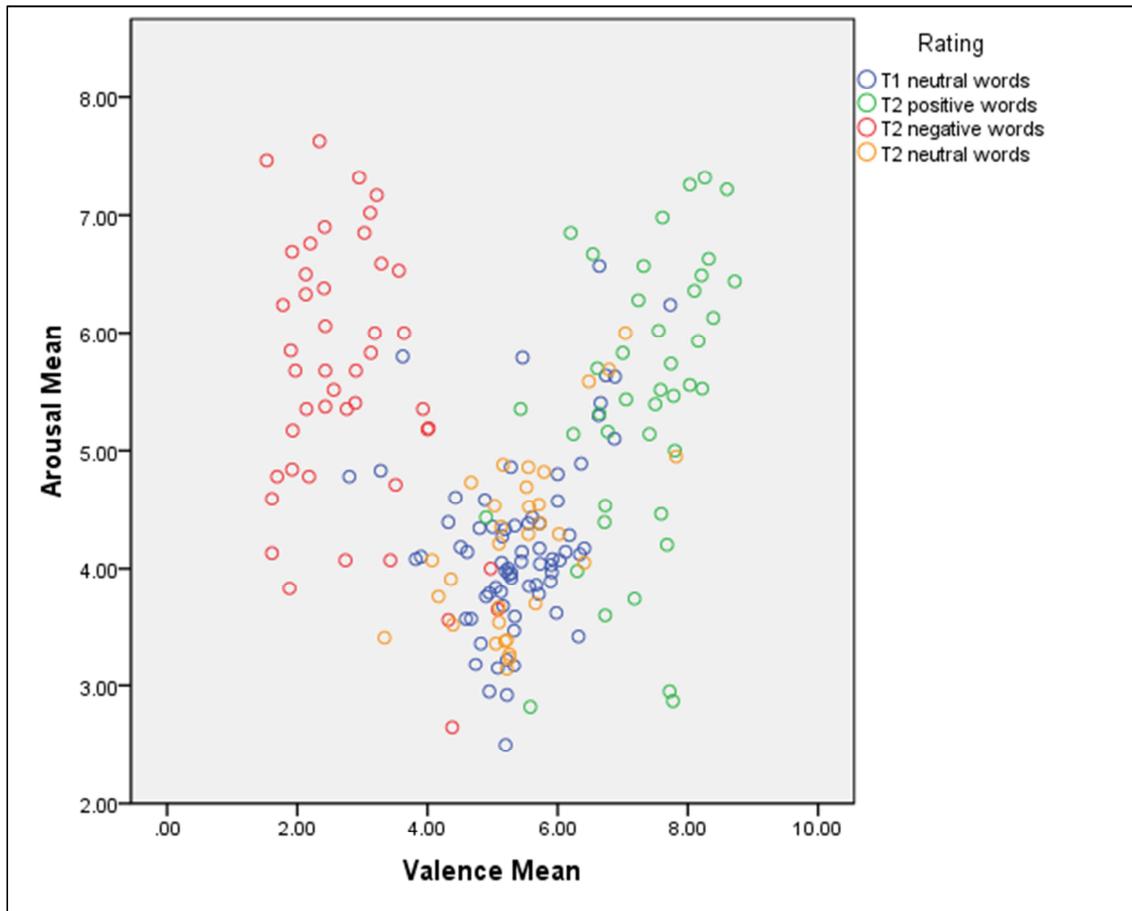


Figure 6: ANEW valence and arousal ratings for T1 Neutral, T2 Neutral, T2 Negative, and T2 Positive words in two-dimensional space

Valence and arousal ratings were made on 9-point scales ranging from unpleasant (valence = 0) to pleasant (valence = 9) and calm (arousal = 0) to excited (arousal = 9).

Number (and percentage) of words used in RSVP paradigm with corresponding valence and arousal ratings in the ANEW database were 72/119 (60.50%), 32/50 (64%), 45/50 (90%), and 41/49 (83.67%) for T1 Neutral, T2 Neutral, T2 Negative, and T2 Positive, respectively.

J. Pilot experiments: RSVP paradigm

i. Methods and results of pilot experiment one

Participants

Behavioural piloting was conducted with 34 participants during the initial screening procedure for participation in the MEG experiment.

Methods

A computerised version of a rapid serial visual presentation (RSVP) paradigm was used. All stimuli were presented on a black background in the centre of a computer screen (with a 60Hz refresh rate). Similar to previous studies using RSVP paradigms, targets were neutral words distinguished from the distractors by the same physical feature, namely colour. The targets were presented for 33ms in yellow (T1) and green (T2) ink. Distractor items were the semi-random arrangements of diamonds and square shapes as used by Dehaene et al. (2001) presented in gray ink. The onset of T1 and T2 were separated by two distractors; the distractor immediately following T1 for 33ms and the distractor presented prior to T2 for 184 or 602ms in the short and long SOA trials, respectively. These two masks collectively created a T1-T2 SOA of 217 and 635ms in the short and long trials, respectively. Two distractors were presented prior to T1 and after T2, each for 33ms. For an example of the stimulus stream see Figure 7. Immediately after the stimulus stream participants were asked to identify T2 in the single task, whereas in the dual task they were asked to first identify T1 and then identify T2. Participants were allowed 1,500ms to respond to these two alternative forced choice (2AFC) questions before the computer automatically began the next trial. The order of the tasks (single then dual or dual then single) was counter balanced across participants with 17 participants in each group. There were a total of 108 trials in each of the single and dual tasks. There were 54 trials

in each of the short and long SOA conditions; in 40 of those T2 was present, whereas T2 was absent in the remaining 14 (see Table 3).

