Mood, Emotive Content, and Reasoning

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To those of you who know who you are.

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Abstract

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Theories of how individuals reason, and how they experience emotion abound in the psychological literature; yet, despite the common lay-theories of how emotions might affect a person's reasoning, very little empirical work has been conducted on this relationship. The current thesis addresses this knowledge-gap by first distilling from the literature two classes of emotion theory; Information, and Load; and then systematically testing the explanatory power of these theories.

A dual-process framework is employed in order to define low (Type One) and high effort (Type Two) strategies. Information theories predict that negative emotion cues more analytic processing relative to positive emotion, whereas load theories predict both positive and negative emotion to suppress use of high-effort strategies. Thus the two theories are compared by varying incidental and integral emotion across syllogistic reasoning, conditional reasoning, and the ratio-bias task, and assessing the engagement of Type One and Type Two processes across positive emotion, negative emotion, and control conditions.

The findings suggest that emotion effects in syllogistic reasoning do not consistently support either Load or Information theories (Experiments 1-4). Emotion effects are found to be typically larger for integral than incidental emotion (Experiment 5), and most frequently serve as Information in verbal (Experiments 6 and 7) and visual conditional reasoning tasks (Experiment 8).

Furthermore, these effects are to a large extent dependent on task properties such as the number of alternative antecedents (Experiments 9 and 10), and are greater on more difficult tasks (Experiments 11 and 12). These findings suggest that emotion

has a greater impact on Type Two than Type One processes. A range of methodological and theoretical implications which will inform future work in this area are also discussed in the closing chapter.

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Author's Declaration

At no time during the registration for the degree of Doctor of Philosophy has the author been registered for any other University award without prior agreement of the Graduate Committee.

Relevant scientific seminars and conferences were regularly attended in order to present work from this thesis, and a number of papers have been, and are currently being, prepared for publication.

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Ethics Statement

The work reported in this thesis received ethical approval from Plymouth University Faculty of Science and Technology Human Ethics Committee and complies with the guidelines set by the British Psychological Society (BPS, 2009)

Chapter One

Emotion

The overall aim of this thesis is to provide a better understanding of whether and how our emotional experiences affect our reasoning processes. Given the broad range of research which has been conducted in the fields of emotion and reasoning, this first chapter will provide a review of the research on emotion, whilst also introducing and evaluating the theories of emotion which will later be of particular relevance to the current work.

It is commonly accepted that emotions affect our reasoning, yet surprisingly little work has been conducted on these effects. There are findings in the literature, to be discussed in this and the following chapter, which report that emotions impair reasoning, and yet other studies which find emotions to be beneficial to reasoning. Understanding more about whether these effects are robust is an interesting an important area, not least because emotion and reasoning are pervasive elements of our lives, but because the theoretical development of both would benefit from such a programme.

Whilst it is important to also discuss some of the philosophical issues inherent in any work on emotions, once these have been considered the remainder of this chapter will focus specifically on research which sheds light on whether emotions interact with reasoning processes, and existing explanations of how this may take place in relation to the findings reported. Central to this chapter is the consideration of emotion research in experimental psychology. Work from across cognitive and social psychology, as well as philosophy, bio- and neuro-psychology will be considered in order to establish an empirically supported framework for understanding emotion. This will then be extended to consider models of cognition, and how emotion has been found to impact cognitive functioning in general, before finally moving on to consider, in Chapter 2, the work on reasoning and how emotions have been studied in relation to syllogistic and conditional reasoning. But first, and in line with the aims of the current chapter, it is important to establish how emotion will be conceptualised in this thesis, which will entail considering different definitions of emotion, their implications for potential models of emotion, and related philosophical issues in emotion research.

1.1 Philosophical Issues in Emotion Research

There are many theories of what emotions are, how they are created, and what they are created from. Evaluating these theories is not the purpose of this thesis, but along with issues such as whether or not emotions are the same for each individual these topics pose interesting and pertinent questions, consideration of which is important before embarking on any research involving emotional experiences. Consideration of these areas and how they serve to inform methodological as well as theoretical decisions later in this investigation will be the topic of this opening section.

1.1.1 A Note on Ontology and Epistemology

The main arguments in the philosophical literature surrounding emotions concern whether and how emotions exist. Numerous theories have been propounded over the years, but of those most relevant to psychology are the James-Lange and Cannon-Bard theories of emotion (Cannon, 1927; James, 1884). The details of these in relation to the current project are outlined below where they apply to models such as appraisal theory, but in summary, the James-Lange and Cannon-Baird theories make the distinction between emotions existing of and for themselves, and emotions being the subjective interpretation of a range of stimuli in a given manner. Secondary to this is the question of whether or not emotional experiences are socially constructed; whether emotions are phenomena that could be experienced without the interpretation of society.

If emotions are purely subjective, how can they be defined in a way which makes them amenable to scientific investigation? With this in mind, the studies here should not only be considered in terms of the effects of this or that emotion, but given the subjective nature of the categorisation of 'that emotion', they should also be considered at the level of the individual. Issues and perspectives such as these will be discussed as they arise. These points constitute an entire field in themselves, and although interesting and important to consider, the purpose of the current section was merely to introduce the topics in order that they be kept in mind throughout the rest of this work.

1.1.2 Definitions of Emotion and their Implications

I have no expectation here of succeeding where countless others have failed; what is required for the investigation of the relationship between emotion and reasoning is, at this stage, not a universal but an operational definition of emotion, and by an operational definition, what is meant is a definition of emotion which is meaningful in the current context. It may not encompass every nuance, it may not do complete justice to the phenomenon of emotional experience, and it may not be representative of all the shades of emotion, but it will serve to aid our understanding of the relationship between emotion (as here defined) and reasoning.

In order to begin exploring the interplay of emotion, decision making, and reasoning, the nature of emotion must first be considered. But again, as with arguments for and against their value, definitions of emotion abound in the literature, and each carries different theoretical implications. The Oxford English Dictionary gives the lexical definition of emotion as:

Emotion •n. a strong feeling such as joy, anger or sadness. ► instinctive or intuitive feeling as distinguished from reasoning or knowledge.

Not only does this definition highlight the distinction commonly drawn between reasoning on the one hand and emotion on the other, but by equating reasoning with knowledge, it supports to some extent the implicit and common implication that emotions are potentially detrimental to decision making whereas 'reasoning' is beneficial. It also highlights issues which will be discussed in more depth below; namely, the suggestion that emotions are somehow instinctive or unconscious and the corollary of this that they are subsequently uncontrollable. However, in terms of psychological research an operational definition is necessary which takes these issues into account, and, along with consideration of the theoretical implications of different definitions, reaching such a definition will be the central focus of this section.

Although definitions of emotion, and their biological basis, have been around since ancient times (Stokes, 2004), one of the first to appear in the psychological literature was the peripheric theory of William James (1884). In his paper 'What is an Emotion?' James argues that emotions are the internal physiological reactions to external events. In this view, as illustrated with the common example of seeing a bear, the sequence of an emotional experience follows the order; *See a Bear*, *Run*, and then *are Frightened,* as a result of the action of running. This is in contrast to what James refers to as the common-sense view in which we see the bear, are frightened, and then run *because* we are frightened. In the peripheric theory, the physiological reactions precede the emotional experience and in large part constitute the emotions themselves.

Cannon (1927) however, presented evidence to refute the peripheric theory, showing that emotions could still be experienced after transection of the cervical spinal cord. This lead to the Cannon-Bard theory (Thompson, 1988), which, contrary to the Jamesian approach (often referred to as the James-Lange theory following similar theorising by Carl Lange), posits that when presented with a stimulus, it is the perceptual system that processes the information, and then makes a decision regarding the necessary action, and it is following this judgement that signals are sent to various organs to instigate a physiological response. In summary, emotions are a combination of different thoughts about the stimulus.

The evidence put forward by Cannon (1927), although suggesting that emotions are not somatovisceral responses, does not eliminate the biological basis of emotions, but instead moves the focus to the top of the central nervous system, placing the biological underpinnings in the brain. This leads us to the work of LeDoux and others (Andrewes, 2004; LeDoux, 1998, 2000, 2006) who propose two neural pathways to reaction. Following the activation of neurons in the perceptual system, the signal is passed both to the amygdala and the neocortex. The amygdala pathway provides a rapid response, but this can be overridden by the neocortical response. This is discussed in more detail when we come to consider models of emotion, and is shown in Figure 1.1 (p31). Experimental work on the fear response has led researchers to associate the amygdala primarily with the processing of emotional stimuli (Mather et al., 2004). This is supported by research showing that damage to the amygdala and other areas of the limbic system can lead to difficulties in both learning and expressing fear responses (Gazzaniga, Ivry, & Mangun, 2002) and symptoms associated with psychopathy (Raine, Buchsbaum, & LaCasse, 1997; Reidy, Zeichner, Hunnicutt-Ferguson, & Lilienfeld, 2008).

In addition to the research on amygdaloid function, the classic case of Phineas Gage (Gazzaniga et al., 2002), who showed drastic changes in personality and mood states following an accident which destroyed the medial region of his prefrontal cortex, highlights the role of this area in emotion maintenance and cognitive processing of emotional stimuli. Experimental evidence also supports the involvement of the prefrontal cortex in emotional experiences. Beer, Knight, and D'Esposito (2006) have shown that the frontal cortex is heavily involved in the integration of cognition and emotion and that the lateral frontal cortex is involved in evaluating the contextual relevance of emotional information. This builds on the work of Tomarken and Keener (1998), who have shown that the frontal lobes are also involved in self-regulation, goal orientation, and inhibitory functioning.

This work has resulted in the development of neurological explanations of conditions such as psychopathy (Blair, Mitchell, & Blair, 2005; Raine et al., 1997; Reidy et al., 2008) and related work on neurotransmitters supported by both animal models (Geyer & Markou, 2000) and human research (Gazzaniga et al., 2002), and has underpinned significant advances in the treatment of mood disorders. This is not the place to provide a review and discussion of the psychopharmacological research (e.g. Harris, Chandran, Chakraborty, & Healy, 2003), but the effectiveness of the treatments that have been developed serve to highlight the role played by neurological systems in the generation and experience of emotion.

Standing in contrast to the biological theories are the cognitive models of emotion, which define emotions purely in terms of appraisals (Lazarus, 1982). Cognitive appraisal theories claim that emotions are judgements made about stimuli presented to the individual. Returning to the bear example: when presented with a bear, the individual sees the bear, feels their heart-rate increase, and then thinks about these stimuli, and 'decides' that they ‘should be’ afraid. Many models of the structure of emotion incorporate or rely solely on dimensions which are considered cognitive, such as judgements of pleasantness or unpleasantness as in the model of Feldman-Barrett and Russell (1999) which will be considered when discussing models of emotion later.

This definition of emotions as cognitive appraisals may at first seem to be refuted by research on unconscious emotions (Berridge, 2003; Winkielman & Berridge, 2004), and the older work on the mere exposure hypothesis (Zajonc, 1968), both of which show that affective states and judgements of liking can be influenced by factors presented outside of conscious awareness. Zajonc (1980, 1984) also argues against Lazarus's (1982, 1984) idea of cognitive appraisal claiming that emotions precede appraisals, so the appraisals cannot be the emotions. However, Lazarus (1984) does not claim that appraisals need necessarily be conscious, leading to much debate over which part or parts of the cognitive system generate these appraisals, and their status in consciousness.

Damasio (1994) has argued that affect and cognition are both functionally and anatomically distinct, and so emotions cannot be appraisals, but must be separate from them; the appraisals must be *of* the emotions, and are not the emotions themselves. This is a view which seems to be supported by anecdotal evidence from clinicians who work with individuals suffering from emotional and cognitive disorders, one such example being the case of Dr.P reported by Oliver Sacks in his famous 'The Man who mistook his Wife for a Hat' (2007, pp.8-24). Dr.P was only able to identify objects through a systematic process of feature identification, lacking any holistic (or emotional) concept of items or people; there was never any feeling of ‘knowing’ or emotional connection which could be appraised.

Duncan and Feldman-Barrett (2007), on the other hand, argue that the neural circuitry involved in generating affective states is distributed throughout the brain, and includes systems associated with other cognitive functions, such as sensory processing and language.

Other theorists have proposed a variety of alternative views, neither wholly biological nor cognitive. For example, Averill (1998), in reviewing Parkinson (1995), summarises emotions as 'fuzzy categories', 'multicomponential', 'a form of communication', 'on-line', 'interpersonal', and 'ineluctably infused with the beliefs, values, and norms of society' (pp.850-851). That is to say that there might not be one simple definition of 'an emotion', that emotional experiences are made up of many components, none of which alone constitute an emotion, and that emotions are essentially evolved systems of communication and so depend on contextual, societal, and personal variables.

Related to this argument, as different elements might have varying effects, Gross (1999) raises the issue of needing to distinguish between regulation *by* emotion, and regulation *of* emotion in relation to both beneficial and detrimental effects on task performance. This also raises again the issue of conscious versus unconscious emotions; dimensions that need to be considered when defining what an emotion is and how it interacts with other systems. Cabanac (2002), building on his work attempting to define consciousness, suggests that an emotion is any mental experience which is intense and has a pleasure-displeasure dimension. This definition appears to limit emotions to the realm of the cognitive, in that the judgement of pleasure-displeasure would seem to require a cognitive appraisal, but it does consider the implications of the biological aspects of emotion in as much as they are experiences which can fall along the pleasure-displeasure dimension, or be used to situate an experience along this dimension.

Alongside biological and cognitive theories, evolutionary theories define emotions as evolutionarily adaptive modules (Marks & Nesse, 1994; Öhman, Flykt, & Esteves, 2001; Öhman & Mineka, 2001), which serve to increase the reproductive fitness of the individual by helping them avoid injury or death. There are also the psychoanalytic theories, which bear a strong resemblance to cognitive theories based on the idea that emotions are the result of stimuli which then affect behaviour (Forgas, 1995).

Yet another view is championed by the embodied emotion movement, and suggests that when presented with a stimulus, biological and cognitive components interact to generate the emotion, and that later, when the stimulus is recalled as a mental image or cognitive representation, the biological components of the experience are also reactivated due to the extensive interconnectedness of the systems involved (Niedenthal, 2007). In this way, the relationship between emotion and cognition can be seen as reciprocal. However, in terms of studying emotions from a cognitive perspective, it raises issues for the type of manipulations used. If purely cognitive tasks are used, such as thinking about happy or sad events, then this leads to a partial reactivation of the response pattern that was experienced at the time, but this may not be the same as the emotion experienced in the situation. Arguably, this is the cognitive component of the emotional experience, and its study is valid, provided it is acknowledged as only one of many aspects of the complete emotional experience.

Despite the differing specifics of these definitions, they all suggest that emotions may in fact be made up of many different aspects, cognitive, biological and neurological, as well as the social and cultural (Averill, 1998). As such, when considering a definition of emotion, there seems to be a need for an eclectic, biopsychosocial approach (Engel, 1977), or at least an awareness of the limitations and difficulties caused by using narrow and restricted definitions of emotion. In line with this, the studies reported here use primarily self-reported measures of emotion, and thus investigate the element of emotional experience available to conscious perception.

Within these definitions, it is possible to consider emotion as part of the cognitive representational system (Sartre, 2008), a view that is supported by the neurobiological literature (Duncan & Feldman-Barrett, 2007), and can accommodate the evidence presented in support of both biological and cognitive theories and the evidence that shows a bidirectional relationship between cognition and emotion (Niedenthal, 2007; Sigall & Johnson, 2006). Treating emotion as part of cognition largely overcomes problems raised by the affective-cognitive primacy debate as the two become almost synonymous, and can overcome the debate surrounding the conscious status of affect by incorporating the possibility that different stimuli are processed at different levels of awareness by different neurological structures.

If emotion is considered to have at least some cognitive component, or be part of the cognitive system, as well as having at least some conscious components, then measures of emotion which rely on self-report can be used to capture this 'experienced' aspect of affective states. Although there are methodological issues associated with self-report measures such as demand characteristics, this approach provides an operational definition for the study of emotion which acknowledges its multifaceted nature. Emotional experiences consist of both *conscious cognitive* and *non-conscious non-cognitive* aspects both of which have a variety of applications, but the former will be the focus of this research as they are the aspects most easily accessible to cognitive-psychological investigation.

Furthermore, there are numerous arguments for drawing a distinction between mood, affect, and emotion. For example, there is little agreement in the literature as to the relative definitions of affect, emotion, mood, and feeling, although some attempt has been made to subcategorise emotional experiences with these terms based on intensity, salience, focus and duration (Forgas, 1995, 2001). However, the experiments conducted as part of this thesis are concerned with the self-reported subjective experience at the time of completing the various tasks, and mood, emotion and affect will be used interchangeably to refer to the reported emotional state of participants, which gives us our operational definition of emotion.

1.1.3 Do we have control of our emotions?

Related to the definition of emotions and their causes is the issue of whether or not we have control over our emotions. It has been argued in phenomenological philosophy that individuals can control what they feel and when (Sartre, 2008; Warburton, 2008), yet this seems initially to contradict the personal experience of almost everyone. Research on appraisals has suggested that prior moods can affect judgments, and that altering judgments can alter moods, these ideas forming the basis of cognitive behavioural therapies. It would appear therefore that individuals can regulate their moods, at least to some extent.

In terms of the impact on reasoning research, which is a central element of this thesis, the implications depend on the mechanism through which moods affect judgments, which in turn depends on the definition of mood adopted. The following studies will aim to investigate not only whether emotion has any effect on reasoning, but also to evaluate the results in light of theories which have been proposed to explain the interaction of emotion, cognition, and reasoning. It is hoped that the conclusions drawn will help to determine which reasoning tasks are affected by emotion, and how, in order to further our understanding of the relationship between emotion and reasoning.

If cognitive re-evaluation of thoughts associated with a task can alter mood, this is in line with definitions of emotion which contain a cognitive component, and falls within our operational definition of emotion. Furthermore, it follows that emotions may require cognitive resources in some way, or may influence the way resources are allocated. This leads to the idea that it may be possible to purposely alter how the limited cognitive resources are used, allowing mood to be brought under volitional control. This has to some extent been supported by the work of Van Dillen and Koole (2007), who have shown that depleting cognitive resources with additional tasks alters the emotions experienced by their participants. This supports the basis of cognitive behavioural therapies mentioned above, and is suggestive of a bidirectional relationship between emotion and cognition which needs to be kept in mind when reviewing the experimental work in this thesis. In addition, why moods may need to be, or benefit from, being under volitional control raises the question of whether emotional experiences are useful to an individual, or whether and in what circumstances they may be detrimental, and some of the issues surrounding this debate will be discussed next.

1.1.4 Whether Emotion is Beneficial or Detrimental

Whether emotion is beneficial or detrimental to individuals and society has been a source of much debate. Many philosophers have argued that emotions should be suppressed. Plato's *Republic* (Warburton, 2008), for example, includes much discussion of the three parts of the soul: *Reason*, which involves the love of truth, *Spirit*, which provides emotional motivation, and *Desire*, which encompasses a person’s wants and their basic needs. Following this, Plato goes on to describe an ideal state, in which the ruling classes are those who have Reason in command. This is paralleled in the Freudian psychic apparatus, which comprises the *Id*, *Ego* and

Super-Ego (Freud, 1997; Schultz & Schultz, 2000); The Id being an animalistic drive seeking immediate gratification, the Super-Ego being the ethical and moral ideals, and the Ego moderating between the two forces and guiding interaction with the world.

Aristotle, in his *Nicomachean Ethics* (Warburton, 2008), also attempted to answer the question of how we should live. His answer is that the overall goal of life is 'eudaimonia', a happy life, and his prescription for achieving this, is to act rationally and live a life of rational virtue. And, as a final example from the many available, Boethius betrays a negative view of the emotions in his *Consolation of Philosophy* (Warburton, 2008) by having the embodied figure of Philosophy soothe his despair with reason.

Why Reason should be the primary part of the soul is unclear, and Aristotle's prescription assumes that human nature is rational, yet the very concept of any type of human nature is debateable (Warburton, 2008), let alone a logical one (the common reading of ‘rational’). This is particularly questionable given the research showing an apparent inability to behave in accordance with the dictates of formal logical rules, even on relatively basic reasoning tasks (Evans, Newstead, & Byrne, 1993).

Hume, in contrast, argued that emotions should play a central role in deciding how to act, and questioned the absolute power of reason (Craig, 2002; Warburton, 2008). Indeed, as de Beauvoir argues, although whilst making a slightly different point, "A syllogism is of no help in making the perfect mayonnaise, nor in quieting a child in tears" (1997, pp. 610-611). In addition to reason and emotion, Hume, like Mill (2006) after him, also realised the importance of social customs in determining behaviour, and both proposed that reason, emotion, and society were important, with none being superior to the others.

Working from a largely evolutionary perspective and touched on above, Rossano (2002) proposes that emotions are evolutionarily adaptive rather than destructive. The fear response when a potential threat is encountered, for example, leads to physiological preparedness, and the exhibition of avoidance behaviours toward potentially harmful situations.

Taking these arguments into account, the benefit or otherwise of emotions seems to be relative to the task at hand. Although the central aim of this thesis is to investigate the relationship between emotion and reasoning, it is important to keep in mind that emotions can be both beneficial and detrimental, and so when deriving testable hypotheses regarding emotions, or considering how the results might generalise, the specific demands of the task need to be considered. More importantly, on a larger scale, how emotions affect cognitive processes and reasoning in a single situation should not be used to make judgements about the overall beneficial or detrimental nature of emotions. Having now defined emotion, and highlighted how it is valued within philosophy and society in general, the following sections will examine how it is conceptualised in scientific research.

1.2 Models of Emotion

As the components that a model of emotion must explain are determined by how emotion is conceptualised, the various models of emotion that have been advanced in the literature are typically based on the dimensions discussed above, focussing on levels of activation, positivity, or conscious awareness. This section will therefore elaborate a selection of models of emotion that use biological, cognitive, and bio-cognitive definitions of emotion as these are most likely to be of use in the current investigation.

Biological and neuropsychological models of emotion have tended to focus on the autonomic nervous system, its activation when stimuli are presented, and the neurological basis of emotional experience. These tend to pay particular attention to the limbic system; the amygdala, and the orbitofrontal cortex, areas alluded to above. LeDoux's work on fear conditioning for example (summarised in Gazzaniga et al., 2002) has led to a model of fear which focuses on the subnuclei of the amygdala, with stimuli first being directed through the sensory thalamus, and processing following one of two routes (see Figure 1.1). The first route processes the stimulus based on features, and is directed through the lateral nucleus of the amygdala providing a rapid, reflex-like response via the central nucleus which controls behavioural, autonomic, and endocrine responses. This requires little or no higher-cognitive involvement (Goleman, 2004a, 2004b). The second route is through the neocortex, which allows higher-cognitive processing of the stimuli before a response is initiated. This pathway is slower, but the processing is based on concepts and context as well as the features of the stimuli.

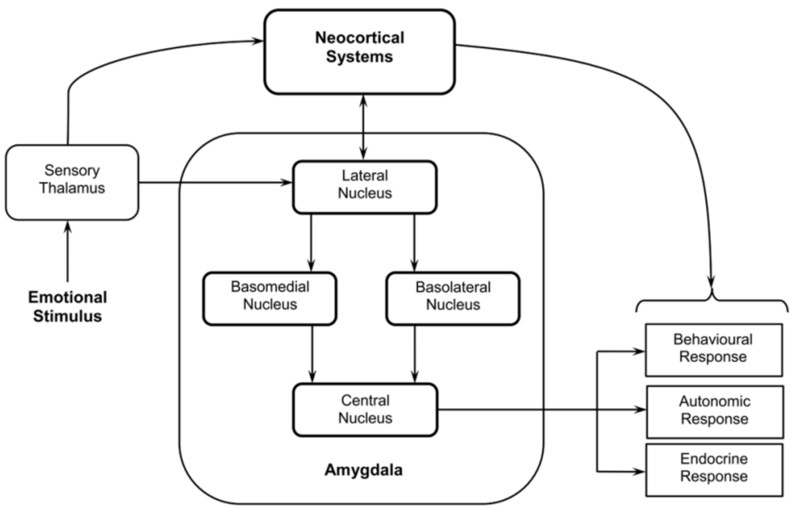


Figure 1.1 Amygdala Sub-nuclei, based on LeDoux (1995)

The amygdala and the orbitofrontal cortex, as well as the hypothalamus, anterior thalamus, cingulated gyrus and hippocampus have been collectively termed the limbic system, and in conjunction with parts of the basal ganglia, are generally considered the neural basis of emotional processing and responding. Although this system appears to provide a relatively clear neurological model of emotional experience, the structures involved are also related to other areas of cognitive functioning and behaviour (Gazzaniga et al., 2002). The hippocampus and amygdala play a role in memory, and may provide the link between memories and their emotional quality. The cingulate gyrus, as well as being involved in the processing of emotional stimuli, is involved in inhibitory functioning, and the thalamus has been implicated in a wide range of functions, from regulation of circadian rhythms to control of the motor systems (Andrewes, 2004).

Although these considerations may at first seem to undermine the limbic model of emotion, the multiple functions of the system's structures allow it to accommodate a vast range of data from psychological studies of emotion, such as mood congruency in memory (Lewis, Critchley, Smith, & Dolan, 2005) and the work on attentional theories which suggests emotional disorders are caused by deficient inhibitory functioning (Langens & Stucke, 2005; Verbruggen & DeHouwer, 2007). This latter line of thought has driven extensive work on conditions such as attention-deficit hyperactivity disorder (Barkley, 2005) and obsessive compulsive disorder (Krikorian, Zimmerman, & Fleck, 2004).

In relation to the biological systems that are associated with the experience of emotion, whether they *cause* the experience of emotion, whether their activation *is* the emotion, or whether emotions *cause* their activation in unclear, although the various systems are relatively well specified and their involvement in the complete emotional experience supported by growing evidence. However, in terms of the structure of emotion - that is, the relationships between different emotional states, and their constituent parts - biological models say much less, and the only clear dimension that seems to be presented is the level of activation. That is to say that the system involved in fear for example is either active, and the individual in a state of fear, inactive, and the individual is in a state of relaxation, or its level of activation and the accompanying level of fear are somewhere between these two extremes. Different emotions each involve slightly different systems, or different clusters of neurons that are activated, and so the structures of different emotions can be thought of as combinations of different levels of activation across these systems.

In terms of the different dimensions or structure of emotion, the cognitive models that have been published have adopted graphical analogues, defined by a given number of dimensions. Feldman-Barrett and Russell (1999) review a range of these models, and conclude that the number of dimensions necessary for capturing the full range of emotions is two, based on the observation that many studies across cultures have utilised two-dimensional scales for the self-reporting of emotions.

Russell (1980) for example uses the dimensions of arousal-sleep and misery-pleasure, whereas Watson and Tellegen (1985) used High-Low and Positive-Negative dimensions, and Thayer (1991) utilised the dimensions of Tension-Calmness and Tiredness-Energy. Using the various models they review as evidence, Feldman-Barrett and Russell (1999) present the dimensions of activation-deactivation and pleasantness-unpleasantness as the two dimensions necessary for capturing all emotional experience (see Figure 1.2). These dimensions relate to the hedonic aspect of cognitive appraisals (often referred to as 'valence'), and the intensity with which they are experienced.

Although structural equation modelling has been used to support geometric representations such as those presented in Feldman-Barrett and Russell's (1999) review, other models that are three dimensional have also been proposed, such as Plutchik's (1980) model, in which all emotional experience is captured in a conical space, with positive and negative dimensions accompanied by intensity and distinctness dimensions (see Figure 1.3).

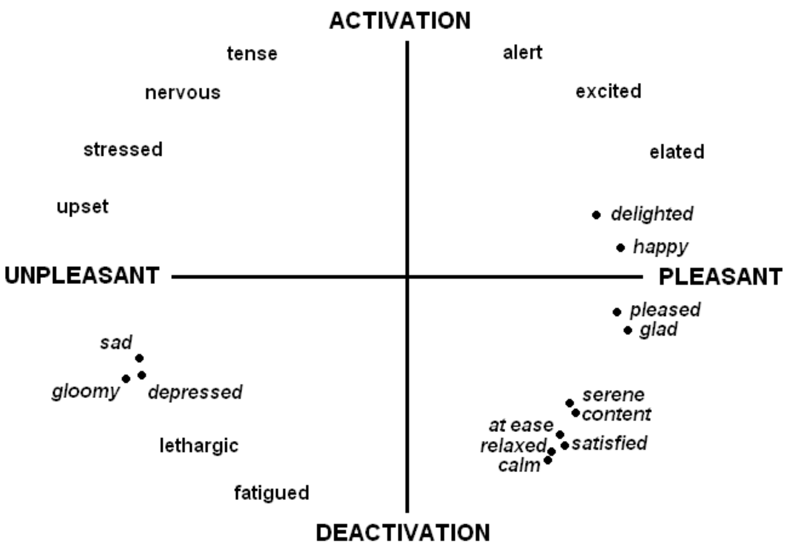


Figure 1.2 The Two-dimensional model of emotion of Feldman-Barrett and Russell (1999) with clustered emotion terms from Russell (1980) indicated in italics.

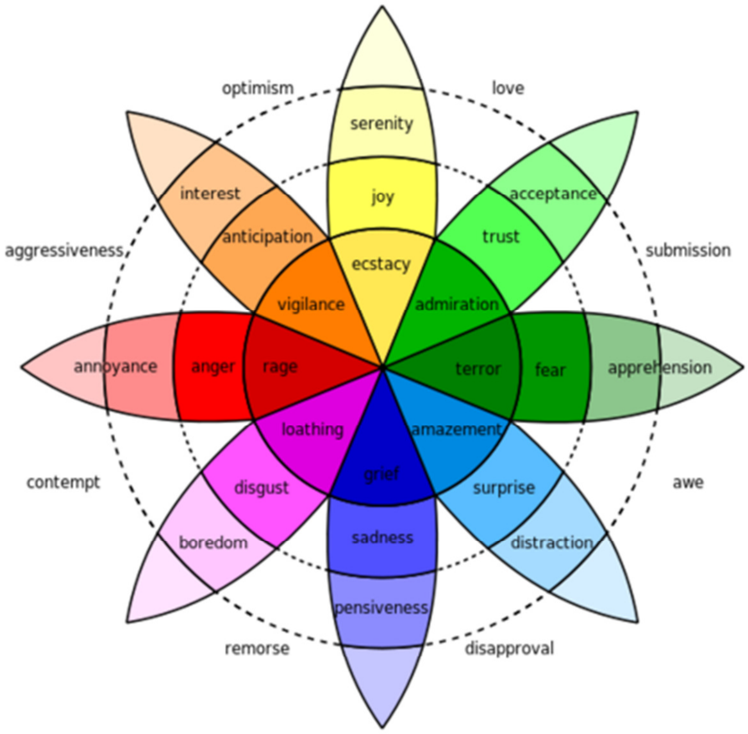


Figure 1.3 Three-dimensional model of emotion based on Plutchik (1980)

Regardless of the number of dimensions proposed, there appears to be a consensus with respect to the inclusion of a positive-negative dimension. However, there is debate over whether the positive-negative dimension is one bipolar dimension, or whether it is two independent dimensions. This latter opinion has received some empirical support from factor analytic studies discussed by Watson, Clark and Tellegen (1988), and resulted in the development of the Positive and Negative Affect Schedule (PANAS, and an extended form by Watson & Clark, 1994). The PANAS provides a measure of independent positive- and negative-affect factors. However, many other researchers continue to use bipolar scales representing positive and negative moods as opposites. Although 'Happy' and 'Sad' may be opposites on both types of scale, the partial or total independence of positive and negative factors should be kept in mind when trying to synthesise findings from the range of experiments in the literature.

Evolutionary models of psychology, as discussed above, considering emotions' adaptive functions, say little about the structure of emotion. That is, other than to offer a structure similar to that of the biologists: that different emotions are caused by the level of activation of a particular emotion module or evolved structure.

The definition of emotion adopted by James, and theorists favouring the affective primacy model of emotion (e.g. Zajonc, 1968, 1980), does not provide a structure of emotion either, other than that it precedes cognition, and is likely to be biological. This again reduces largely to an activation dimension. Advocates of cognitive appraisal theories of emotion (e.g. Lazarus, 1982) provide more in the way of a structure of emotions by outlining the cognitive processes which they claim are involved in generating the appraisals of stimuli. In these cases the structure of emotion can be reduced to the dimensions of activation and pleasantness outlined by Feldman-Barrett and Russell (1999), with the location of the emotion along each dimension being determined by the appraisal.

Embodied theories of emotion (Niedenthal, 2007) provide a link between the biological and the cognitive aspects of emotions. Much like work in embodied cognition which has shown that the perceived objects can cue associated actions (Symes, Tucker, Ellis, Vainio, & Ottoboni, 2008), embodied emotion research has shown that different postures or expressions can cue associated emotions (Parzuchowski & Szymkow-Sudziarska, 2008). These theories provide models of emotion which take into account biological aspects, via sensory feedback, but still accommodate the cognitive ones. Although they do not make predictions regarding the primacy of affect in relation to cognition, they provide a model of emotion which can accommodate the data on the reciprocal effects of emotion and cognition as well as being able to accommodate both areas of research if emotion is considered part of the cognitive system or vice versa (Ciompi, 1997).

Of the models discussed above, this research will make most use of the circumplex model developed by Watson and colleagues (1988), which underlies the PANAS (discussed in more detail below), initially proposed by Watson and Tellegen (1985). This scale is associated with the model of emotion shown in Figure 1.4, which can incorporate situations where positive and negative affect are both high (Segment A), both low (Segment B), or one high and one low (Segments C and D) through the independent nature of the positive and negative dimensions, as indicated by the crossing of the High-Low Positive Affect and High-Low Negative Affect axes. Discussion of the findings reported in this thesis will not be restricted to this one model, despite its theoretical strength in treating positive and negative affect as semi-independent dimensions. It will be used instead as a starting point for the measurement of emotion as defined earlier.