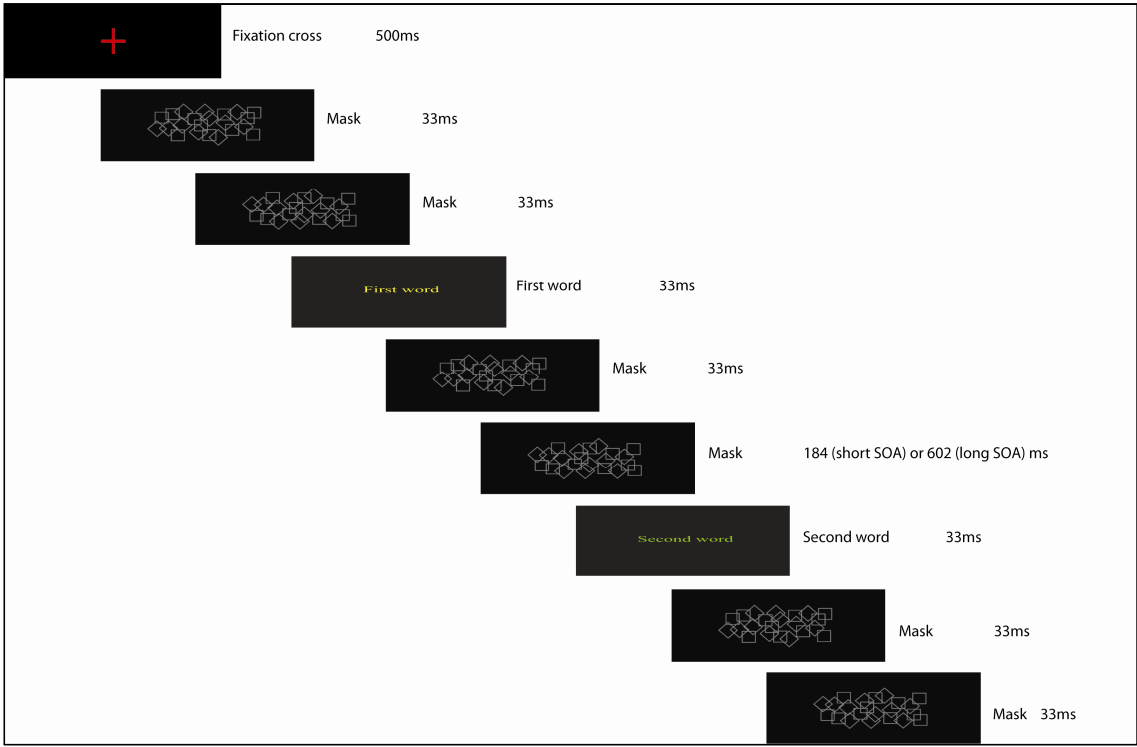


Figure 7: Example of the rapid serial visual presentation (RSVP) paradigm used in pilot experiments one, two, and three

Task	Duration	T2 word valence	Experiment one	Experiment two	Experiment three		Experiment four	
					2AFC	Confidence	2AFC	Confidence
Single	Short	Neutral	40	40	40	-	40	-
		Negative	-	-	40	-	40	-
		Positive	-	-	40	-	40	-
	Long	Neutral	40	40	20	-	20	-
		Negative	-	-	20	-	20	-
		Positive	-	-	20	-	20	-
Dual	Short	Neutral	40	40	40	10	40	10
		Negative	-	-	40	10	40	10
		Positive	-	-	40	10	40	10
	Long	Neutral	40	40	20	10	20	10
		Negative	-	-	20	10	20	10
		Positive	-	-	20	10	20	10

Table 3: Number of trials in each condition of the task for each of the four behavioural pilot experiments

Results and Discussion

Visual inspection of the data showed that participants were performing at near ceiling level (see Table 4).

Task	Duration	Word	Mean % correct responses	Standard Deviation	Minimum	Maximum
Single	Short	T2	97.15	4.37	83	100
	Long	T2	98.88	1.68	95	100
Dual	Short	T1	94.82	8.78	50	100
		T2	95.96	4.22	83	100
	Long	T1	95.86	9.83	43	100
		T2	98.46	2.95	88	100

Table 4: Descriptive statistics for the percentage of correct responses to the T1 and T2 questions in the single and dual task conditions in pilot experiment one

To test the presence of the AB effect, the outcome measure (percentage of correct T2 responses) was analysed in a parallel-groups repeated-measures ANOVA with *Task* (single and dual) and *Duration* (short and long) as the within-group factors and *Order of tasks* (single the dual or dual then single) as the between-group factor. There was a main effect of *Duration* [$F_{(1, 32)}=13.613, p=0.001$] such that participants made more correct responses in trials with the long

compared with short SOA. There was no main effect of *Task* [$F_{(1, 32)}=2.293, p=0.140$] or *Task by Duration* interaction [$F_{(1, 32)}=0.792, p=0.380$]. Importantly there were no main or interaction effects of *Order of tasks* thus suggesting that any effects were independent of the order that participants completed the tasks in. The same analysis was computed with the outcome variable reaction time to make a correct response. There was a main effect of *Duration* [$F_{(1, 33)}=13.452, p=0.001$] such that participants were slower to make responses in trials with the long compared with short SOA ($t_{(33)}=3.668; p=0.001$). Again, there was no main effect of *Task* [$F_{(1, 33)}=2.411, p=0.130$] or *Task by Duration* interaction [$F_{(1, 33)}=0.493, p=0.488$], nor any effect of *Order of tasks*. The results of these analyses demonstrate that although participants made fewer correct responses in trials with the short compared with long SOA, this effect did not differ between the single and dual task conditions, therefore did not show an AB effect.

To further investigate whether the AB effect was present, the outcome measure (percentage of correct T2 responses) was analysed in a parallel-groups repeated-measures ANOVA with *Word* (T1 and T2) and *Duration* (short and long) as the within-group factors and *Order of tasks* (single the dual or dual then single) as the between-group factor. There was a main effect of *Duration* [$F_{(1, 32)}=7.951, p=0.008$] such that participants made more correct responses in trials with the long compared with short SOA. There was no main effect of *Word* [$F_{(1, 32)}=1.321, p=0.259$] or a *Word by Duration* interaction [$F_{(1, 32)}=2.722, p=0.109$]. Again there were no main or interaction effects of *Order of tasks*. The same analysis was computed with the outcome variable reaction time to make a correct response. There was a main effect of *Duration* [$F_{(1, 32)}=31.084, p<0.001$] such that participants were slower to make responses in trials with the long compared with short SOA. Interestingly, there was a main effect of *Word* [$F_{(1, 32)}=472.328, p=0.001$] such that participants were faster to respond to T2 than T1. To examine whether the order of questions had an effect on reaction times, a linear regression analysis (enter method) was performed with “Reaction time to T2 in trials with the short SOA” as the dependent variable and “Reaction time to T1 in trials with the short SOA” as the independent predictor

variable for the dual task. The same analysis was performed for trials with the long SOA. These analyses demonstrated a significant linear relationships between reaction time to T1 and T2 in both trials with the short ($\beta = 0.73, p < 0.001$) and long ($\beta = 0.62, p < 0.001$) SOA, showing that participants were faster to respond to T2 when they had been previously required to respond to T1. It was therefore considered important to correct for this effect in the single task trials and thus equate the reaction time to T2 between the single and dual tasks. Accordingly linear transformations of reaction time to T2 in the single task was computed for trials with the short and long SOA using regression equations derived from the dual task experiment. Subsequently, a parallel-groups repeated-measures ANOVA with *Task* (single and dual) and *Duration* (short and long) as the within-group factors and *Order of tasks* (single the dual or dual then single) as the between-group factor was conducted using the outcome variable reaction time with the original data from the dual task and the newly computed data for the single task. There was a main effect of *Task* [$F_{(1, 33)} = 125.132, p < 0.001$] as well as an interaction of *Task by Duration* [$F_{(1, 33)} = 20.973, p < 0.001$] demonstrating that participants were slower to respond in the dual compared with single task and there was a greater discrepancy in reaction time between trials with the short and long SOA in the dual compared with single task (see Figure 8).