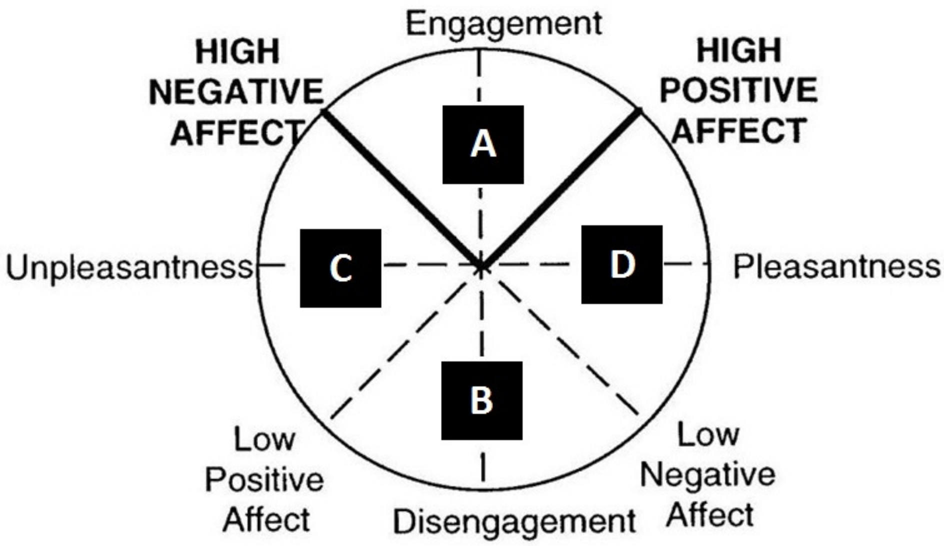


Figure 1.4 Circumplex model of emotion developed by Watson and Tellegen (1985)

In addition to accommodating the independence of positive and negative affective dimensions it can easily accommodate the existing research from a range of areas, including the different psychological and biological systems involved in approach and avoidance behaviours. It also has a number of methodological advantages, which will be discussed in the later experimental chapters. Furthermore, it accommodates the few instances when positive and negative emotions are experienced simultaneously (Bentall, 2004), which improves the scope and generalisability of the emotion aspect of the current thesis. With this distinction between positive and negative emotions in mind, the following section considers the validity of the general ‘positive’ and ‘negative’ mood classifications, before moving on to consider how emotions can be manipulated experimentally. A central part of this review is exploring how the literature on specific emotions is related to these positive and negative categories, and to what extent the findings in relation to specific emotions can be used to inform predictions about the effects of general positive and negative classes of emotion.

1.3 Positive and Negative Emotions

Much of the existing research on emotion-cognition interaction has focused on negative mood states. This may be due to the fact that it is negative moods which tend to have the most detrimental effects on everyday quality of life, and so demand more immediate attention. Depression, social anxiety, dysphoria, phobias, and many other emotional disorders prevent people from living their lives in the ways they want, and so seem to require treatments, which rely on the development of a more thorough understanding of the disorders (e.g. Barlow, 1991; Bodkin et al., 2011). Excessive happiness, or eternal optimism in comparison do not seem to be considered disorders (with all the associated negative connotations of the term), as is apparent from the difficulty faced by someone trying to list emotional disorders resulting from positive emotions. However, the difference between an emotion and an emotional disorder is to a large extent a difference in degree, intensity, and duration, as indicated by clinical cut-off criteria for disorders (e.g. Kroenke, Spitzer, & Williams, 2001); such that chronic depression might be considered an extended period of feeling upset or pessimistic, and social phobia could reasonably be considered extreme nervousness in a specific setting. Other authors may argue that depression and feeling sad are qualitatively different, and that anxiety disorders are experienced as something totally different from nervous apprehension, but then we come full circle to the arguments surrounding the subjective nature of emotional experience. Physiologically, emotional experiences and emotional disorders have been shown to rest along a continuum, and it thus seems reasonable to treat happy and sad moods as at least in part operating on the same mechanisms as euphoria and depression – though it must be kept in mind that the relationship between measures of subjective experience and physiological responses may not be simply linear.

It could also be argued that generalising any findings from specific positive and negative emotions (be they effects on cognitive, physiological, or any other measures) to general positive and negative emotion may raise issues of validity because ‘positive mood’ may not necessarily behave in the same way as any specific positive mood (euphoria, joy, or contentment for example), and ‘negative mood’ may not necessarily behave in the same way as any given specific negative mood (anxiety, anger, or shame for example). However, considering the research on models of emotion, all emotions that can be grouped into 'positive' and 'negative' fall at similar locations on shared dimensions. If these dimensions are considered factors of emotional experience, then there also appears to be shared components between positive and negative emotions. This is shown nicely in Russell’s (1980) paper, which presents a precursor to the model of Feldman-Barrett and Russell (1999). Based on dimensional scaling of various affective words, it can be seen that terms such as sad, gloomy and depressed are clustered together, as are emotions such as pleased, glad, happy and delighted (Figure 1.2). As such, results from studies on anxiety might be expected to generalise to emotions which are clustered close to anxiety, an assumption supported at least in part by the similarity in the diagnostic symptoms of anxiety and depression-related disorders (APA, 1994) and neuropsychological research (Heller & Nitschke, 1998). Similarly, results from research on relaxation might be expected to generalise to other positive mood states such as happiness and contentment. Finally, as an example of data which supports the points made above with respect to similar effects being found for related but phenomenologically distinct emotions, Bugman and Schnall (2008) have shown that disgust and sadness, both negative affective states, have the same influence on cognitive judgements of distance even though the experiences of each state are often reported as very different.

1.4 Manipulating and Measuring Emotion

Researchers in the area of emotion typically adopt one of the definitions discussed in Section 1.1.2, and as a result focus on manipulating specific aspects of the whole emotional experience. Regardless of the definitions used, a range of manipulations have been developed to alter and measure participants' moods.

Emotional images, video (Silvestrini & Gendolla, 2007) or pieces of music (Allwood, Granhag, & Jonsson, 2002), or combinations of manipulations (Mayer, Allen, & Beauregard, 1995) are common in the literature. Reading or writing about emotional events (Brand, Reimer, & Opwis, 2007; Tamir & Robinson, 2007) as well as completing emotional sentences (Ikegami, 2002) have also been commonly used as direct mood manipulations, whereas others have manipulated mood indirectly by varying task difficulty (Kitamura, 2005; Sakaki, 2004).

Although these manipulations are largely effective as shown by the reported manipulation checks, the duration of the mood states that they elicit has not been reported by the authors cited above, and the manipulations have often been criticised on the grounds that the mood states they create do not last for the duration of the subsequent tasks (Eich & Macaulay, 2001). Very little work has investigated directly the duration of induced emotive states and experiences (Salovey, 1992). This is important to consider as it may lead to problems when interpreting the results with respect to the mood that participants were in during task completion. To overcome this, a technique known as the continuous music technique (CMT) has been adopted by some researchers (Eich & Macaulay, 2001), which requires participants to listen to music whilst contemplating emotive thoughts, and at various intervals record their mood on a nine-by-nine grid which has the two dimensions labelled unpleasant to pleasant and low arousal to high arousal. Participants are not allowed to begin the experimental task until their mood reaches a pre-specified point.

This method, although it has been shown to generate strong and lasting moods (Eich, Macaulay, & Ryan, 1994), is based on a two-dimensional model of mood similar to those reviewed by Feldman-Barrett and Russell (1999), and so may not be suited to the investigation of moods that cannot easily be defined along intensity and pleasantness dimensions. In addition, the subjective interpretation of the terms 'pleasant' and 'arousal' may result in different participants indicating different moods with the same squares; this is aside from the potential practical and time constraints introduced by setting a threshold which may in some cases never be reached. The current work will evaluate the extent to which emotions are experienced during the experimental procedures by adopting a technique similar to that outlined by Salovey and Birnbaum (1989), which embedded Likert-type mood rating tasks within their experimental procedures.

In a meta-analysis of published mood manipulations Westermann and colleagues (1996) concluded that of the manipulations they compared, film or story based manipulations were the most effective; that effects were larger when participants were explicitly instructed to enter a given mood; and that effects covaried with study characteristics such as setting, controlling for demand characteristics, and the overall purpose of the study. However, overall, effect sizes appear to fall within the medium to large categories, suggesting that all mood manipulations can be effective if administered carefully. In addition, induction into negative mood seemed to elicit larger effect sizes. This may be due to negative affective states being more distinct and clearly defined (in a socio-cultural sense, as discussed in Section 1.3) than positive states, which lends some support to the idea that the positive and negative dimensions of mood are distinct; the negative dimension being easier to manipulate. However, this may also be due to average pre-manipulation moods being positive, resulting in less scope to make moods still more positive.

An additional concern when using manipulations based on the presentation of pre-selected materials, in whatever modality, is the issue of subjectivity. The materials selected by the experimenter, even if pretested, may not be rated similarly by every participant. One way around this is to use manipulations which allow the individuals to choose their own materials. This has been achieved by researchers such as Brand and colleagues (2007), and Tamir and Robinson (2007), who used written mood manipulations asking participants to recall and write about a life event which made them feel a certain way thus overcoming the issue of experimenter subjectivity in the selection of materials. As a result of these considerations, the self-guided writing task used by Brand and colleagues (2007) will be adopted for experiments reported here which include a manipulation of mood, and is discussed in more detail in the appropriate methodology sections.

In relation to measuring emotions, given the importance of considerations of the strength, stability, and sincerity of generated moods in experimental manipulations (Forgas, 2001), some measures may be preferable to others. Assessing the strength and the stability of the mood requires measures which can capture the full range of emotions, or at least are based on dimensions to which the emotions of interest can be reduced. As for the sincerity of the emotions generated, it seems reasonable that the use of manipulations which allow the individual to choose their own materials will result in more 'genuine' emotions. Although the current work begins with a consideration of how mood states affect an individual's reasoning (Chapter 3, later revisited in Chapters 6, 8, and 9), the impact of emotive content is also of interest, and presents its own challenges. These will be discussed as they arise (in relation to reasoning in Chapter 2, and specific experiments in Chapters 4, 5, and 7).

Biological and physiological measures such as diastolic blood pressure, galvanic skin response, and heart rate, as well as adrenalin, cortisone, and catecholamine responses (Hamer, Tanaka, Okamura, Tsuda, & Steptoe, 2007) have been used in a number of studies investigating both the biological responses to emotional stimuli and their relationship to cognitive factors (Averill, 1969; Simeon et al., 1992). More commonly used in the psychological literature are self-report measures of mood based on a range of response scales. One example already mentioned is the continuous music technique, whilst others are variations on analogue responses. Examples of these include those such as are used by Mayer and

Gaschke (1988) and Mayer (2008), which require participants to rate their overall mood along an axis ranging from *very unpleasant* to *very pleasant*, or the scale used by Allwood et al (2002) which required participants to rate their mood along activation and pleasantness dimensions.

Studies comparing various biological and psychological measures in emotion research and other fields have found mixed results, with wide variation in reported correlations of different physiological and psychological factors (Craig, Tran, Wijesuriya, & Boord, 2006; Gevins & Smith, 2000; Hand, Phillips, & Dudgeon, 2006; Simeon et al., 1992) but this may be due to the variability in the measures used, the different types of tasks participants had to engage in, and the myriad individual differences that can affect the measures. It may also be the case that the biological measures lack the discriminative power of cognitive measures designed to assess specific constructs, or it may be due to differences in the constructs that are measured, given that psychological measures are typically highly correlated with other measures of the same theoretical construct, and biological measures of the same systems are highly correlated.

However, given the focus of this thesis is on the cognitive components of emotion, and the impact of emotion on cognitively based reasoning tasks, self-report measures such as the PANAS, which was introduced earlier, are justified as measures of mood. Developed by Watson and colleagues (1988) the PANAS provides an easy to administer and easy to score scale. The scale requires participants to rate the extent to which they are experiencing a series of thirty emotion words in order to measure both the positive (PA) and negative affective dimensions (NA). In line with the discussion of models of emotion earlier, this allows all possible emotional states to be captured, including those which comprise apparently contradictory emotions, and allows for the possibility that the positive and negative factors of mood are different in nature, and potentially therefore affect cognitive processes differently.

In addition, the instructions can be re-worded to capture state or trait emotionality, and the data collected on the scale to date shows that it is correlated with longer measures of mood, supporting the construct validity of positive and negative factors of mood, and the convergent validity of the PANAS as a mood scale.

Although open to the argument of subjective definitions of emotional states and interpretation of the words that are to be rated, the flexibility, both practically and theoretically of the PANAS make it well suited to investigating the relationship between cognition and emotion. These properties further support the use of the PANAS as a measure of mood state where one is required, and as mentioned above, details of its administration will be discussed further in the experimental chapters. Where alternative methods are used to assess emotional experiences, these will provide an opportunity to cross-validate the PANAS in a reasoning-focussed setting, and details will be discussed in more depth where appropriate.

1.5 Cognition and Emotion

Having now considered definitions of emotion and how they can be manipulated and measured, the current section develops the ideas of positive and negative emotion to consider their impact on cognitive processes. What follows is a review of models of emotion and cognition and the implications of each in relation to understanding how emotion might affect cognitive processes. That is, the elements which comprise emotion in relation to cognitive abilities, and the theories which have been developed to account for their interaction in a range of domains, though with a focus on the cognitive and social-psychological literature as this is where most of the work has been conducted.

1.5.1 Inappropriate Activation, Networks, and Priming

Barlow (1991) and Alloy (1991) both propose models of emotional disorders where the disorder arises from an inappropriate activation of an emotion, which is stored in memory, and is subsequently thought of as uncontrollable. This perception of uncontrollability then leads to a focusing of the individual's attention on the emotion, which in turn intensifies the emotion, and a feedback loop is created which is difficult to break (see Figure 1.5)

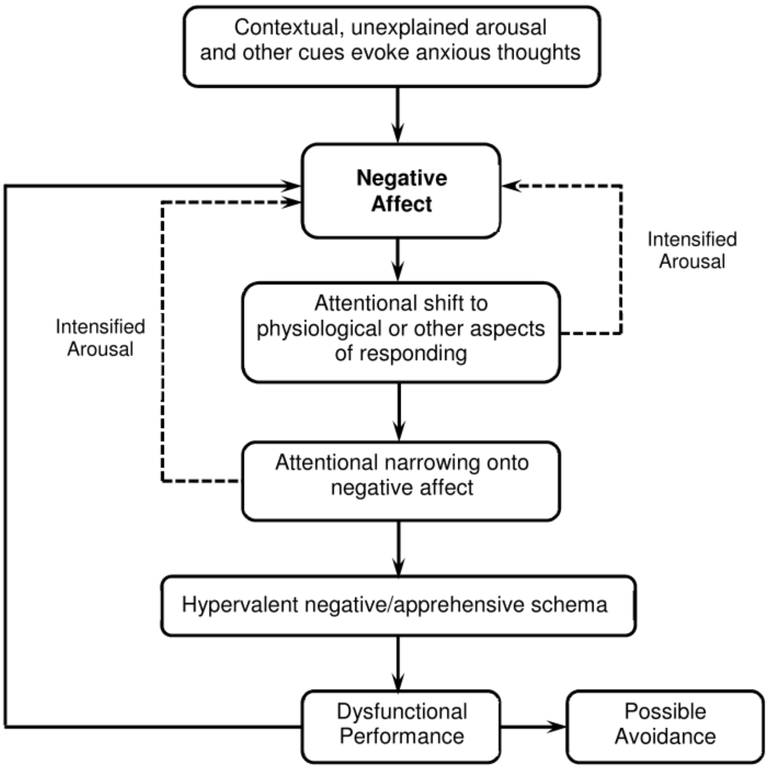


Figure 1.5 Barlow's process of negative apprehension, adapted from Barlow (1991, p61)

In terms of how these models predict mood would affect behaviour, they suggest that emotion has a cognitive basis, and that the experience of emotion requires some cognitive involvement as it is retrieved from memory. This process then focuses attention on the emotional experience, which would reduce attentional and other resources available for processing of task-relevant information (as working memory has a finite capacity), thus emotions may impair task performance if sufficient resources are not possessed to process the emotion in parallel with other information.

However, other research suggests that individuals suffering from obsessive compulsive disorder show improved inhibitory control relative to those not suffering from the disorder, and increased activity inhibition in people suffering from negative mood (Krikorian et al., 2004; Langens & Stucke, 2005). These findings suggest that negative mood states would increase the individual's ability to ignore the negative mood and avoid the feedback loop, which seems somewhat paradoxical, yet it should be noted that this is an increase in ability to reduce the focus on negative mood after it has been acknowledged. However, as Langens and Stucke (2005) comment, there may be ironic effects of mood suppression (Bushman, 2002), similar to those found in thought suppression (Matlin, 2003).

Although these and other early models focus on the effects of negative mood, recent studies on the effects of positive moods on attention have shown that they direct attention to positive stimuli in the same way (Tamir & Robinson, 2007). This provides further support for the idea that such models developed initially in light of negative moods can reasonably be applied to positive moods as well, a claim which is also partly supported by work on mood-congruent attentional bias (Forgas, 2001).

Bower's (1981) affect priming model on the other hand focuses on the informational value of emotions. Affect is seen as a feature of mental representations of the world, and will thus prime related ideas in much the same way as spreading-activation in network models of cognitive processes. Most work on the affective-priming model seems to have been directed towards explaining mood congruency effects in memory (Forgas, 2001), and might serve as an explanation for any content effects in thematic reasoning tasks when they are encountered in later chapters.

Though mood-congruency might explain some content effects in reasoning, such as that individuals with certain emotional disorders reason more accurately when the material relates to their condition (Johnson-Laird, Mancini, & Gangemi, 2006), it seems unlikely as an explanation of the increased bottom-up processing claimed to be caused by negative mood (Schwarz & Clore, 2003), or as an explanation of mood effects found with neutral material (e.g. Forgas, 2001).