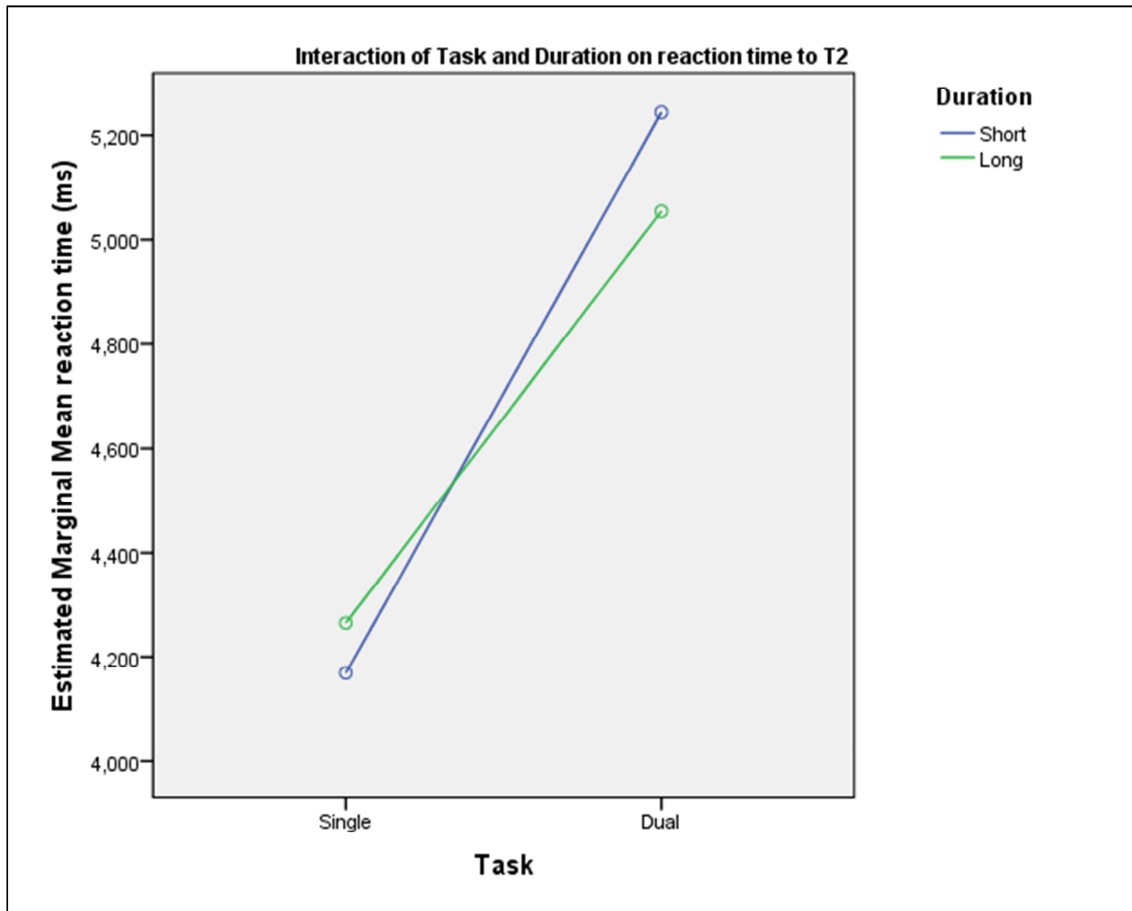


Figure 8: Interaction of task and duration on reaction time to the T2 question; $p < 0.001$

These data demonstrated that there was a significant effect of order of questions on reaction time to respond to the T2 question. It was therefore decided to invert the order of questions in the dual task so that reaction time to respond to the T2 becomes comparable between the dual and single tasks.

ii. Methods and results of pilot experiment two

Participants

Following experiment one, behavioural piloting was conducted with a further six participants.

Methods

The same RSVP paradigm was used as described in pilot experiment one. The only variation was that following the RSVP stimulus stream the order of questions in the dual task was reversed so that participants were asked to identify T2 and then T1.

Results and discussion

Similarly to experiment one, participants were performing at near ceiling level (see Table 5).

Task	Duration	Word	Mean % correct responses	Standard Deviation	Minimum	Maximum
Single	Short	T2	92.50	7.42	80	100
	Long	T2	97.50	2.74	93	100
Dual	Short	T1	84.88	16.99	52	100
		T2	83.33	23.06	38	100
	Long	T1	94.44	6.09	83	100
		T2	94.17	10.69	73	100

Table 5: Descriptive statistics for the percentage of correct responses to the T1 and T2 questions in the single and dual task conditions in pilot experiment two

To test the presence of the AB effect, the outcome measure (percentage of correct T2 responses) was analysed in a parallel-groups repeated-measures ANOVA with *Task* (single and dual) and *Duration* (short and long) as the within-group factors and *Order of tasks* (single the dual or dual then single) as the between-group factor. There was only a significant main effect of *Duration* [$F_{(1, 4)}=12.237$, $p=0.025$]. Participants made more correct responses in trials with the long compared with short SOA. The same analysis was computed with the outcome variable reaction time to make a correct response. There were significant main effects of *Task* [$F_{(1, 4)}=45.891$, $p=0.002$] and *Duration* [$F_{(1, 4)}=10.423$, $p=0.032$] which were qualified by a *Task by Duration* interaction [$F_{(1, 4)}=12.689$, $p=0.024$]. Post-hoc paired samples t-tests showed that

participants were slower to respond in trials with the short compared long SOA in the dual ($t_{(5)}=4.035$; $p=0.010$) but not single ($t_{(5)}=0.269$; $p=0.799$) task (see Figure 9).

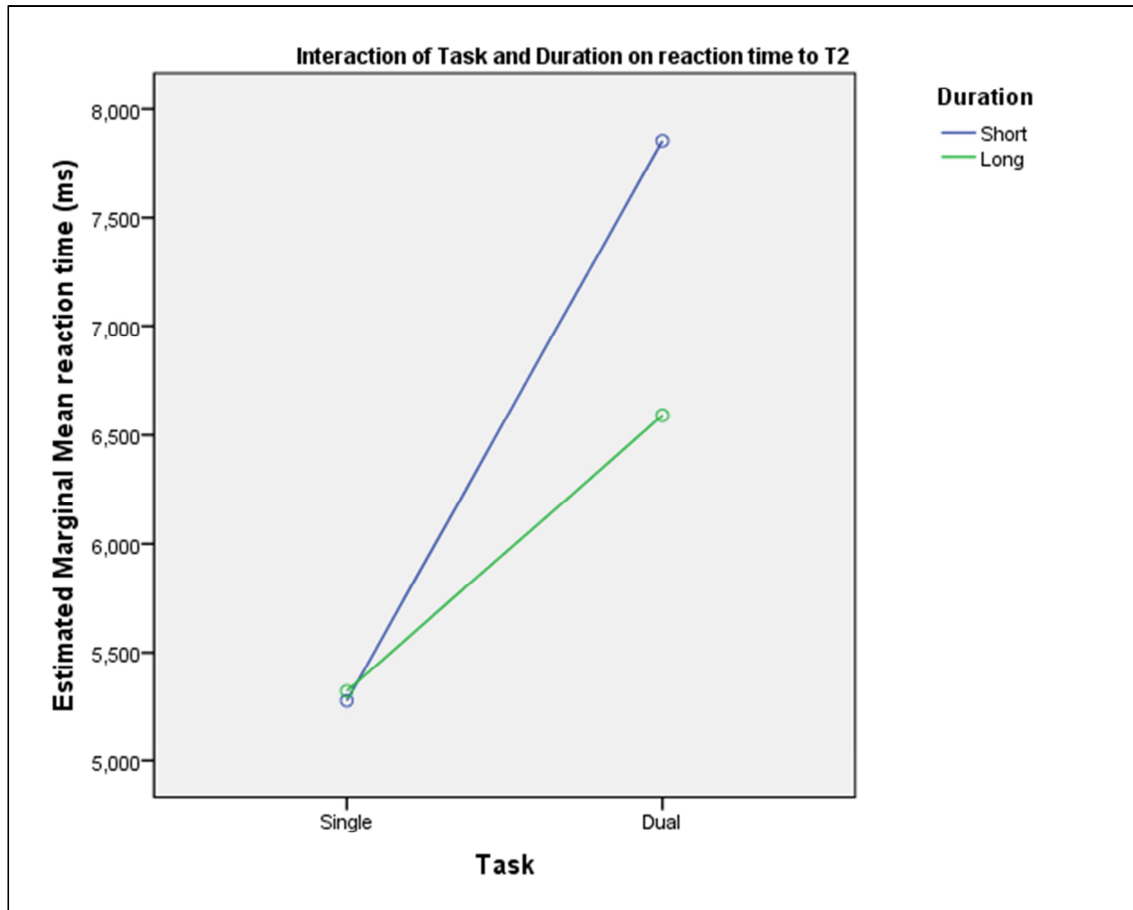


Figure 9: Interaction of task and duration on reaction time to the T2 question; $p=0.024$

As in experiment one, to further investigate whether the AB effect was present, the outcome measure (percentage of correct T2 responses) was analysed in a parallel-groups repeated-measures ANOVA with *Word* (T1 and T2) and *Duration* (short and long) as the within-group factors and *Order of tasks* (single then dual or dual then single) as the between-group factor. There was a significant main effect of *Duration* [$F_{(1, 4)}=12.237$, $p=0.025$]. The same analysis was repeated with the outcome variable of reaction time. There was a significant main effect of *Word* [$F_{(1, 4)}=21.791$, $p=0.010$], a trend towards an effect of *Duration* [$F_{(1, 4)}=5.075$, $p=0.087$] and a significant interaction of *Word by Duration* [$F_{(1, 4)}=20.336$, $p=0.011$]. Post-hoc paired samples

t-tests showed that this effect was attributable to significantly slower reaction times to T2 in trials with the short compared long SOA ($t_{(5)}=4.035$; $p=0.010$), which did not occur for response times to T1 ($t_{(5)}=0.543$; $p=0.610$).

iii. Methods and results of pilot experiment three

Participants

Behavioural piloting was then conducted on a further five participants however data from one participant was excluded as they reported difficulties understanding the objective of the tasks thus leaving four participants.

Methods

The same RSVP paradigm was used as described in pilot experiment two. One variation was that T2 stimuli were neutral, negative, or positive, and there were no trials in which T2 was absent. The neutral T1 and T2 as well as the negative and positive T2 words were those to be used in the MEG experiment; therefore and importantly none of the participants from this behavioural pilot experiment were included in the MEG experiment. In the single and dual 2AFC tasks, there were a total of one hundred and eighty trials. In the confidence and 2AFC task there were a total of sixty trials. For a breakdown of the number of trials in each condition see Table 3. Another variation from the previous two experiments was that participants underwent a neutral MIP prior to completing the single and dual tasks.

Results and discussion

Similarly to experiments one and two, participants were performing at near ceiling level (see Table 6).

Task	Duration	Word	T2 word valence	Mean % correct responses	Standard Deviation	Minimum	Maximum
Single	Short	T2	Neutral	95.00	4.56	90	100
		T2	Negative	95.63	4.27	90	100
		T2	Positive	96.88	2.39	95	100
	Long	T2	Neutral	100.00	0.00	100	100
		T2	Negative	97.50	5.00	90	100
		T2	Positive	98.75	2.50	95	100
Dual	Short	T1	Neutral	97.50	1.91	96	100
		T2	Neutral	94.00	6.73	84	98
		T1	Negative	96.50	5.74	88	100
		T2	Negative	94.50	3.42	90	98
		T1	Positive	96.50	1.91	94	98
		T2	Positive	88.00	11.89	72	98
	Long	T1	Neutral	97.50	1.67	97	100
		T2	Neutral	99.17	1.67	97	100
		T1	Negative	98.33	3.33	93	100
		T2	Negative	99.17	1.67	97	100
		T1	Positive	98.33	1.92	97	100
		T2	Positive	98.33	1.92	97	100

Table 6: Descriptive statistics for the percentage of correct responses to the T1 and T2 questions in the single and dual task 2AFC conditions in pilot experiment three

As in experiments one and two, to test the presence of the AB effect, the outcome measure (percentage of correct T2 responses) was analysed in a parallel-groups repeated-measures ANOVA with *Task* (single and dual 2AFC), *Duration* (short and long), and *T2 word valence* (neutral, negative, positive) as the within-group factors and *Order of tasks* (single the dual or dual then single) as the between-group factor. There were no main or interaction effects including that of *Task by Duration* [$F_{(1, 2)}=26.408$, $p=0.508$] although a means plot demonstrated effects in the expected direction: participants made more correct responses in trials with the long SOA in both the single and dual tasks, but made fewer correct responses in the single compared with dual task in trials with the short SOA (see Figure 10). The same analysis was computed with the outcome variable reaction time to make a correct response. There was a significant main effect of *Task* [$F_{(1, 2)}=102.498$, $p=0.010$] such that participants made significantly faster responses in the single than dual task. There was a trend towards a

main effect of *Duration* [$F_{(1, 2)}=11.474$, $p=0.077$] wherein participants made faster responses in trials with the long compared with short SOA. There were no other significant main or interaction effects. A lack of a main or interaction effect of *Emotion* in these analyses might demonstrate that these stimuli were processed similarly during a neutral mood state or there may be no differential effect of emotion on the AB as performance was already at near ceiling level.