Blanchette (2006) also makes the interesting point that emotions may prime associations which subsequently load working memory. Although standing apart from other network models, and unallied to any one particular theoretical position, this observation is of relevance when evaluating the possibility that emotions can interfere with cognitive processes by acting as cognitive load.

1.5.2 Affect-as-Load

In the discussion above, the relationship between cognition and emotion was thought of in terms of network models and activation models. This led to the idea of emotion acting as cognitive load. How emotions generate this load was presented as being the result of inappropriate activation. A related concept is that rather than explicitly activating irrelevant information in memory or irrelevant nodes in a cognitive network, emotion might load the attentional system, or alternatively redirect resources to emotion-related processes. These ideas are considered in the following sections.

Attentional Bias and Cognitive Appraisals

A meta-analysis by Bar-Haim, Lamy, Pergamin, Bakermans-Kranenburg and van Ijzendoorn (2007) found that the bias for processing threat-related stimuli exhibited by anxious individuals, both with stimuli that required conscious perception and with stimuli presented outside of conscious awareness was reliable across studies. They also found that the bias is similar across clinical and non-clinical anxiety groups, but is not present in non-anxious individuals. Whether this bias is the result of the threat, is cued by anxiety, or is a different phenomenon, Bar-Haim and team (2007) provide a model of threat evaluation in which on-going processes may be halted by threat, depicted in Figure 1.6, which is applicable to the current discussion. In terms of a range of cognitive theories, the initial goal in a given task would be to deploy appropriate strategies to reach a decision or conclusion. The presence of threat or anxiety would deplete the cognitive resources available to these goals, and thus lead to the abandoning of more carefully considered strategies in favour of faster, lower effort strategies.

Öhman, Flykt and Esteves (2001) as well as Poliakoff and colleagues (2007) provide evolutionary accounts of emotion directing and thus facilitating attention to threatening stimuli, and Derryberry and Reed (1998) discuss this effect in terms of global and local processing, with anxious participants showing improved processing at a local level. This is supposedly due to increased attention to component features, and reduced attention to the global environment; similar to the findings of Schnall and colleagues (2008) who, using the embedded figures task, found that positive mood reduced attention to detail relative to negative mood. This difference in global and local processing is incorporated in Eysenck and colleagues' (2007) attentional control theory, in which it is explained in terms of anxiety impairing efficient functioning of the goal directed attentional system, and promoting instead stimulus-driven processing. As such, anxiety decreases attentional control, which leads to increased attention to threat related stimuli in anxious individuals. The impact of anxiety on cognitive processing, then, seems to depend on central executive functioning, specifically in the form of inhibitory control and shifting (either inhibiting attention to or directing it away from the irrelevant aspects), and in addition, the extent to which anxiety may lead indirectly to the use of compensatory strategies so as not to lead to decreases in efficiency or effectiveness.

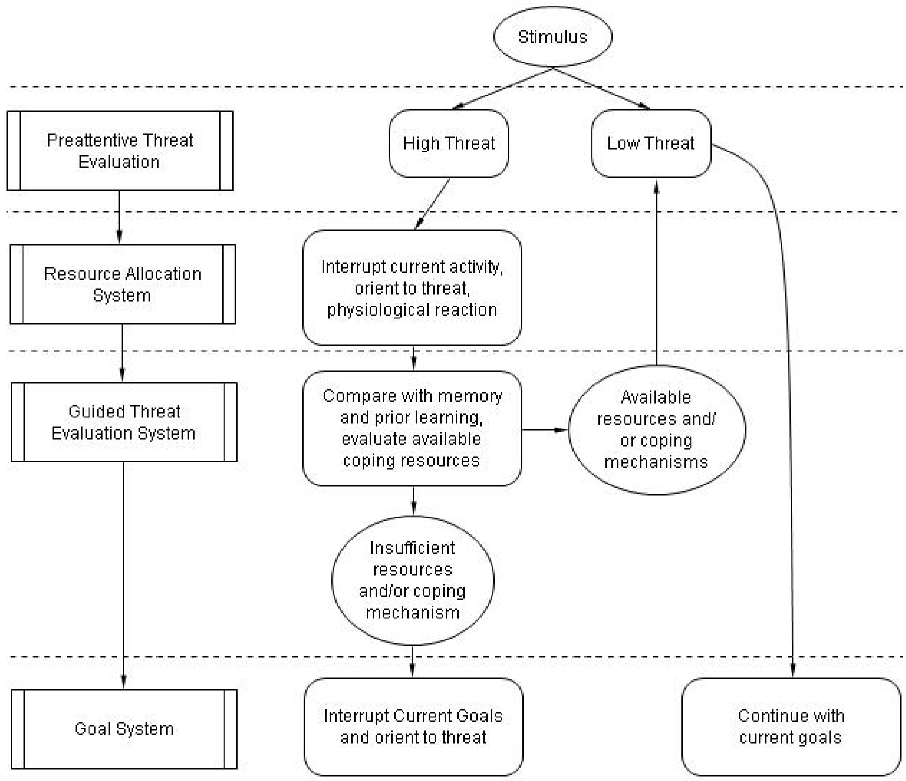


Figure 1.6 A cognitive model of threat evaluation processes, adapted from Bar-Haim et al (2007, p17)

If the effects of emotion are caused by the allocation of limited attentional resources in such cases to anxiety related content, combined with evidence of differences in attention allocation in syllogistic reasoning (Ball, Phillips, Wade, & Quayle, 2006) and between creative and analytic thinkers in other tasks (Ansburg & Hill, 2003), there would seem to be a large individual differences factor involved in the role of attention in emotion-cognition interaction. This in turn may be related to individual differences in coping strategies which require controlled attention and cognitive resources to function (Forgas & Ciarrochi, 2002; Gross, 1999). In support of the limited attentional resources being depleted or reallocated by anxiety is the study reported by Lavric et al (2003), which showed that anxiety selectively disrupted visuospatial working memory. This was explained by the shared use of the attentional system by anxiety and visuospatial working memory.

Hyper-Emotion Theory (Johnson-Laird et al., 2006) is one of the more recent theories presented to explain emotion-cognition interaction with recourse to attentional processes. Originating from three epidemiological case studies, and supported by three empirical studies, the theory argues that individuals suffering from emotional disorders reason more accurately about topics relevant to their conditions due to a tendency of the individuals to focus on the situations in which they experience the effects of their disorders. Johnson-Laird and colleagues (2006) argue that this heightened attention to the situations surrounding their disorder leads them to develop accurate inference patterns in these areas, which then lead to the facilitation in reasoning and decision making about related topics. However, this pattern of results might also be explained by the attentional theories discussed above. Furthermore given that these effects on reasoning can be mediated by self-esteem and personality variables (Rusting, 1998; Smith & Petty, 1995), it may be that specific personality traits such as extroversion, need-for-cognition, or reward responsiveness (to take just a few possible examples) are comorbid with the emotional disorders investigated by Johnson-Laird and colleagues (2006), and thus lead to the effects found by directing attention or encouraging perseverance.

In relation to cognitive appraisals as the basis for a model of the relationship between emotion and reasoning, appraisal theory argues that the emotions experienced by individuals are determined by their appraisals of given stimuli (Lazarus, 1982). However, appraisal theorists do not generally try and explain the cognition-emotion relationship, although a cognitive basis of emotions would constitute the starting point. It seems reasonable to assume that the experience of any emotion would therefore require processing, and this processing would draw on cognitive resources. The appraisal process then provides one possible mechanism of how this loading effect is generated.

Resource Allocation and Processing Efficiency Theory

The ideas of limited cognitive resources and emotion serving as cognitive load form the basis of another group of theories which are concerned with resource allocation, including that by Ellis and Ashbrook (1988), which claims that induced mood states reduce performance on concurrent tasks by depleting central executive resources. Tohill and Holyoak (2000) provide empirical support for this, showing that anxious individuals are less able to complete complex tasks than non-anxious individuals, an impairment which they attributed to the depletion of cognitive resources.

Developing these ideas, Eysenck and Calvo (1992), and Eysenck, Payne, and Derakshan (2005) have proposed their processing efficiency theory, which draws a distinction between efficiency (accuracy divided by time or effort) and effectiveness (raw accuracy). Anxious thoughts are thought to deplete the resources of working memory (WM), and so impair its functioning. Furthermore, anxiety motivates the avoidance of the task, which is achieved by implementing alternative strategies which are less cognitively demanding; a claim supported by Steinhauser, Maier and Hübner (2007), and which is consistent with the research on attention and anxiety already discussed. Richards, French, Keogh and Carter (2000) also provide support for the processing efficiency theory using an inferential reasoning task, showing that anxiety reduces speed and accuracy on both verification tasks and when processing unnecessary inferences. If anxiety can be accepted as related to other negative emotions as argued above, these results might be expected to generalise across different mood states.

Further support for the idea of mood depleting cognitive resources comes from a study by Dutke and Stöber (2001) which found that not only is anxiety associated with poorer performance on complex tasks, but that the negative effects are reduced when individuals have the opportunity to update working memory; such that the load increase caused by the anxiety is balanced by a reduction in the WM-demands of the task. Anxiety has also been associated with deficiencies in interference resolution in WM (Levens & Phelps, 2008), and the implication of WM in relation to mood-as-cognitive-load is supported by the findings of Van Dillen and Koole (2007) who showed that increasing cognitive load reduced negative mood, suggesting that mood generation and maintenance involves working memory resources.

Oaksford, Morris, Grainger, and Williams (1996) also provide strong evidence in support of the idea in their first experiment by showing that both positive and negative moods decreased performance on the Wason selection task. Similarly, in their second experiment, a concurrent distracter task which loaded WM generated the same pattern of responses. Finally, in their third experiment however, the results showed only positive mood to deplete central executive ability as measured by the Tower of Hanoi task. This final result suggests that there is the possibility that positive and negative mood do not affect reasoning in the same direct way via the central executive, despite still supporting the conceptualisation of emotion as cognitive load, and subsequently emphasises the necessity of including both positive and negative conditions, rather than focussing solely on the more heavily researched negative emotions (as discussed in section 1.3).

McNally (1998), in his review of the effects of anxiety on different tasks draws a distinction between content dependent and content independent effects of emotion on cognitive functioning; selective processing of anxiety stimuli versus general detriments in task performance caused by anxiety, and discusses the evidence to support each type of effect, focussing on attention and memory, but also drawing links to neurobiology.

The cognitive component of the causes for processing abnormalities in anxiety disorders that McNally (1998) addresses are supported by studies such as that by Eysenck, MacLeod, and Mathews (1987) which showed that processing differences are a function of trait anxiety. Their results, although supporting the idea of processing abnormalities caused by anxiety, found that the effects were context dependent, only occurring when threatening and non-threatening stimuli are presented concurrently.

Eysenck and colleagues (1987) concluded that the anxiety was interfering with processing through the pre-attentive, attentional, and interpretative stages, by acting as a form of bias for interpreting stimuli as threatening because the anxiety primed the negative interpretations of stimuli, similarly to how priming models explain mood congruency, and similarly to pre-attentive and selective processing theories. This study does however have limited use in terms of explaining or predicting how anxiety would affect processing of neutral content, other than that its effects may be reduced if neutral content is present without any equivalent anxiety content to compare it to. However, that anxiety appears to have an effect from the pre-attentive stages of processing supports the idea that emotion is meta-cognitive, or at least has an influence prior to central executive allocation of resources.

In summary, there is some support for conceiving of emotion as a form of cognitive load, and there is considerable experimental data which can be interpreted in this way. However, as will be considered next, treating emotion as cognitive load is not the only possible way of accounting for mood effects.

1.5.3 Affect-as-Information

Rather than treating emotion as a source of cognitive load, affective-priming models are based around the informational value of emotion in stimulus processing. This informative aspect of emotions is made explicit in the affect-as-information model of Schwarz and Clore (2003), in which affect influences judgements by serving as a cue for which type of cognitive processing to utilise. Positive mood serves as a cue to top-down heuristic processing, whereas negative mood serves as a cue to bottom-up processing (Clore & Huntsinger, 2007). This mechanism could be conceptualised as affect acting as a 'switch', redirecting cognitive resources to different processing systems, rather than as cognitive load models, in which emotion might be conceptualised as an additional process which draws on the cognitive resources and forces one or another type of processing, depending on how many resources remain and the task demands.

This particular cognitive model, affect-as-information, is supported by a large amount of empirical evidence, and much more exists supporting the particular mechanisms that the model implicates in emotion-cognition interaction. One such example is provided by Kitamura (2005), who showed that individuals in positive moods relied on a feeling of familiarity in judging whether or not particular company names were famous, and thus made more errors than did those in the negative condition; a result which was attributed to positive mood cueing lower-effort strategies such as reliance on the initial familiarity of the names, and negative mood cueing the use more demanding deliberative processing, considering factors beyond the immediate familiarity of the name. This builds on the work of Zajonc (1968) which has shown that familiarity with arbitrary stimuli increased ratings of liking, and Monin (2003), who has shown that liking a stimulus increases ratings of familiarity (see also Garcia-Marques, Mackie, Claypool, & Garcia-Marques, 2004 for similar findings). Interestingly, the combined results of Zajonc (1968) and Monin (2003) provide evidence for the cognitive appraisal view of emotions by supporting the bidirectionality of the emotion-cognition relationship, and provide support for the validity of manipulations of mood based on cognitive tasks.

Affect-as-information models are further supported by studies of the discounting effect first discussed by Schwarz and Clore (1983). Discounting is when the effects of mood are reduced if the source of the mood is made salient. Initially, when asked to make a judgement, people may use mood as an additional source of information, and thus show the biases discussed above – relying on the mood as an anchor or valid factor on which to make various judgements. However, when the person making the judgement is made aware of the source of their mood, even simply by a passing reference which cues them to attend to this alternative source of affective state (Schwarz & Clore, 1983), they correct for the informational influence of their mood on their subsequent judgment of unrelated variables (Forgas, Bower, & Moylan, 1990; Sechrist, Swim, & Melvin, 2003).

This applies not only to positive moods leading to higher ratings of, as in Schwarz and Clore's original paper, life satisfaction, but also to negative moods. When in an environment likely to cause less positive, or more negative moods, people rated their life satisfaction as lower. Rather cleverly, Schwarz and Clore had used local weather conditions as their happy-sad manipulation, finding that individuals asked about life satisfaction in places where the weather was nice reported higher satisfaction than those in locations suffering from bad weather conditions. As the questions were asked via telephone, a casual reference to the weather such as asking how it was provided a subtle way of drawing attention to a possible source of the individuals' current mood state, which is when the discounting effect was found to occur.

Overall, these findings suggest that emotion may affect cognitive processes by acting as a meta- or extra-cognitive cue, similarly to how perceived time distortion has been shown to affect judgements about enjoyment of a task (Sackett, Meyvis, Nelson, Converse, & Sackett, 2008). This implicates mechanisms such as source monitoring (Matlin, 2003) in mediating the effect that emotions may have on cognitive tasks generally and reasoning tasks specifically.

1.6 Summary: Emotion

Before considering the literature on reasoning, it is worth summarising the key points from the current chapter on emotion. Ultimately, the emotional life of *homo sapiens sapiens* is multifaceted and diverse, and each individual emotion comprises a number of elements, from the neurological to the experiential. As the focus of the current research is on how emotions affect reasoning, and reasoning is primarily a cognitive process, the cognitive components of emotion will be taken as the basis for an operational definition of emotional experience; specifically emotional experience will be defined as the self-reported, conscious and subjective ratings of emotion. Treating emotion in this way overcomes a number of methodological issues, such as those concerned with measuring unconscious or physiological elements of emotions, whilst still allowing clear predictions to be made, and models based on the cognitively based ideas of emotion as information and as cognitive load to be tested.

Furthermore, although not committing to any one model of emotion, the adoption of the PANAS and similar cognitively based measures of mood allows a consideration of positive and negative dimensions as separate factors. This in turn relates to the fact that although most of the research reviewed has focussed on specific, mostly negative, emotions such as anxiety or depression, a case can be made for considering these as comprising similar dimensions, such that work on specific emotional states may reasonably be used to formulate hypotheses concerning more general 'positive' and 'negative' emotional states.

Finally, discussion of the nature of emotional states and their positive or negative valence led to a discussion of how they can be manipulated. Many different manipulations have been used, but to overcome issues of subjectivity, a self-directed writing task will primarily be used where mood is manipulated externally to the other tasks being performed by the individuals.

Having now considered how emotion will be conceptualised, measured, and manipulated, we turn to a consideration of reasoning tasks and how people reason. This is followed by a discussion of how emotions may affect reasoning processes specifically, and the models which will be tested in the subsequent experimental work.

Chapter Two

Reasoning

Chapter 1 has outlined definitions and models of emotion, and begun to suggest how emotion impacts upon cognitive functioning. Some consideration was given to its effects on reasoning, although that is the focus of the current chapter, and will be covered in more detail below.