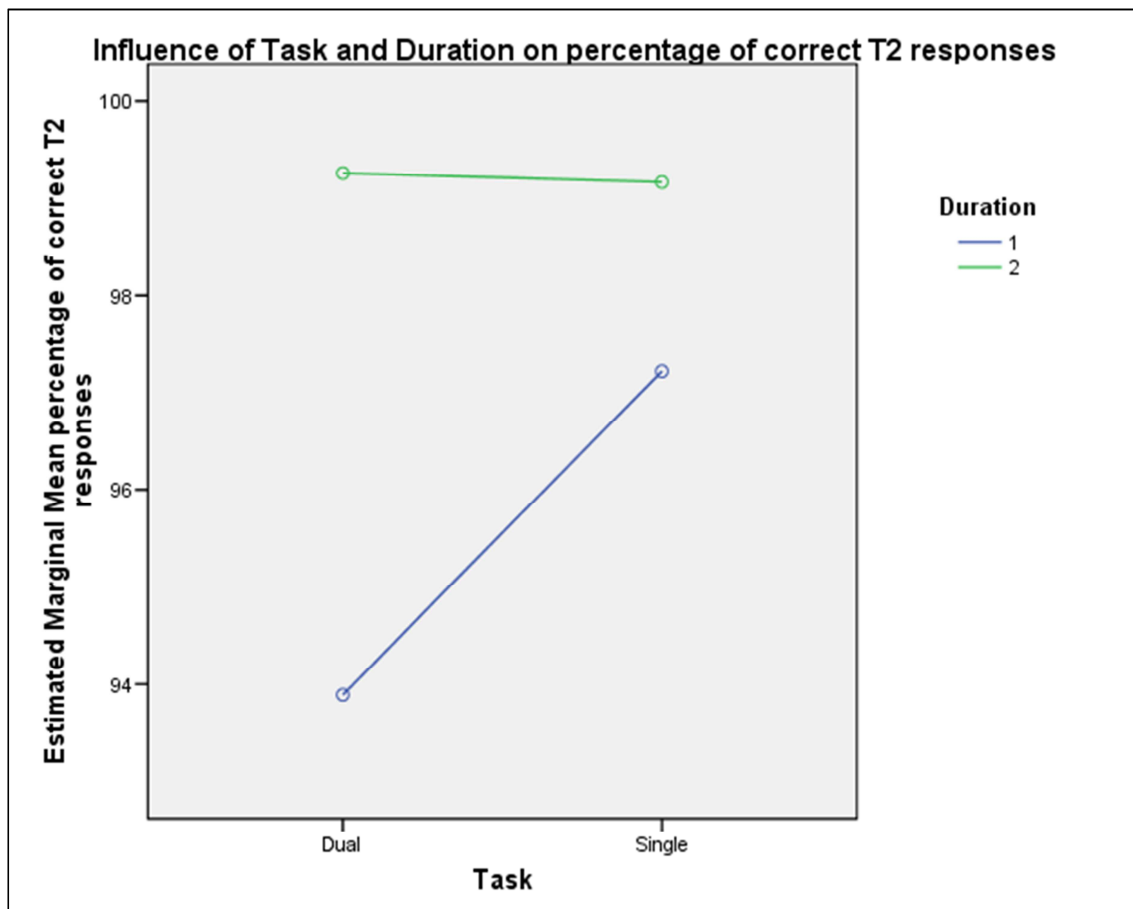


Figure 10: Interaction of task and duration on percentage of correct T2 responses; $p=0.508$

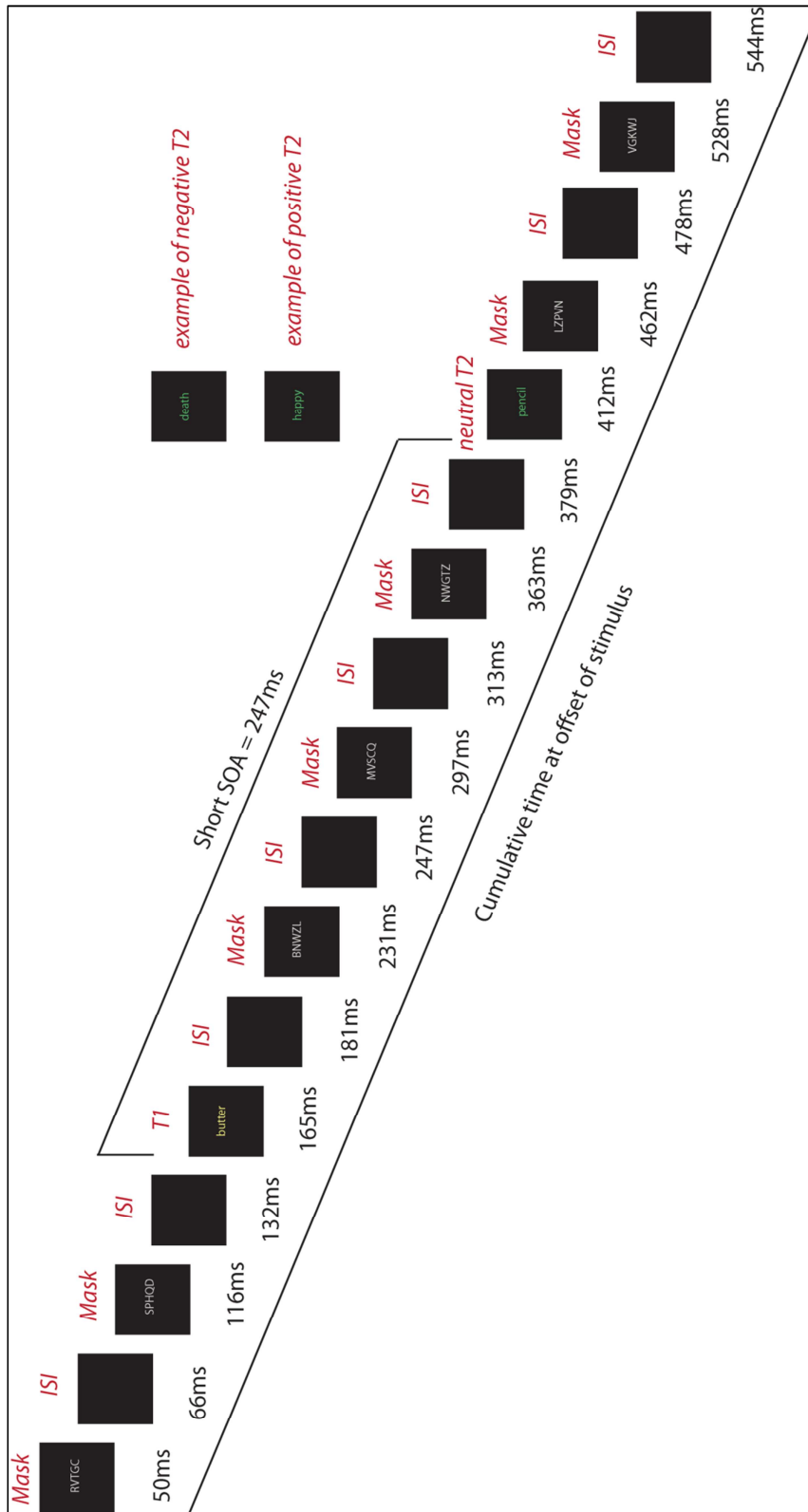
iv. Methods and results of pilot experiment four

Participants

Behavioural piloting was conducted on eight participants.

Methods

A similar RSVP paradigm was used as described in pilot experiment three. However, as a result of the near ceiling performance and lack of an AB effect in pilot experiments one, two, and three, it was decided to change the masks from shapes to strings of letter consonants. This was in accordance with previous research that has demonstrated that the more similar the distractors to the targets, the greater the AB effect (Chun & Potter, 1995). Another variation was that distractors were presented for 50ms followed by a blank screen presented for 16ms. Further, instead of varying the lag latency between T1 and T2 by the duration of the pre-T2 mask (i.e. 184 or 602ms), a string of either 3 or 9 masks (letter consonants and blank screens) were used between T1 and T2 to create the short (247ms) and long (643ms) lag latency, respectively (see Figure 11). In keeping with pilot experiment three, T2 stimuli were neutral, negative, or positive, with the addition of trials in which T2 was absent. All T1 and T2 word stimuli were those to be used in the MEG experiment therefore none of the participants from this behavioural pilot experiment were included in the MEG experiment. The same numbers of trials were used as in experiment three (see Table 3).



Results and discussion

Visual inspection of the mean percentage of correct responses demonstrated that participants were no longer performing at ceiling level to T2 in the dual task in trials with the short SOA (see Table 7).

Task	Duration	Word	T2 word valence	Mean % correct responses	Standard Deviation	Minimum	Maximum
Single	Short	T2	Neutral	81.56	21.08	38	100
		T2	Negative	80.94	17.88	45	98
		T2	Positive	82.50	17.11	45	95
	Long	T2	Neutral	88.75	10.94	70	100
		T2	Negative	94.38	6.23	85	100
		T2	Positive	90.00	10.35	70	100
Dual	Short	T1	Neutral	87.00	9.44	76	96
		T2	Neutral	68.25	21.04	42	98
		T1	Negative	89.50	9.67	72	100
		T2	Negative	70.75	24.98	32	100
		T1	Positive	87.50	13.68	58	98
		T2	Positive	68.25	23.38	34	98
	Long	T1	Neutral	89.58	8.05	77	100
		T2	Neutral	91.67	11.27	67	100
		T1	Negative	85.42	12.34	67	97
		T2	Negative	90.83	12.82	63	100
		T1	Positive	86.67	10.39	77	100
		T2	Positive	87.92	9.58	70	100

Table 7: Descriptive statistics for the percentage of correct responses to the T1 and T2 questions in the single and dual task 2AFC conditions in pilot experiment four

As in the previous experiments, to test the presence of the AB effect, the outcome measure (percentage of correct T2 responses) was analysed in a parallel-groups repeated-measures ANOVA with *Task* (single and dual 2AFC), *Duration* (short and long), and *Emotion* (neutral, negative, positive) as the within-group factors and *Order of tasks* (single the dual or dual then single) as the between-group factor. There was a significant main effect *Duration* [$F_{(1, 6)}=8.146$, $p=0.029$] and a trend towards a main effect of *Task* [$F_{(1, 6)}=5.668$, $p=0.055$] such that participants made more correct responses in trials with a long compared with short SOA and in

the single compared with dual task. These effects were qualified by a significant *Task by Duration* interaction [$F_{(2, 12)}=17.492, p=0.006$]; participants made significantly fewer T2 correct responses in trials with the short SOA in the dual compared to single task ($t_{(7)}=-3.350; p=0.012$) but there was no effect of task in trials with the long SOA ($t_{(7)}=-0.315; p=0.762$); see Figure 12.

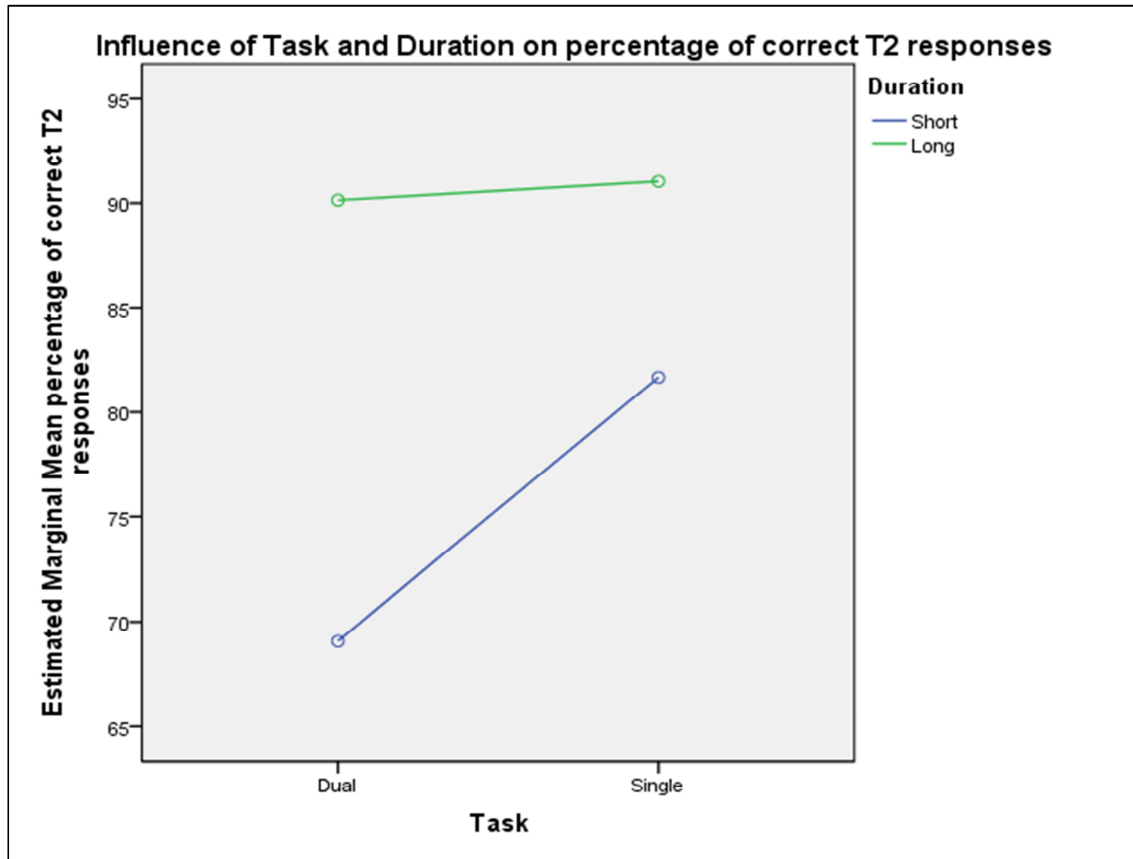


Figure 12: Interaction of task and duration on percentage of correct T2 responses; $p=0.006$