The field of reasoning is well established, and it is the consideration of emotion which is the main focus of the current work, and the inclusion of which constitutes the novel contribution of this thesis. In order to achieve this aim, as with emotion, a number of issues first need to be considered with respect to reasoning. As such, the current chapter will define what is meant by reasoning, and then review theories of reasoning such as mental models and dual process theory (DPT; DeNeys, 2006a, 2006b; Evans, 2002b; Evans, 2003); the latter will be made much use of in the following chapters. Syllogistic and conditional reasoning will be described alongside key phenomena in the literature as these will be the focal paradigms of the experimental chapters. Once the paradigms and theoretical models which explain robust findings have been described, it is possible to move towards an integration of emotion and reasoning theories, and this will form the concluding sections of this chapter.

Specifically, the focus will be on positive and negative emotions, effects of problem content versus the effects of mood states, and how these patterns vary across different reasoning domains in order to develop our understanding of the mechanisms underlying the relationship between emotion and reasoning. Developing a better understanding of these mechanisms is important in that it will help us better understand human behaviour in a more holistic, less restricted manner than has so far been done in the reasoning and emotion domains independently.

The majority of emotion-cognition research, as will be seen, has focused on social reasoning and social interaction (Forgas, 2001), with relatively little research looking at the interrelationships between emotion and non-social reasoning. A better understanding of this will provide the grounding for understanding how emotions affect everyday decisions and understanding how people might act in different emotive situations; but first, a definition of reasoning is required.

2.1 What is Reasoning?

Having outlined a working definition of emotion for the purposes of this investigation, this section aims to consider what is meant by 'reasoning' in the psychological literature, and the following sections aim to deal briefly with the implications of the different possible definitions in relation to how they allow reasoning to be incorporated into models of emotion. Taking the Oxford English Dictionary definition of reasoning as a starting point again:

Reason. •**n**. **1** a cause, explanation, or justification. ▶good or obvious reason to do something ▶ *Logic* a premise or argument in support of a belief, especially a minor premise given after the conclusion. **2** the power of the mind to think, understand and form judgements logically. ▶(**one's reason**) one's sanity. **3** what is right, practical, or possible. •**v**. **1** think, understand, and form judgements logically. ▶(**reasoning something out**) find a solution to a problem by considering possible options. **2** (**reason with**) persuade with rational argument.

Leaving aside ‘reason’ as used to refer to justifications or explanations, the everyday definitions of reasoning focus around the manipulation of information towards the goal of a solution or persuasive argument. It is the definitions centring on logic which will form the basis of ‘reasoning’ as it is used in this thesis, particularly in terms of forming judgements *logically*. However, the OED merely provides a common-sense or lexical definition, and does not do justice to technical definitions which abound in the literature, and these will be considered below.

Though there is much work on judgement and decision-making, the current research project will focus on reasoning towards judgments of logical properties, such as evaluating the logical validity of conclusions. However, the term ‘logical’, and what is meant by it raises a number of issues. Before discussing them further and in more detail, it is important to understand that performance on reasoning tasks is usually, though not always, assessed against formal logic. This is often referred to as the normative standard, or normatively logical responding.

Subsequently, the judgements of logical validity are derived from this normative logic. Taking the OED definition concerning the integration of premises; premises are individual statements, such as “All men are mortal” and “Socrates is a man”. A conclusion might follow these premise statements, such as “Therefore, Socrates is mortal”. In much work on reasoning, individuals are asked to judge whether the conclusion is (logically) valid or not, assuming the truth of the premises. So, assuming that all men are mortal, and that Socrates is indeed a man, the conclusion, that Socrates is mortal must be true (valid). There are some conclusions, such as the one presented here which must be true if the premises are true; that is, they necessarily follow. Others may only represent one possible conclusion that can be drawn, and yet other conclusions are impossible to draw logically; but more on necessity and possibility later (Chapter 3).

Assessing judgements against normatively logical criteria allows the use of a generally accepted measure of *logical* accuracy. This is not to say that normative standards of logic are the correct ones to apply to everyday decision making and judgments, or that normative responses are more, or less, *rational* than standards based on, for example, ecological or pragmatic factors (e.g. Marewski, Gaissmaier, & Gigerenzer, 2010). However, as logic provides a clear, objective, and unambiguous means of defining problem and conclusions types, it will be adopted as the standard in this thesis.

Related to how reasoning accuracy is defined is the rationality debate. In the same way as reasoning may be assessed against normative or pragmatic criteria, decisions may be assessed in terms of rationality. The topic of whether or not humans are rational, and what standards should be used to measure rationality is an interesting one, but only one key point will be raised here. It is important, given how emotionally driven responses are commonly framed as irrational, to highlight the fact that logical accuracy as used in the experimental work reported here is not necessarily indicative of rational behaviour. Many have argued that normative theories don't provide a valid measure of rationality, not least because logical responding is not necessarily 'rational' as it doesn't typically account for situational variables. Alternative pragmatic theories, which take into account situational and social variables have been proposed by many researchers to account for the patterns of non-logical responding in a range of reasoning tasks, most notably thematic versions of the Wason Selection Task (Evans et al., 1993; Manktelow, 2000; Rossano, 2002).

A nice example, because of how its visual representation instantly illustrates its complexity, can be found in the Nash Equilibria, discussed by Bentall (2004, p112), and others (Sugden, 2008; Walliser, 1998; Young, 1998). This equation which aims to provide a model of rational behaviour where rational is equated with logical decisions in economics, and can be stated as:

$$\forall_i, x_i, \in S_i, x_i \neq x_i^* : f_i(x_i^*, x_{-i}^*) \geq f_i(x_i, x_i^*)$$

In summary, the statement above is used to determine the action of one individual ($\forall_i$), when choosing one strategy (x^*) from a set of possible strategies ($S_i = (S_1)(S_2)\dots(S_n)$) and a set of possible pay-offs ($f_i = (f_1)(f_2)\dots(f_n)$), taking into account the strategies available to the n-other individuals involved (x_{-i}). 'Equilibrium' is reached when no change in strategy made by the individual results in an increased payoff. This would predict that for systems in equilibrium, no individuals would change strategy. Although this applies reasonably well to mathematical models of economics, how well it applies to people is doubtful, not least because it fails to consider the possibility that a player might be willing to suffer a loss if it harms another player's payoff as well.

To return to the relationship between reasoning and emotion, one case where this logical-rational contrast is especially obvious is in pathological indecision. This is where normative rules are applied excessively to everyday decisions to which they are not suited (Lehrer, 2009; Zahra, 2012), and arguably, where the usual weighting influence of emotion is not included in the calculations, leaving two or more options equally viable candidates. This leaves the individual with no way of deciding logically between the two. Applying formal logic to psychological reasoning processes assumes that people have an infinite processing capacity, and, as the Nash Equilibria hopefully demonstrates, this is unlikely to be the case. However, the concept of bounded rationality provides some scope to account for processing limitations in psychological models of reasoning and decision making (Hanoch, 2002a, 2002b). These theories might also be compatible with models of emotion effects in reasoning which treat emotion as impacting the amount of available cognitive resources. In summary, although there is room to develop this discussion in the reasoning literature, the current thesis does not aim to determine the rationality or otherwise of decisions under different emotional states but will adopt formal logic as a means of categorising responses to reasoning problems.

2.1.1 Working Memory

Given its importance to the following models of reasoning, it is worth considering the Working Memory (WM) construct. Central to almost all cognitive theories of reasoning, WM is a replacement for the older 'short term memory' construct (Atkinson & Shiffrin, 1968). Although the working memory system has been outlined in different ways (Miyake & Shah, 1999), the most widely adopted and empirically supported is Baddeley's multi-component model (Baddeley, 1996; Baddeley & Hitch, 1974) with its central executive system, and visuospatial sketchpad, primary acoustic store, and phonological loop subsystems, later combined with an episodic buffer to link the WM system more closely to long-term memory (Baddeley, 2000; Repovš & Baddeley, 2006). WM is thought to be a limited capacity system in which the central executive allocates cognitive resources to the subsystems. It is this limited nature of working memory and cognitive resources which has led to much research and theorising on individual differences in reasoning. For example, Barrouillet and Lecas (1999), Gilhhooly, Logie, and Wynn (2002), as well as García-Madruga, Gutiérrez, Carriedo, Luzón, and Vila (2007), to select just a few examples, have shown WM capacity to be predictive of reasoning responses on syllogistic and conditional reasoning tasks, the two main paradigms used in this thesis. This limited capacity has led some researchers to equate reasoning ability with WM itself (Kyllonen & Christal, 1990; Suβ, Oberauer, Wittman, Wilhelm, & Schulze, 2002). This view has been contended (Garlick & Sejnowski, 2006; Ruff, Knauff, Fangmeier, & Spreer, 2003), and Evans and colleagues (1993), for example, point out that true logical competence, measured by normative rules, may be masked by other factors that affect task performance; such as the type of processing adopted or the load exerted by concurrent tasks. Despite this, the finding that WM performance correlates with reasoning performance suggests that the two are related and that the cognitive models of reasoning based on the WM construct are not seriously undermined by the possibility that additional factors contribute to reasoning ability.

From a neuropsychological perspective, working memory, central executive functions, and higher cognitive functioning in general have been considered the role of structures within the neocortex (Andrewes, 2004), the brain systems which are youngest in evolutionary terms (Rossano, 2002). This relatively recent development of 'reasoning' provides evolutionary support for the notion that reasoning and emotion are distinct systems, with the amygdala and basal ganglia responsible for emotional responses developing much, much earlier on the evolutionary timeline (Gazzaniga et al., 2002).

Reasoning tasks undoubtedly involve many systems in the brain, from perceptual processing in the primary visual cortex, through the evaluation of potential threat in the limbic system, to the use of memory structures such as the hippocampus in finding similar cases. Recent research has attempted to isolate the areas and systems involved in the reasoning aspect of this process; specifically those centres which evaluate the options constructed from this flood of information and decide on a response. Although the biological underpinnings of interactions between these aspects are outside the focus of the current research, and will not be directly investigated, the work on the underlying neurology of reasoning serves to emphasise the importance of WM and cognitive resources in reasoning, and provides a counterpoint to neurological models of emotion discussed earlier.

As such, WM as a construct provides the basis for theories of reasoning which refer to cognitive load, capacity, or processing limitations, and the literature in support of the construct very briefly touched on here provides one way of linking the reasoning literature with the emotion literature from the previous chapter, namely that emotion may affect reasoning by acting as additional cognitive load and thus reducing the availability of WM resources which are central to logical reasoning.

Stanovich and West (2000) argue that the discrepancy between normative responding and how people actually respond is accounted for by performance and computational error. In a response to this Bucciarelli (2000) makes the case that there is greater variability in performance errors on complex problems than simple problems, citing data collected by herself and Johnson-Laird (1999). However, she also raises the issue of variability in working memory capacity as a predictor of both performance and computational limitations. The control of working memory capacity and related constructs such as IQ therefore become important in the design of studies aiming to investigate factors affecting reasoning performance. These studies are also related to work such as that by Newstead, Thompson, and Handley (2002) which has shown that performance on syllogistic reasoning tasks is related to an individual's ability to generate alternative interpretations of the information presented in the problem. That is, when reasoning, most theorists suggest that individuals form mental representations of each statement which are then manipulated in working memory in such a way as to allow the evaluation of a conclusion. Given that information in reasoning tasks can be combined in different ways, the number of these mental representations that are created is thought to determine an individual's success (normatively defined) on reasoning tasks. Such work shows the importance of considering a range of individual differences variables as potential predictors, mediators, or moderators of emotion and reasoning interaction. Having defined reasoning and how it will be measured, the following section will review theories of reasoning, elaborating on this idea of mental representations and what people do with them after they are created. This in turn will provide a basis for combining theories of emotion and reasoning.

2.2 Theories of Reasoning

Evans (1991) outlines four types of theory relating to reasoning; those based on inference rules, context-dependent rules or schemas, mental models, and those based on heuristics. This section will broadly follow these categories, although more recent integrative theories which transcend these groupings will also be considered. In addition, selected neuropsychological evidence will be introduced where it is relevant to the theories under discussion, where it describes the physical basis of the cognitive processes, and where it relates to the models of emotion presented previously.

2.2.1 Mental-Logic and Mental-Rules

The following section is concerned with those theories which fall under the general headings of mental logic, inference rules, or rule-based theories (Manktelow, 2000). Mental-logic theories propose that people reason by following logical rules, built around the functions of the logical operators *and* for conjunction, *no*t for negation and *if… then* for conditional relationships. Generally speaking, rule-theories envisage reasoning as the progression through a series of steps determined by sets of rules. Consequently, they predict that the difficulty of reasoning problems will be determined by the number of steps required to reach a conclusion, and that errors in reasoning can be explained by either the limitations of the cognitive system, by the application of incorrect rules, or the misapplication of the correct rules. Largely, rule-based models propose three stages to this process; encoding, reasoning, and decoding (Rijmen & De Boeck, 2001). Encoding involves representing the logical structure of the problem in working memory, reasoning involves applying one or more basic rules to the problem, and decoding involves transforming the resulting conclusions back into whichever format is required.

Although rule-theories may take an axiomatic form, whereby every step through the stages is determined entirely by specified rules (such as 'IF Elimination', see Table 2.1), the more recent and more fully developed psychological theories are based on natural deduction, whereby the aim is to provide a psychological model of reasoning as it occurs naturally (Manktelow, 2000).

Table 2.1 Example of IF Elimination

IF Elimination (Modus Ponens)
If the statement If P then Q is given, and P holds in the given situation, Then Q can be taken as being the case via modus ponens, thus eliminating the IF.

Some of the most elaborated mental logic theories are those of Rips (1994) and Braine and O'Brien (1998), and these will be outlined as a basis for contrast in the following section on the model-based alternatives (See Evans et al., 1993 for a more detailed discussion). PSYCOP, the theory presented by Rips (1994), builds on natural deduction with the aim of accounting for how 'ordinary people', those 'who have no training in formal logic' (p103) reason, acknowledging that strict axiomatic representations are not likely to be employed by the average human being. In short, PSYCOP proposes that when presented with premises and conclusions to evaluate, people reason sententially, using their existing set of inference rules to justify the links they make. Errors, as in other rule theories, are accounted for by either the misapplication of or lack of knowledge of the correct inference rules. Braine and O'Brien's (1998) model also takes a similar approach, agreeing with Rips (1994) and other theorists that reasoning proceeds according to a set of inference rules, and that it is related to natural language, much as Rips suggests reasoning proceeds through a series of linking sentences.

To summarise, rule theories argue that reasoning is accomplished by applying a set of clearly defined logical rules to a problem, that problem difficulty is thus determined by the number of rules required to reach a solution, and that errors occur from either the use of inappropriate rules, misapplication of those rules, or insufficient cognitive capacity to apply those rules.

Related to the previously outlined rational-logical distinction and difference between 'mathematical' (the Nash Equilibrium being an extreme example) and 'human' processing of reasoning tasks, Stanovich (1999) argues that the strict logical rules on which rule theories are based are an inappropriate norm against which to compare, or to try to model, human reasoning. The reliance on mathematical models means that these theories have yet to be fully developed in terms of psychological processes, as discussed by Oberauer (2006) when fitting the probabilistic model of Oaksford and Chater (2001) to data on conditional reasoning. There is also the issue, raised by Braine (1978), amongst others, that terms with one meaning in logic have another in everyday language. For example, 'some', strictly speaking, means 'at least one, *possibly all*' in logic, whereas in natural language 'some' is very rarely used to imply 'at least one, but anything up to every instance', instead being commonly used to suggest more than one, *but not all*.

Although rule theories provide a useful framework for computer programmers and researchers in artificial intelligence working with programs that function solely on a logical basis, the limited processing capabilities and subjective factors involved in human reasoning make such strict procedures seem unlikely to provide a complete account of human reasoning. Furthermore, rule-theories cannot account for the poor use of logical rules on abstract tasks, which is reversed if the content is made pragmatic (Johnson-Laird & Byrne, 2002). These facilitation effects found with thematic content may be to some extent accounted for by the contextual information cueing an individual to the linguistic implications of the operators or logical terms in the problem, mentioned above.

Countering some of these criticisms to some extent, theories focussed on the ideas of rational analysis and information gain have also been developed (Manktelow, 2000), which claim that people proceed in reasoning tasks based on the perceived informational value of each action, following logical rules (though not necessarily explicitly), but with recourse to heuristic processes where necessary. This theory largely explains errors in a similar way to rule theories, with individuals working through different stages of reasoning in a pre-determined way (the heuristics and biases will be discussed in more detail below). Ultimately, despite the attempts at addressing them, this range of criticisms has led to the favouring by some researchers of model based theories.

2.2.2 Mental Models

Model theories, from the early Euler Circles and Venn Diagrams (Garnham & Oakhill, 1994) to the later Mental Models theory of Johnson-Laird (1983) propose, as the title suggests, that people reason by constructing models of the information in reasoning problems in order to evaluate conclusions. More specifically, they propose three stages to the reasoning process. First, people read the initial information, or 'premises', and make sense of them, constructing models representing the information presented (Comprehension). They then combine the models of the premise information (Description), and then attempt to validate the combined model by searching for alternative models (Validation), looking for those that are able to represent the same information but in different ways (Manktelow, 2000). For example, take the syllogism "(1) No Postgraduates are Undergraduates; (2) All PhD Students are Postgraduates; (3) Therefore No PhD Students are Undergraduates". The first premises (1) can be thought of in terms of independent sets, as represented at the top of Figure 2.1.