There was no main effect of *Emotion* [$F_{(2, 12)}=1.456, p=0.272$] however there was a trend towards a three-way interaction of *Task by Duration by Emotion* [$F_{(2, 12)}=46.275, p=0.061$] demonstrating that the AB effect was influenced by the valence of the T2 word stimulus. Specifically the AB effect was most pronounced (i.e. a greater difference of the slopes between trials with the short and long SOA in the single compared with dual task) when T2 was neutral and positive and was reduced when T2 was negative. Paired samples post-hoc t-tests demonstrated that when T2 was neutral or positive participants made significantly more

correct responses in trials with the long than short SOA in the dual task but no difference in the single task. In contrast, participants made more correct responses in trials with the long than short SOA in both the dual ($t_{(7)}=-3.673$; $p=0.008$; significant) and single ($t_{(7)}=-2.278$; $p=0.057$; trend) tasks when T2 was negative. No other main or interaction effect reached significance.

v. General discussion

In the pilot experiments one, two, and three, there was no statistical evidence to suggest the presence of the AB effect: reduced percentage of correct responses to T2 in trials with the short compared with long SOA in the dual but not single task. Similarly, when the presence of the AB effect was explored by comparing the percentage of correct responses to T1 and T2 in trials with the short compared with long SOA in the dual task, there was also no evidence for the AB effect in pilot experiment one. Interestingly, however, the same analysis with the outcome variable of reaction time in pilot experiment one did reveal that participants were faster to respond to T2 than T1 in the dual task, and a regression analysis confirmed that the order of questions (i.e. identify T1 then identify T2) had an effect on reaction times to T2. After the reaction time to T2 in the single task had been corrected for this effect, the data demonstrated an interaction between task (single, dual) and duration (short, long) such that participants were slower to respond in trials with the short compared with long SOA in the dual but not single task. These data demonstrated that there was a significant effect of order of questions on reaction time to respond to the T2 question. Importantly, when the order of questions in the dual task was inverted in pilot experiment two, the pattern of results matched those of pilot experiment one after correction for the effect: that is the presence of the AB effect on reaction time to T2. By changing the order of the questions from pilot experiments one to two, the single and dual tasks became more equivalent as participants were always

asked to identify the second word immediately after the stimulus stream in the single and dual tasks, and then to identify the first word in the dual task only.

As the reaction time data demonstrated the AB effect, the influence of T2 word valence on this effect was explored in pilot experiment three. Analysing the reaction time data neither showed the AB effect nor an influence of emotion. Although there was no statistical evidence for the AB effect using the outcome measure percentage of correct T2 responses, a means plot showed the AB pattern. Specifically, participants made more correct responses in trials with the long SOA in both the dual and single tasks, but made fewer correct responses in trials with the short SOA in the single compared with dual task. There was, however, no influence of emotion on this pattern of responding.

The lack of statistical evidence for the AB effect in pilot experiments one, two, and three might be caused by the near ceiling level of performance that participants showed. Indeed, across these three experiments the lowest mean percentage of correct responses was 83.33%. To increase task difficulty, distractors that were more similar to the targets were used in pilot experiment four. This was in accordance with previous research showing that the more similar the distractors to the targets, the greater the AB effect (Chun & Potter, 1995). Statistical analysis of pilot experiment four demonstrated the presence of the AB effect. This result is in keeping with the predictions of Chun & Potter's (1995) two-stage model, confirming their hypothesis that when it is more difficult to discriminate targets (i.e. T1) from distractors (i.e. post-T1 item), stage 2 takes longer at the expense of T2 entering stage 2 for consolidation in working memory. This effects T2's presented in the short but not long T1-T2 SOA conditions because the processing of T2 at stage 2 has a larger delay at the short SOA (i.e. because T2 is presented in closer temporal proximity to T1 and the post-T1 distractor). This may also be in keeping with predictions from the boost and bounce theory (Olivers & Meeter, 2008) which suggests that the AB effect is reduced when there is a greater difference between the target

and distractors (i.e. in pilot experiments one, two, and three). This is because inhibition of task-irrelevant distractor stimuli is facilitated by increased dissimilarity between targets and distractors, thus reducing the need for the gating mechanism and consequently reducing the AB effect.