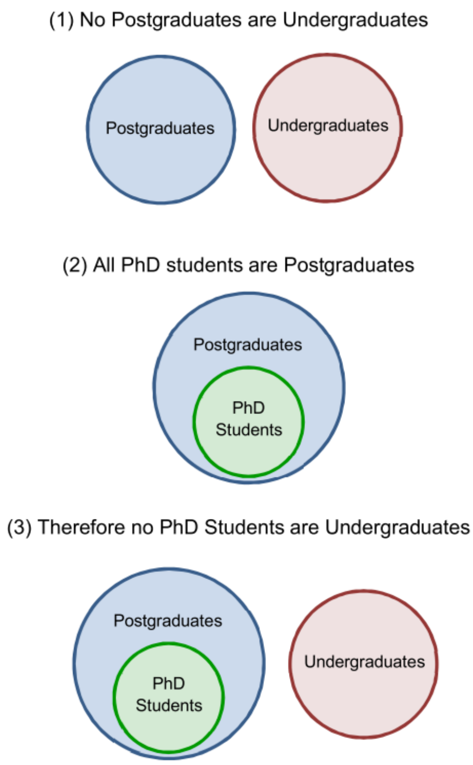


Figure 2.1 Representations of premises and conclusions

The second premise (2) can be thought of as PhD Students being a subset falling entirely within the larger set ‘Postgraduates’. Finally, these two premises can be combined to create the model shown at the bottom of Figure 2.1, which can then be used to evaluate the conclusion (3) as valid; in this model, there is no overlap between PhD Students and Undergraduates.

These models are more commonly written using notation derived from mental models theorists (e.g. Johnson-Laird, 1983), with a, b and c representing Postgraduates, Undergraduates, and PhD Students respectively, and closed brackets represent completely contained sets, such that (1), (2), and (3) above would be rendered as:

(1)	[a]		
		[b]	
(2)	a	[c]	
(3)	[a	[c]]	
			[b]
	...		

Model theories explain the difficulty of reasoning problems in terms of the number of models required to represent the information in the premises (Ford, 1994; Johnson-Laird & Byrne, 1992). If the information in the premises can be combined in a number of different ways, more models need to be constructed, remembered, and compared in order to evaluate any given conclusion. To demonstrate, if we changed the quantifier in the first premise to ‘some’ in the example above, the information contained in that premise (1.1) can now be represented in either of the two ways shown in Figure 2.2.

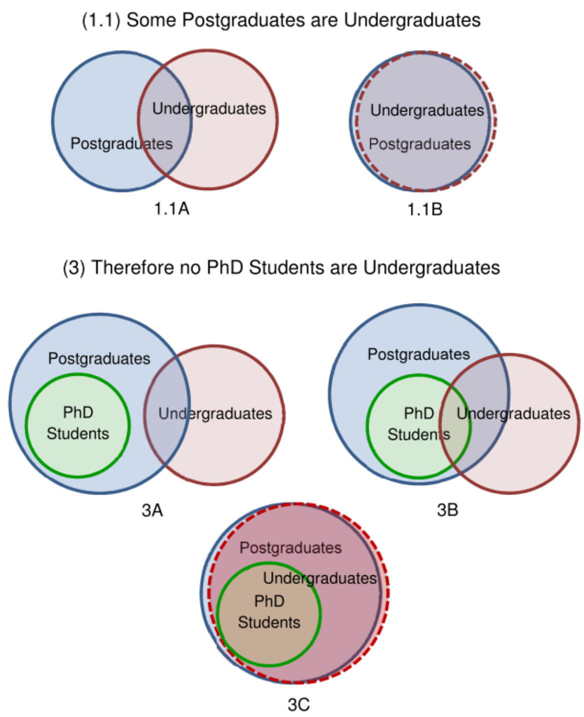


Figure 2.2 Alternative Models

At least one (1.1A) but possibly all (1.1B) Postgraduates are also Undergraduates. This then leads to a number of models for the conclusion which are consistent with both premises, and given that in at least one of them there is overlap between PhD Students and Undergraduates, the conclusion is now invalid. If only the first of these models was constructed, this decision could not have been reached, thus more models need to be considered at the cost of more cognitive effort.

Again, in terms of mental models notation, these might be rendered as;

1.1A	a	b	
1.1B	[a	b]	
3A	a	[c]	
	a		b
	...		
3B	a	b	
	a	c	
	...		
3C	[a	[c]]	
	[a	b]	
	...		

The models in Figure 2.1 and Figure 2.2 can also be used to describe the difference between logical necessity and logical possibility, two ideas which are central to the paradigms employed in Chapters 3 and 4. The syllogism shown in Figure 2.1 leads to only one model of the conclusion (3). In such a case, where all models (albeit only the one in this case) lead to the conclusion following, that conclusion is said to be *necessary*. The conclusion must follow if the premises (1 and 2) are true. In Figure 2.2 however, it can be seen that the premises (1.1, and 2 from earlier) can be combined in at least three ways (3A, 3B, and 3C). Of the three models presented, the conclusion holds in only one of them. There are alternative models in which it does not hold. The conclusions is therefore *possible*, because the premises can be combined in such a way as for the conclusion to hold, but it is *not necessary*; there are ways of combining the premises in which the conclusion does not hold. This distinction will be discussed further in Chapter 3.

In relation to syllogistic reasoning, which will be the focus of the first experimental chapters, the mental models theory of Johnson-Laird (1983; Johnson-Laird & Byrne, 1992) also argues that the order in which terms are presented in a syllogism (it's 'figure'; discussed below) will affect its difficulty. This is because it is assumed that the terms are preferred when they appear in the problem in the order A, B, C. If the terms do not appear in this order, then, it is argued, people transform the premises before beginning the construction of the models, and the transformation requires additional cognitive effort and resources, thus influencing the difficulty of the problem (Ford, 1994).

The most widely applied theory of reasoning, and arguably the most empirically supported, is the above mentioned mental models theory of Johnson-Laird (1983), which is the most fully specified of the model based theories, and possibly the most specified of the reasoning theories in general. The process of model construction and combination outlined by Johnson-Laird (1983) has been used to explain empirical findings relating to both syllogistic reasoning (Bucciarelli & Johnson-Laird, 1999; Manktelow, 2000) and conditional reasoning (Barrouillet & Lecas, 1999; García-Madruga et al., 2007; Johnson-Laird & Byrne, 2002), providing a theoretical framework which has been investigated in relation to the tasks used in this thesis. This in turn provides a more empirically supported model of reasoning than rule theories which can be developed through the addition of emotion as a variable.

The main strength of the mental models theory over the various rule theories lies in its comparatively parsimonious account of reasoning across tasks. The number of models which need to be evaluated can account for error rates on different types of inferences, as opposed to rule theories which often require post-hoc additions to the sets of rules to account for experimental findings (Manktelow, 2000).

Although on the face of it 'more models' as an explanation for difficulty would appear to be very similar to 'more rules' (e.g. Evans & Over, 2004), the number of models required to solve a problem does not directly map onto a problems difficulty or success rates (Rijmen & De Boeck, 2001). Yet mental models theory more closely predicts experimental results than alternative rule-based theories, and is more flexible in that it also allows a range of other factors to be taken into account more easily than rule-based theories, such as preferred models and reasoning styles (Oberaurer, 2006).

Expanding on the difference between 'more models' and 'more rules', under rule theories, where the difficulty of a problem is solely a function of the number of rules, all problems that require one basic rule to be employed should be equally difficult, yet this is not found to be the case (Rijmen & De Boeck, 2001). This is one of the main areas where the model theory excels relative to the rule theory: in providing an account of why different basic rules, which should, in rule theories, be of equal difficulty, appear to vary in their actual difficulty. As Johnson-Laird and Byrne (2002) point out, models are not based solely on logical rules, but take into account the individual's understanding of the premises within a given context – for example, whether an individual understands 'some' in the logical sense or in the everyday sense. Thus models can represent a range of possibilities, rather than being restricted to the certainties of inference rules.

However, mental models theory in its original or even in its revised formulations by no means provides a perfect account of all forms of reasoning. For example, Evans, Over and Handley (2005) provide a critique of Johnson-Laird and Byrne's (2002) explanation of conditional reasoning, pointing out that suppositional theory provides a better account of a range of conditional instances (e.g. Evans & Over, 2004; Handley, Evans, & Thompson, 2006).

Suppositional theory suggests that when people reason about relationships of the 'if *p* then *q*' variety; that is, conditional relationships, they suppose that *p* is the case, and assess the probability that *q* follows. Evans and Over (2004) make the case that typically reasoning research instructs people to assume that the premises are true, and to draw only logically necessary conclusions. They point out that this ignores the distinction between what follows from beliefs or probabilistic statements and what follows from true, or assumed-to-be-true premises. In the Socrates example presented earlier; "All men are mortal", "Socrates is a man", "Therefore, Socrates is mortal"; whether or not you decide that the conclusion is valid will vary depending on whether you have to assume the premises are true, or if you can assign a likelihood or probability to them being true. If there is a chance that not all men are mortal, or that Socrates is not a man, then you may be less likely to agree that the conclusion is valid. As Evans and colleagues (2007) summarise the situation, according to suppositional theory, people reason by simulating cases where the premises are true, and then evaluating their belief that the conclusion follows.

Barrouillet and colleagues (2008) acknowledge criticism of mental model theory (e.g. Evans et al., 2005), but suggest that there are two kinds of reasoning; reasoning about probabilities given assertions, and about assertions given probabilities. They argue that suppositional theory tries to reconcile these issues but fails, and offer a revised model theory, so the debate goes on.

Setting aside for now the arguments against accepting completely the extension of mental-models theory from syllogistic to conditional reasoning, model-based theories of reasoning are more generally supported by recent empirical research, with rule-based theories having largely fallen out of favour. This body of work which continues to grow thus provides a strong basis on which to build the current work, and provides a basis for the predictions of chapters on syllogistic reasoning. The issues with the mental models treatment of conditionals that are raised by suppositional theory will be considered again in the chapters which investigate the effects of emotion on conditional reasoning, and both syllogistic reasoning and conditional reasoning will be discussed in detail after considering next heuristic and then dual-process theories of reasoning.

2.2.3 Heuristics

Whereas formal logic provides one mechanism which people may rely on to reach conclusions when reasoning, heuristics provide an alternative. Heuristic 'reasoning' processes are often referred to in textbooks as 'mental shortcuts', but more specifically, they are in one sense 'rules' (although distinct from the logically derived rules of rule-based theories) which have, according to some accounts, been deduced or inferred from repeated exposure during and since the environment of evolutionary adaptedness so as to be evolutionarily adaptive (Stanovich, 1999). Although other heuristic systems based on frequency and probability detection have to some extent become biologically ingrained, such as foveal (versus peripheral) detail and other elements of our perceptual processes (Gigerenzer & Goldstein, 1996), 'heuristics' as used here will refer to decision processes based on prior experience or elements of the problem which are not logically relevant. In the reasoning tasks used in the experimental chapters believability would be one example of these salient but logically irrelevant features. Given the statement 'all cats are mammals', and 'all mammals have live young', you are more likely to accept the conclusion 'therefore, all cats have live young' than you would be to accept the conclusion "all cats lay eggs" given the statements "all cats are mammals" and "all mammals lay eggs", even when instructed to assume the truth of each premise statement. The believability of the conclusion is irrelevant to an evaluation of its logical validity, yet it can still be used as a heuristic means of reaching a judgement about the conclusion. This has been used to explain the findings in the literature that suggest people are more likely to endorse believable conclusions than unbelievable ones across a range of reasoning tasks (e.g. Evans & Curtis-Holmes, 2005), and the believability of a conclusion or the extent to which an individual agrees with a conclusion may be used as heuristic strategies for problem evaluation. This will be discussed in detail when the heuristic approaches are contrasted with logical approaches in relation to the specific tasks employed to investigate the effect of emotion on reasoning (e.g. Chapter 5).

Other commonly used examples of heuristics include availability, representativeness, and anchoring. These broadly correspond to using the number of examples easily accessible to memory, the similarity between cases, and a particular starting point as the basis for evaluating decision options (see Gilovich, Griffin, & Kahneman, 2002 for details). These are not the only heuristics, though they are possibly the most frequently studied. In the same way that any biological adaptation that is in any way useful to the organism can be acted on by natural or sexual selection (Darwin, 1998), it is feasible that any variable which is correlated in any degree with a correct or useful decision may be developed into a more clearly defined heuristic tool.

Another way in which heuristics may be used to investigate the relationship between emotion and reasoning is by utilising paradigms based on heuristics rather than logical rules. Rather than using syllogistic or conditional reasoning, assuming a logical approach, and then explaining differences in terms of ‘incorrect’ reliance on heuristics, problems can be devised which cue the use of heuristics but in which such reliance can be overcome by thinking in terms of normative logic. One example of this is the Ratio-Bias Task (Pacini & Epstein, 1999), and forms the third type of task, alongside syllogistic and conditional reasoning, which will be used in this thesis.

In the Ratio-Bias Task, individuals are presented with two boxes; whether these are two-dimensional on a screen, described in a short instructional paragraph, or physical boxes in a laboratory is irrelevant; let's call them A and B. Boxes A and B each contain a number of white balls and a number of black balls. The quantities of each are varied depending on the particular variable under investigation, but for this example, let us assume Box A contains seven white balls, and three black balls. Box B on the other hand contains forty white balls, and ten black balls. Your task is to decide from which box you have more chance of drawing a black ball if you were to reach in without looking and remove one ball at random.

There are two main ways people make their choice. The first is by choosing the box which contains the most black balls. This is a heuristic response and is based on frequency. Using such a strategy leads to the selection of Box B; it has ten black balls versus Box A's three. The second, and normative, strategy is to consider the probabilities of drawing a black ball. This leads to the selection of Box A; there is a 30% chance versus the 20% chance of drawing a black ball from Box B.

Reliance on heuristics has often been used as a case to illustrate the irrationality of human reasoning, though having discussed the difference between logic and rationality, it will be clear that the use of heuristics, if they have evolved to allow humans to deal with their everyday environment, at the very most can show that our behaviours do not typically conform to formal logic, and cannot say anything about the rationality or otherwise of our behaviour. Many researchers have made this point repeatedly (e.g. Oaksford & Chater, 2009). Regardless, it is apparent that although some individuals may use formal logic, others rely on these non-logical heuristics, and they therefore need to be considered when explaining reasoning processes.

The Probability Heuristic Model presented by Chater and Oaksford (1999) is one example of an attempt at this, and is based on the idea that reasoning is probabilistic rather than absolute as it is in the inference rules found in mental logic theories or the logical rules that supposedly guide the construction of mental models. The probability heuristic model is based on the idea that when people reason, they accept conclusions based on the prior probability of that conclusion given the initial (minor) premise (Oberaurer, 2006), and in addition, these probabilities are based on everyday experience (Oaksford & Chater, 2001). Much like the evolutionary development of heuristics outlined above; when one relationship is consistently seen, although not logically justified, it may provide a useful, adaptive, problem solving strategy.

Given that people can use logical rules, but that they also frequently use heuristic strategies, models which can account for both of these approaches have gained ground over recent decades in the field of thinking and reasoning. Often referred to as dual-process theories to reflect the logical and heuristic processes they seek to explain, these will be discussed next.

2.2.4 Dual-Process Theories

In light of the research on logical rules versus heuristics and the theories which have been advanced to explain them, models of reasoning obviously need to be able to accommodate both elaborated reasoning processes such as model construction, combination, and validation as well as heuristic response patterns.

To this end, many researchers have adopted approaches that maintain a set of two or more reasoning systems or broad types of reasoning processes. Ferreira, Garcia-Marques, Sherman, and Sherman (2006) for example, use the process dissociation procedure to provide empirical evidence for what they term 'automatic' and 'controlled' processes. Ameel, Verschueren, and Schaeken (2007) adopt a similar framework for interpreting their results on transitive inference tasks, and Evans and Curtis-Holmes (2005) use the concepts of analytic and heuristic processes to account for different patterns of reasoning under speeded and non-speeded responding conditions.

Given the agreement between researchers on the potential properties of each of the two systems, many authors have developed dual-process theories of reasoning, which aim to combine the previous research (DeNeys, 2006b; Ferreira et al., 2006; Rips, 2001). Of these theories, the dual-process theory (DPT) of Evans (2003, 2008) provides a framework which synthesises the work in the area and is based on numerous reviews of the theoretical and empirical work on dual processes in reasoning, and much empirical research from both the cognitive and biological domains (Evans, 2008; Evans & Curtis-Holmes, 2005; Masicampo & Baumeister, 2008). As an example of this empirical work, and related to the distinction between heuristic and logical or analytic processing outlined above, is the work on the belief bias effect. Belief-bias in relation to reasoning and emotion will be discussed in more detail in Chapter 3, but for the purpose of this discussion, the key features are that problems are presented to individuals which can be responded to based on logic, or based on believability. The case of egg-laying cats above is an example of this. Both conclusions are logically valid, based on the structure of the argument, but the believable conclusion is accepted more frequently (Torrens, Thompson, & Cramer, 1999). As the logical approach is considered more cognitively demanding (Quayle & Ball, 2000), additional load and speeded responses would be expected to impair logical responses, and result in use of a lower-effort 'belief' heuristic, and this is what has been found in the literature (e.g. Evans & Curtis-Holmes, 2005).

To elaborate on the distinction between logical-analytic and heuristic responses; DPT proposes two systems of reasoning, which are generically named Type One and Type Two, although these labels have evolved with the theory to refer to Type One and Type Two processes. These can be considered representative of the heuristic-analytic divide espoused in the research on dual processing. The properties of each are shown in Table 2.2, adapted from Evans (2008, p257). Although the labels 'Heuristic' and 'Analytic' connote a limited subset of the properties of each system, they will be used here to represent Type One and Type Two processes respectively in order to aid fluency and understanding.

Table 2.2 Properties of Type One and Type Two (adapted from Evans, 2008)

	Type One (Heuristic)	Type Two (Analytic)
Consciousness	Unconscious/Preconscious Implicit Automatic Low Effort Rapid High Capacity Heuristic	Conscious Explicit Controlled High Effort Slow Low Capacity Analytic
Evolutionary Characteristics	Evolutionarily Old Pragmatic Rationality Shared with Animals Non-Verbal Subcortical	Evolutionarily Recent Logical Rationality Unique to Humans Language Based Neocortical
Functional Characteristics	Associative Domain Specific Contextualised Pragmatic Parallel	Rule-Based Domain General Abstract Logical Sequential
Individual Differences	Universal Independent of Intelligence Independent of WM	Heritable Related to Intelligence Related to WM

The interaction between the two types of processes has been the source of much debate in the literature. Three possibilities have been identified and discussed by Evans (2007b). The two types of processes may interact in a pre-emptive fashion, in which the type that will be used is decided before any processing has taken place. Alternatively, the two types may be engaged in a parallel-competitive fashion, whereby both types are used for processing the problem at the same time, and the responses of each are decided between or integrated. Finally, the two types may process information in a default-interventionist fashion, which suggests that the heuristic system is engaged first, and will provide the solution unless analytic processes intervene. It may also be possible that different patterns of interaction between the two types of processes are found under different task demands. In relation to the interpretation of results, the different possibilities should be considered in so far as they may lead to different mechanisms of cognition-emotion interaction, though discussion of this will have to wait until the presentation of experimental data.

Research which has aimed to evaluate the DPT has generally been supportive. The initial work by Evans, Barston, and Pollard (1983) showing a dissociation between belief-based (Type One) and logic-based (Type Two) responses, and the later work briefly outlined above supporting the differentiating effect of time-pressure (Evans & Curtis-Holmes, 2005) are good examples of supportive work. There is also the work of Quayle and Ball (2000) who show reliance on beliefs is increased when greater demands are placed on working memory.

Although there is much support for DPT, alternative accounts of the different patterns of responding have been presented. For example, Osman (2004) argues that the different response patterns are not due to separate systems or types of processing, but that one system applies different processes to the information in reasoning tasks depending on how it is encoded. However, there is as yet little support for these alternative explanations of the findings in the literature; though the different processes could still be conceptualised as distinct to all intents and purposes with respect to differing resource requirements.

There is recent work which presents results challenging the acceptance of belief-based responses as heuristic, which in turn begins to challenge the use of the above mentioned studies as support for dual-process theories. Dube, Rotello, and Heit (2010) for example, present an analysis of belief-bias based on response-operator curves, and make the case that apparent belief-bias effects are a response bias rather than an accuracy bias. Their argument is that traditional analyses which compare the effects of validity and believability are flawed, though this doesn't necessarily destroy the distinction between two types of processing and the properties associated with each.

Given the work by Oberaurer (2006) for example, whose analyses suggest that the mental-model theory and DPTs provide some of the best fits to the data in the reasoning literature, DPT would appear to provide a good starting point, at the very least, in terms of a framework under which different types of processing can be incorporated; although the recent debate over the nature of some processes previously designated 'heuristic' needs to be taken into account. Furthermore, Oberaurer (2006) comments that both mental-models and DPT's use non-normative parameters to improve their fit to the data. In the case of mental models, it is a directionality parameter, in the case of DPT, it is the use of heuristic processes. Given that it is these aspects, use of alternative strategies and the interaction between the systems, which are likely to be affected by emotion because they are dependent on cognitive resources, the use of a DPT is doubly justified. The following chapter will detail exactly how emotion is expected to affect the interaction of the two types of processing in outlining the experimental hypotheses.

The neuropsychological literature also supports the proposal of separate neural systems for heuristic processes, conflict resolution, reasoning under certainty and uncertainty as well as with familiar and unfamiliar material (e.g. Goel, 2007), but all of the areas activated appear to be within the frontal regions of the brain, around the frontal lobe and prefrontal cortex (Kane & Engle, 2002).

The idea that reasoning and central executive functioning are situated in the prefrontal cortex is further supported by the vast body of research on attention-deficit hyperactivity disorder and its treatment with methylphenidate, which has been shown to improve performance on tests of central executive functioning by increasing catecholamine neurotransmission in the prefrontal cortex (Arnsten & Dudley, 2005; Barnett et al., 2001; Berridge et al., 2006; Kempton et al., 1999). This link to research on catecholamines, which have been heavily implicated in mood disorders such as schizophrenia and depression (Gazzaniga et al., 2002), provides a possible link to a biological mechanism of action that could underlie the interaction between cognition and emotion.

However, following the definitions of emotion and reasoning adopted in this thesis, the focus will be on the cognitive work and how it relates to emotion. The following section will detail the two most prevalent paradigms used in the cognitive literature on thinking and reasoning, and outline the key phenomena in order to provide a basis for discussing how these tasks will be combined with emotion, and how the models of reasoning discussed here will be combined with the models of emotion described earlier.

2.3 Reasoning Paradigms

Although a range of tasks have been alluded to above, this section will outline the two main paradigms to be utilised in the current investigations; syllogistic and conditional reasoning. Whereas previous sections have introduced these terms briefly and in order to illustrate theories of reasoning, the current section treats them in more detail, describing the structure of the tasks used and common phenomena reported.

2.3.1 Syllogistic Reasoning

The Nature of Syllogistic Reasoning

Of the many reasoning tasks in the literature, the first to be encountered in this thesis are syllogistic. Syllogisms have been used as examples earlier, but in short, they are reasoning tasks that require the individual to combine information in premise statements to derive or evaluate a conclusion.

As outlined above in relation to Socrates' mortality, premises are statements, typically assumed to be true, which are then combined to form or evaluate a conclusion. The terms in the problem can be either concrete; Socrates, men, and mortality; or abstract – "All A are B. All B are C. Therefore all A are C" (Evans et al., 1993). The structure may be relatively simple, such as "All cats have tails. Suki is a cat. Therefore Suki has a tail", or they may be more complex and comprise more terms "All A are B. Some B are C. No C are D. All D are E. Therefore, all A are E".

Typically, however, syllogistic reasoning problems consist of two premise statements, and a conclusion which combines them. Because no new information can be gained from the process of combining the premises, the process is deductive; moving from general information in the premises to specific information about a certain case in the conclusion, as a result of which, if the premises are true, and the conclusion necessarily follows, then the argument is valid. This is in contrast to inductive reasoning, in which specific cases may be used to support general rules, where the conclusions follow with a degree of probability rather than with certainty. Each premise and conclusion can be in one of four 'moods', which are determined by the quantifiers in the statements. These are shown in Table 2.3, along with their notation and names.

Table 2.3 Syllogism Moods

Mood	**Denoted by**	**Referred to as**
All A are B	A	Universal Affirmative
Some A are B	I	Particular Affirmative
No A are B	E	Universal Negative
Some A are Not B	O	Particular Negative

Syllogisms are also classified by their figure. That is, the order in which the terms appear. There are four ways in which the terms of the premises can be set out, independently of the mood of each premise or the conclusion (Garnham & Oakhill, 1994). These are shown in Table 2.4.

Table 2.4 Syllogism Figures

Figure 1	*Figure 2*	*Figure 3*	*Figure 4*
A-B	B-A	A-B	B-A
C-A	C-A	A-C	A-C

Each of the statements in the figures can be presented in any of the four moods. Furthermore, each figure can be accompanied by a conclusion which can take any mood, and either the order A-C or C-A. Given these various combinations, Johnson-Laird (1983) proposes 512 possible syllogisms, although most of these combinations generate syllogisms that do not have logically valid conclusions. Relatively few studies have used the complete set of 512 syllogisms in their experiments (Evans, Handley, Harper, & Johnson-Laird, 1999), with researchers more commonly selecting a subset of theoretical interest and manipulating content, figure, and task instructions to test their hypotheses.

Syllogisms thus provide a flexible means of investigating reasoning, and have been employed to investigate the use of verbal and visual strategies in reasoning (Bacon, Handley, & Newstead, 2003), the effects of beliefs (Moutier, Plagne-Cayeux, Melot, & Houdé, 2006; Quayle & Ball, 2000), time pressure (Evans & Curtis-Holmes, 2005; Thompson, Striemer, Reikoff, Gunter, & Campbell, 2003), and how concurrent load affects performance, as well as a means of investigating factors that affect reasoning, such as the involvement of the working memory central executive and subsystems (Gilhooly, Logie, & Wynn, 1999; Gilhooly et al., 2002), so that the reasoning processes underlying responding are comparatively well understood. Using a task which has been extensively studied in the reasoning field provides a solid basis for comparison of the response patterns generated when emotion is included as a variable.

Key Phenomena in Syllogistic Reasoning

Another of the main reasons syllogistic reasoning has been adopted in the current work is that there are a selection of key phenomena which can serve as indicators of the impact of emotion on reasoning. The first finding encountered in most reviews of syllogistic reasoning is the figural effect. This is the finding that the figure of a syllogism affects how easily the premises can be processed and combined, and thus the ease or difficulty of generating or evaluating conclusions. Figure 1 syllogisms (Table 2.4) are found to be easiest, figure 4 syllogisms the hardest, and figures 2 and

3 somewhere in between. This is thought to be because the terms in figure 1 syllogisms appear in an order similar to the natural order of processing (Evans et al., 1993).

Atmosphere and Matching are two other common ideas encountered in reviews of syllogistic reasoning. The atmosphere hypothesis suggests that individuals prefer conclusions which have a similar mood (in the syllogistic sense; see Table 2.3) to the premises. If one or more premises are negative, negative premises will be preferred, and if one or more premise is particular, then particular premises will be preferred. Although these simple guidelines appear to predict much empirical evidence well, as summarised by Evans, Newstead and Byrne (1993), the atmosphere hypothesis does not really explain why such guidelines are apparently applied. The Matching Hypothesis is quite similar in its outline. This theory suggests that people choose conclusions in which the quantifiers are the same as in the premises, though preferring more conservative quantifiers. Again, however, this provides little in the way of explaining why this behaviour should be the case (Evans et al., 1993).

Another robust finding is the effect of conclusion validity. Syllogisms can be constructed so that their conclusions are either logically valid or logically invalid, and what is typically found is that people endorse valid conclusions more frequently than invalid conclusions (e.g. Evans, 2003). That is, they agree that the conclusion follows more frequently when it is valid than when it is invalid. In addition, problem complexity can be manipulated. For example, the information in some syllogism premises can only be represented by one (mental) model, whereas others can be represented in a number of different ways. The examples given above to illustrate mental-models theory highlight this. As might be expected, those which are more complex, and can be represented by multiple models, lead to poorer performance on tasks such as conclusion validation or lower endorsement rates (Garnham & Oakhill, 1994).

Not only can the problem complexity and validity be manipulated, but the believability of the conclusions can also be manipulated by altering the terms. For example, the simple syllogism “All A are B. All B are C. Therefore all A are C” can be given a believable conclusion if the terms are changed to “All cats are mammals. All mammals are warm-blooded. Therefore all cats are warm-blooded”. It could equally as easily be given an unbelievable conclusion; “All cats are dogs. All dogs can fly. Therefore all cats can fly”. Both are logically valid, and of the same form, but conclusion believability now varies. It is typically the case that believable conclusions are endorsed more than unbelievable ones.

Furthermore, validity could also be varied alongside believability by altering the form or order of terms in the conclusion. This enables a comparison of how logic and belief affect reasoning, and will be detailed later in Chapter 4, and also in Chapter 5 where the belief-bias paradigm which exploits these effects is utilised. However, by way of explanation and in order to provide a basis for later discussion in the current chapter, the belief bias paradigm involves participants being presented with syllogisms whose validity is crossed with their believability. The results which are commonly found and have been replicated on numerous occasions are that not only do validity and believability show the effects outlined above; that valid conclusions are endorsed more frequently than invalid ones, and believable conclusions are endorsed more frequently than unbelievable ones, but the two factors, validity and believability also interact. This interaction is manifest as an increase in the difference in endorsements between valid and invalid conclusions being larger for unbelievable than believable conclusions.

One final reason for utilising syllogistic reasoning in the current thesis is that although some work has been conducted on emotions and conditional reasoning (Blanchette, 2006; Blanchette & Richards, 2004), little research has yet investigated the potential effects of emotion specifically on syllogistic reasoning, or in relation to *how* emotions may affect reasoning.

2.3.2 Conditional Reasoning

The Nature of Conditional Reasoning

Whereas syllogistic reasoning involves the combination of premises in order to construct or evaluate a conclusion, conditional reasoning is typically concerned with how people process statements of the form "*If… then*". In the literature the terms in these conditionals are, like in syllogistic reasoning, often denoted by letters; *If p then q*. They are also broken down into their constituent parts. The *If* part, represented by *p*, is called the antecedent, and the *then*, *q*, part, the consequent. Negation is also an important part of the research on conditional reasoning. If a term is negated, as for example *p* in the following "*If not-p then q*", this can be denoted as ¬*p*. Although the work presented in this thesis does not include work on negated terms, familiarity with the terminology and notation will serve to make the examples in this section more accessible.

Given the conditional statement, *If p then q*, a number of premise and inference pairings can be constructed (Evans & Over, 2004). Those most commonly studied in the reasoning literature are:

Modus Ponens (MP; Affirming the Antecedent)

If *p* then *q*. Given *p*, then *q*.

Modus Tollens (MT; Denying the Consequent)

If *p* then *q*. Given ¬*q*, then ¬*p*

Affirming the Consequent (AC)

If *p* then *q*. Given *q*, then *p*

Denying the Antecedent (DA)

If *p* then *q*. Given ¬*p*, then ¬*q*

Of these four inferences, MP and MT are logically valid. For MP, if the conditional is assumed true, and you have *p*, then you must have *q*. For MT, if you do not have *q*, you cannot have had *p*. AC and DA on the other hand, are not logically valid inferences. If the conditional is true, knowing that you have *q*, and inferring that you must also have *p* (AC), is not valid as the rule says nothing about the state of *p* given *q*, only about the state of *q* given *p*. Similarly, under DA, the rule says nothing about the state of *q* (or *not-q*), if you do not have *p*.

This discussion is assuming that *If p then q* ($p \rightarrow q$) is not interpreted as a biconditional. In the biconditional interpretation, the direction of implication, for want of a better term, in *If p then q* is read as reversible; not only does *p* imply *q*, but *q* also implies *p* ($p \leftrightarrow q$). Biconditional interpretations have been proposed as possible explanations for some findings in the literature, with critics claiming that the content or context in which the statements are presented allow or even encourage biconditional readings of the conditionals; this issue will be returned to where relevant in the experimental chapters.

Key Phenomena in Conditional Reasoning

One of the most famous conditional reasoning tasks is undoubtedly the abstract version of the Wason selection task. In this task, participants are presented with four cards and a rule, for example, A, D, 3, 7, and 'If there is an A on one side of the card, then there is a 3 on the other'. They are then asked which of the cards needs to be turned over to check that the rule is true or false. This format corresponds to the logical rule *if p then q*, with the options being *p*, ¬*p*, *q*, and ¬*q*, and given that the rule can be proved or disproved only by MP or MT (Priest, 2000), the correct choice of cards is *p* and ¬*q*; only finding an A without a 3 would disprove the rule.

However, as few as 10% of people select the correct cards on this form of the task (Evans & Over, 2004), which has led many researchers to claim that people are irrational (See Garnham & Oakhill, 1994 and; Stanovich, 1999 for discussions), and a wide range of research trying to explain this very robust finding. However, on thematic versions of the task, that is, when the rule and cards contain real world content such as drinking age laws, the age of people at a bar and the drinks they have (Manktelow, 2000), people show much higher rates of accuracy. The theorists in favour of pragmatic or ecological rationality (Gilovich et al., 2002) argue that when the content relates to real-life tasks, people can engage rules that are evolutionarily adaptive or that they have learnt in everyday life, and these rules, although not rational by the standards of formal logic, are reasonable and rational on a day-to-day basis. They just so happen to coincide with logic in the thematic versions of the selection task.

Beller and Spada (2003) also report some interesting results using thematic versions of the Wason selection task in which the task was framed in terms of promises. These can be treated either in terms of assessing whether a promise was kept, or whether a promise was broken. The results suggest that taking these different perspectives alters the most common responses to those which test the rule in a way most beneficial to the perspective. Bella and Spada conclude that content is important in conditional reasoning as it serves as a source of information which cues relationships between the content. As with pragmatic-reasoning explanations of content effects, these results further show the importance of content in conditional reasoning tasks.

In the literature, besides the abstract selection task, there have also been many deontic versions of the task. Deontic versions relate to rules and regulations, and deontic conditionals are possibly those most frequently encountered in everyday life; If you drink, you shouldn't drive; If you handle chemicals, you should wear gloves; If you park here, you must have a ticket. However, the interpretation of connectives such as 'should', 'ought', and 'must' in these types of conditionals is the subject of much debate, and the current work will therefore focus on simple implicative conditionals; those which take the form of *If p then q*, where the interpretation is (universally) that *p leads to q*.