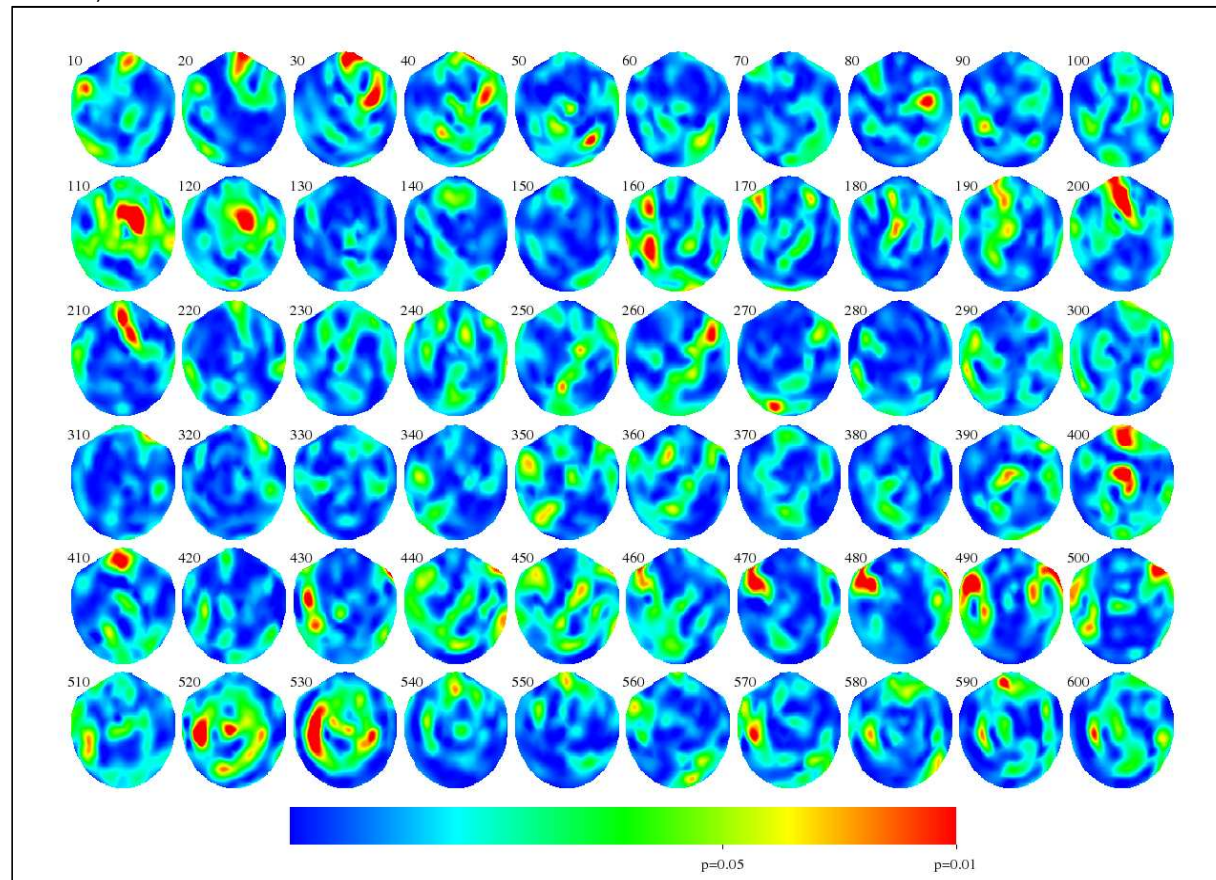
In pilot experiment four, there was some evidence for the influence of T2 word valence on the AB effect, which confirmed the hypothesis that a lack of a differential effect of emotion on the AB effect found in pilot experiment three could be attributable to the already near ceiling level of performance displayed by participants.

Given the results of these experiments, the stimulus stream and timings used in the RSVP paradigm for the MEG experiment was identical to that described in experiment four as this was likely to produce a reliable AB effect on performance measured using the outcome variable of correct T2 responses.

K. Wilcoxon analysis: short SOA, correct versus incorrect responses

Spatial distribution of the statistical difference between T2-related activity when participants made correct (minus absent) compared with incorrect (minus absent) responses from 10-600ms post-T2 onset

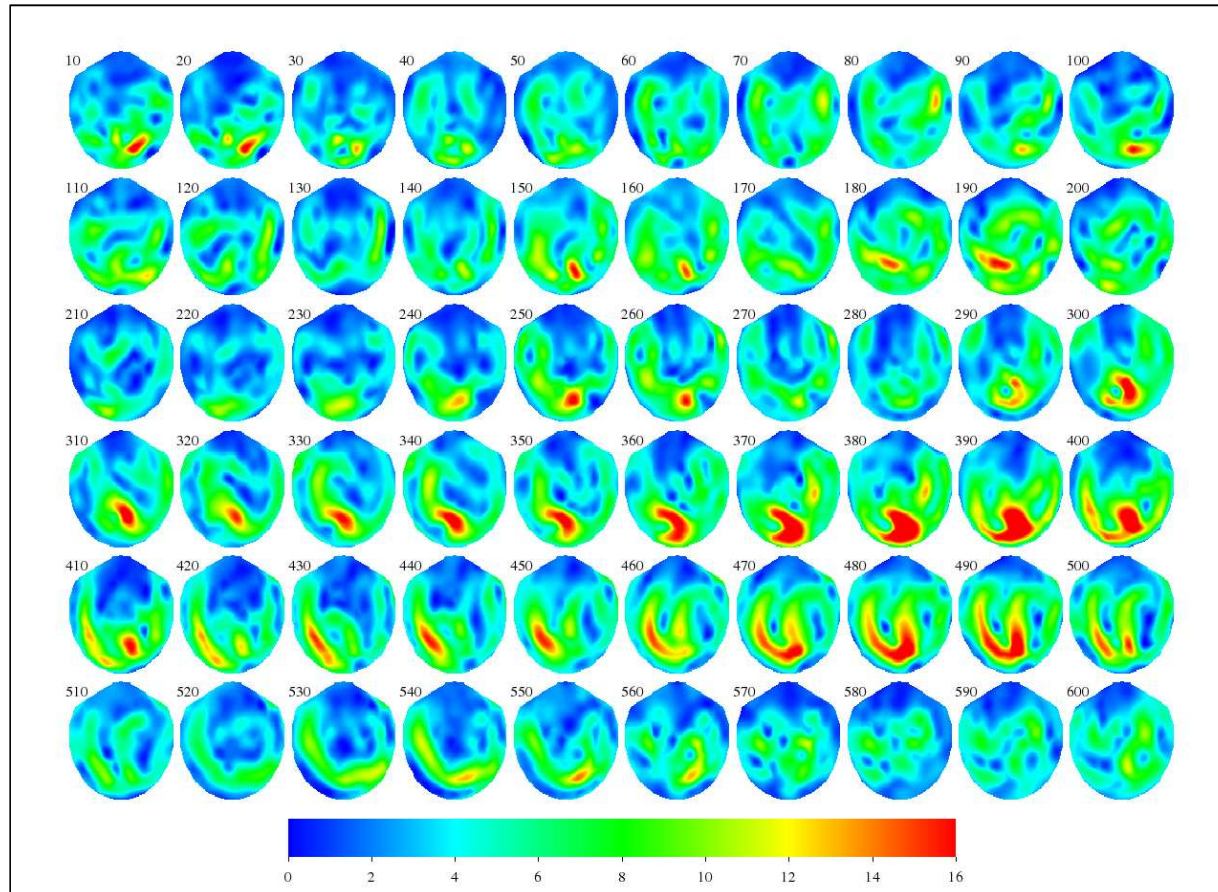
Data presented were for a subset of participants (N=13; N=8 sad MIP group, N=5 happy MIP group) that had enough data available for each of the conditions (i.e. >4 trials per condition).



L. Grand averaged local rms maps: short SOA, correct responses

Spatial distribution of grand averaged T2-related activity when T2 was correctly (minus absent) identified from 10-600ms post-T2 onset

Data presented were for a subset of participants (N=13; N=8 sad MIP group, N=5 happy MIP group) that had enough data available for each of the conditions (i.e. >4 trials per condition).



M. Grand averaged local rms maps: short SOA, incorrect responses

Spatial distribution of grand averaged T2-related activity when T2 was incorrectly (minus absent) identified from 10-600ms post-T2 onset

Data presented were for a subset of participants (N=13; N=8 sad MIP group, N=5 happy MIP group) that had enough data available for each of the conditions (i.e. >4 trials per condition).