Other content effects involve the presence or absence of disablers and alternative causes. Disablers are conditions which would prohibit the $p \rightarrow q$ relationship, and alternatives are other possible causes of q. Using alternatives as an example; given If p then q, the number of alternatives that can cause q is likely to affect the extent to which people draw AC and DA inferences. With AC inferences, given if p then q, and q, it is unlikely that p also occurs as the presence of q may be the result of other causes. It may be the case that l, m, n, or o have occurred to produce q instead. Similarly, with DA, given if p then q, and $\neg p$, one of these other causes may have generated q, thus concluding $\neg q$ would be misguided. Indeed, Cummins, Lubart, Alksnis, and Rist (1991) present data showing these types of effects being due to the number of alternative causes. The impact of alternatives is considered in detail in Chapter 8 where their effect on the probabilities of *p*$\rightarrow$*q* and *q*$\rightarrow$*p* are discussed as possible mediators of the effects of emotive content in conditional reasoning.

Given that the content in thematic versions of the selection task, and the manipulation of the believability of content in syllogistic reasoning, can have such dramatic effects, this is one way in which the effect of emotion will be investigated in the current thesis; through the use of emotive content. The purpose of this section was to outline the key paradigms of syllogistic and conditional reasoning, and the phenomena most commonly found within the literature on each; specific effects of emotive content will be considered in the introduction to experimental chapters which manipulate problem content, and the current review now considers how reasoning and emotion will be brought together in the following chapters.

2.4 Combining theories of Reasoning and Emotion

The vast majority of research into the effects of emotion on cognitive functioning have focussed on social judgements, such as how group membership can determine inter- and intra-group behaviour (Baron & Kerr, 2003; Brewer, 2005), and how social stereotype activation can affect judgements (Forgas, 2001; Kunda, 1994). Relatively little work however has been conducted on how emotions affect *non-social* reasoning, although some, considered in Chapter 1, has investigated the impact of emotions on related functions such as attention (Eysenck et al., 2007), working memory (Derakshan & Eysenck, 1998; Dutke & Stöber, 2001; Phillips, Channon, Tunstall, Hedenstrom, & Lyons, 2008), and spatial processing (Lavric et al., 2003; Poliakoff et al., 2007). The current section returns to these areas of cognition which have been studied in relation to emotion, and provides a review focussing on work which has investigated reasoning specifically. The aim in this section therefore is to consider the effects of both mood and emotive content on reasoning before presenting the few theoretical models that exist which propose explanations of how emotion may affect reasoning.

Finally, although there are many models of reasoning, the dual process theory of Evans (e.g. 2010) will provide a central theory from which to work as it provides a flexible framework which has much empirical support. The concepts of Type One (Heuristic) and Type Two (Analytic) processes provide an account of logical and non-logical performance, and explanations of response patterns across a range of reasoning tasks, and these can be developed in relation to emotion. The theoretical consistency which DPT provides at the interface of reasoning and emotion makes DPT a valuable tool for the current project, and how it relates to models of emotion and reasoning will be discussed next.

2.4.1 Cognition and Emotion Revisited

As mentioned above, the majority of work on mood effects in reasoning has been in the social domain. This is understandable given the applicability of such work to everyday societal issues such as stereotyping and other judgments. For example Estrada, Isen, and Young (1997) show that physicians in a positive mood consider and integrate relevant information earlier than those in a neutral mood, but that they do not differ in instances of premature closure. As another example, Sechrist, Swim, and Melvin (2003) found that women in a negative mood reported more instances of discrimination than those in positive moods. However, this effect was only found when the women were unaware of the source of their moods. When explanations of their mood states were provided by the experimenters, no differences in reported discrimination were found between women in positive and negative moods; this is the phenomenon referred to as 'discounting', introduced earlier (Section 1.5.3) whereby mood only affects judgments when it is not attributed to another source.

By turning the focus to the effects of mood on non-social reasoning tasks, we can develop our understanding of how emotions affect reasoning, and potentially gain some knowledge of how these effects are generated. One interesting study which specifically investigated mood effects on non-social reasoning was conducted by Schnall, Jaswal, and Rowe (2008) who show that positive moods, relative to negative, reduce children's attention to detail, as measured by their performance on the embedded figures task. They explain this in terms of positive mood cueing top-down processing strategies. This determination of strategy by mood is an important one, related to attentional bias as discussed earlier, and also relevant to mood states determining use of Type One or Type Two processing.

Although not typically considered under attentional factors, work on eye-tracking in syllogistic reasoning has provided support for the selective processing theory of belief-bias. Ball, Phillips, Wade, and Quayle (2006), using such techniques, show that the time-course and fixation of participants' gaze during a belief-bias task supports the theory's claim that attending to different problem features (e.g. the believability of the conclusion) influences which processing strategies are employed. This is in line with other theorising on the topic by Evans and Over (2004) which suggests that believability does not necessarily alter the reasoning process, but that prior knowledge is factored in before reasoning-proper commences, dictating which strategies are used. How emotional content might impact this attentional bias has not been investigated, but may provide one possible answer to *how* emotion affects reasoning if it is found to have an impact; selective processing theory will be returned to later (Chapter 5).

Furthermore, in relation to reasoning, in which attention to structure is typically required over attention to content, considering that a large number of people adopt spatial strategies (Handley, Capon, Copp, & Harper, 2002), anxiety would be expected to reduce logical accuracy given that the attention of anxious individuals will be drawn to anxiety related stimuli and possibly anxiety related thoughts. This would also be predicted if attentional effects of negative mood were considered independently of working memory, with anxiety causing a local, content focused view of the problem, which would then impair perception of the structure (Schnall et al., 2008). Similarly, positive emotional states might be expected to lead to increased attention to emotion-congruent stimuli, either internal or external, and thus lead to poorer reasoning performance given the limited availability of attention.

Another viewpoint, discussed in Section 1.5, which provides a strong model of how emotions affect judgements is the affect-as-information model of Schwarz and Clore (1983). The majority of research reviewed so far on affect-as-information models has come from social psychology, with little investigating the informative effect of emotion on reasoning. However, Chang and Wilson (2004) have shown that on cheater detection and altruism variants of the Wason selection task, negative mood seems to improve performance relative to positive moods. They also found mood congruent facilitation across groups, supporting elements of the network model conceptualisation of emotion, in that mood cues relevant related concepts which then serve to facilitate task performance. These findings provide support for the affect-as-information model as an explanation of the emotion-reasoning relationship when the activation of these related ideas – be they content relationships or previous experiences of processing similar tasks in particular ways - is seen as additional information, and is similar to the findings of Beller and Spada

(2003) discussed briefly above. Emotions may therefore determine or adjust which types of processing are engaged.

These effects of mood might be expected to generalise to other tasks if the factor determining accuracy is which processing strategy is adopted. That is, if the use of heuristic processing leads to lower accuracy on a given task than analytic processing, then mood, serving as information, would influence accuracy rates on that task. This is the basis of the work presented here, and will be discussed in more detail over the following chapters and in relation to the specific tasks employed. The studies which show mood altering strategy choice can be collectively considered affect-as-information theories (Information Theories), and they suggest that emotion affects cognition by serving as a cue to either heuristic or analytic processing, irrespective of the cognitive demands of the task.

Another model which includes the informational value of mood states is the Affect Infusion Model (AIM) proposed by Forgas (1995) which attempts to provide a model that can account for how a range of factors determine which processing strategies are adopted (Figure 2.3). In the AIM, four strategies are outlined, each prone to varying degrees of affective influence. The direct access and motivated strategies are least prone to the influences of emotion, whereas substantive and heuristic strategies are more prone to the influences of emotion as they are generative and thus provide more opportunity for additional factors to be integrated in problem solutions. Overall, processing which is constructive is influenced more than processing which relies on the retrieval and application of existing knowledge.

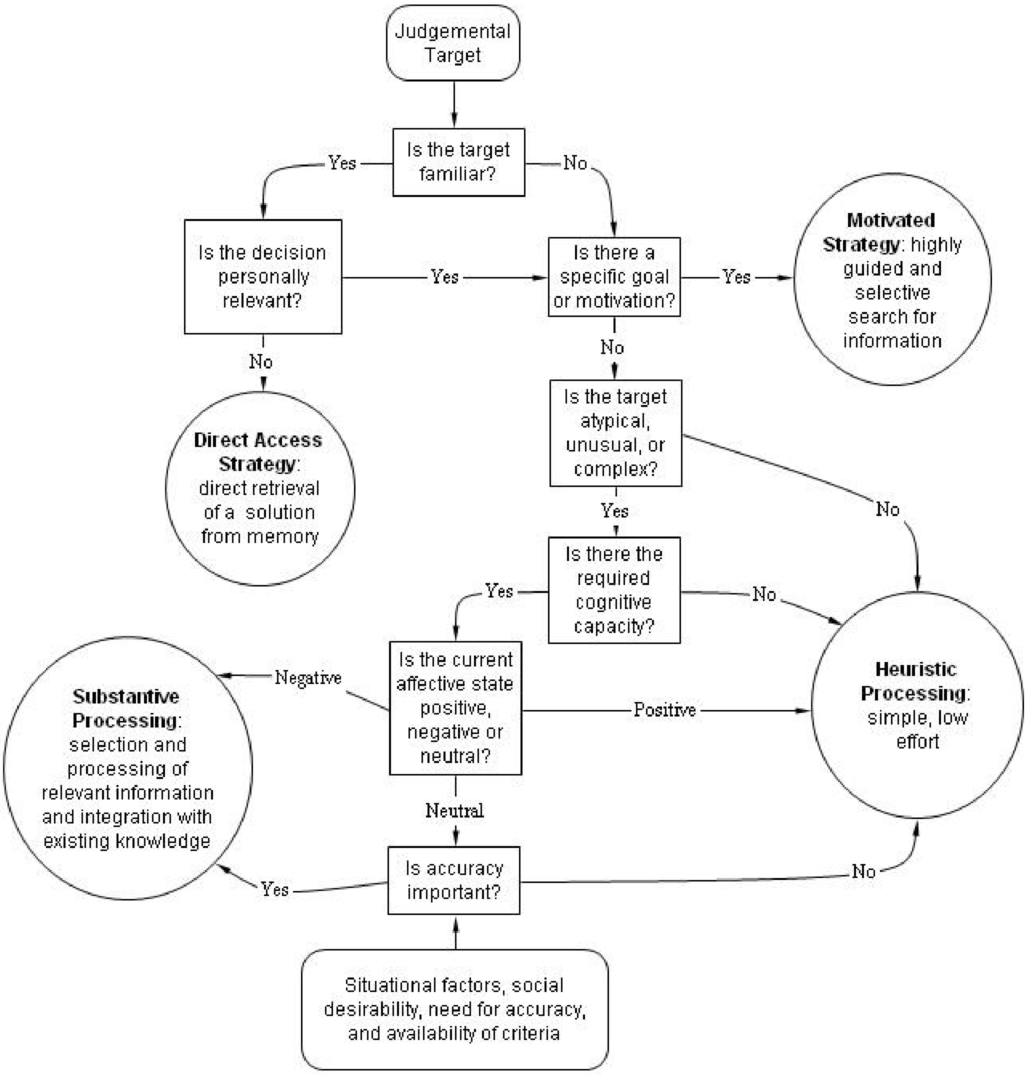


Figure 2.3 The influence of various factors on judgments within the AIM model, adapted from Forgas (1995, p. 49)

The model includes the ability to account for differences in processing caused by limitations of working memory by considering cognitive capacity, as in the load theories, and it also accommodates information and load theories by allowing emotional state to determine between what are essentially heuristic and analytic processing strategies. Although the AIM says little about how tasks should be categorised, what would count as a goal or motivation in determining which type of strategy would be selected, or how emotion and cognitive load might interact in determining strategy, it is a useful model for beginning to bring together empirical findings and may help in interpreting the results of the current research programme. It also provides a link between the classes of theory which can broadly be defined as information and load based, lying as it does at the intersection of the two.

Consideration of emotion as cognitive load was introduced above under discussion of Processing Efficiency Theory, and the equation of emotion with load was supported by the work of Richards, French, Keogh and Carter (2000) which shows that anxiety reduces speed and accuracy on reasoning tasks. As suggested above, if anxiety can be considered similar to other negative emotions, the results of Richards and colleagues might be expected to generalise across different mood states.

Furthermore, the findings of Eysenck and colleagues (2005) show that it is the central executive that is impaired rather than the visual or phonological components of working memory. This is in contrast to the selective impairment of the visuospatial components shown by Lavric et al (2003; Shackman et al., 2006). It would therefore seem that anxiety can impair all components of working memory, and thus would be expected to impair reasoning in those using both verbal and visual strategies. This discrepancy also suggests that when investigating the effects of emotion on reasoning, there may be an interaction between emotion and reasoning style, and as such, a measure of both may be informative in terms of more clearly specifying the underlying mechanisms (Chapters 4 and 6 for example consider attention to emotions and approach-avoidance behaviour). Furthermore, given the distinction between efficiency and effectiveness highlighted in the previous chapter, a measure of effort or time seems likely to be a useful extension of previous work on reasoning and emotion (Chapter 3, for example will consider response latencies in reasoning).

The majority of the work which has combined emotion and reasoning to date is concerned with reasoning about emotive content; that is, when the problems people are presented with include emotive terms. Although the current thesis is interested in both the effects of an individual's mood state, and the effect of content, the following sections will provide a more detailed review of historical and contemporary research on content effects in reasoning. The review will focus primarily, though not exclusively, on syllogistic reasoning, as this is the paradigm adopted in the first experimental chapters. These review sections are presented separately from the preceding discussion of reasoning paradigms as the findings can be used to inform and develop predictions about how emotion, be it in the form of content or individual mood, may affect reasoning across the paradigms. These implications will be discussed after reviewing the findings.

Historical and Research on Content Effects

Conducting research around the middle of the Second World War, in the spring of 1941, Janis and Frick (1943) investigated syllogistic reasoning, but varied the terms such that they represented social and cultural groups, for example, "No Bolsheviks are idealists and all Bolsheviks are Russians. Therefore, some Russians are Idealists" (p. 74). Their aim was to investigate whether an individual's 'attitude' towards the conclusion affected logical accuracy. They found that people made more errors in judging the logical validity of a syllogism when they agreed with the conclusion (when people felt the conclusions were believable), than when they disagreed with the conclusions. These results are directly relevant to research on the belief-bias effect in syllogistic reasoning, touched on above, and so will be discussed in more detail in Chapter 5 which adopts this paradigm.

Morgan and Morton (1944), conducting their research around the same time as Janis and Frick (1943), in the winter of 1942, also investigated the effects of content and attitudes ('convictions') on syllogistic reasoning. They replicate the conclusions of the earlier work, stating that individuals are much more likely to endorse conclusions that are consistent with their existing beliefs regardless of the logical accuracy of those conclusions.

In the summer of 1944, and now specifically investigating the effects of emotional content on syllogistic reasoning, Lefford (1946) reports the results of an early study based around content designed to elicit an emotional response. Adopting a paradigm in which logical structure and validity were controlled, and only the emotionality of the content was varied between neutral and emotional, Lefford (1946) reports results which show that whilst logical accuracy on non-emotional stimuli was normally distributed, logical accuracy on emotional stimuli was skewed such that emotional content was found to drastically reduce logical accuracy. Lefford (1946) explains this decrease in logical accuracy by suggesting that although the normal distribution results from a combination of factors, the skewed distribution is the result of a particularly potent factor which is used in orienting an individual's strategy on the task, in this case, the emotional content. He goes on to elaborate an approach-withdrawal element, in which the extent to which an individual agrees or disagrees with a conclusion is inversely proportional to the endorsement rate, but only when reasoning about emotional content.

Later work, following the aftermath of the Second World War, and taking place during the Cold War, continued to investigate the effects of attitudes on syllogistic reasoning, possibly driven by the political climate of the era. Studies reported by Gorden (1953) and Henle and Michael (1956) have a distinctly anti-Russian feel. Both studies show that the content which is, by virtue of being related to contentious issues of the time, 'emotional', resulted in lower rates of logical accuracy.

Across these studies, the 'emotional' content is largely negative, or related to negative cultural events. However, it is important to consider the possibility that positive emotions leads to different patterns, and questions related to this point form the basis of this thesis.

Contemporary Research on Content Effects

Although there is a relatively extensive literature on the effects of thematic versus abstract content in reasoning tasks, such as in investigating pragmatic interpretations of the Wason selection task, or in investigating belief-bias, very little recent work has investigated the effects of *emotional* content on syllogistic reasoning.

In one of the only papers discussing the effects of emotional content on syllogistic reasoning, Blanchette and Campbell (2005) present data from a sample of British war veterans who were asked to judge the logical validity of conclusions to a series of syllogisms with either neutral or emotive content. The results revealed an interesting effect of problem content. They found that items with emotional content were responded to more accurately than those with neutral content. Having opened their paper by making the claim that detrimental effects of emotions on reasoning have been shown across a range of studies, it is interesting that they then report data which appears to show beneficial effects of emotive content.

Unfortunately, Blanchette and Campbell (2005) do not elaborate on why they may have found these apparently anomalous results. They do however include a note that the more intense the combat experience of the veteran, the less advantageous emotive content was, although exactly how this may fit with theories of emotion and reasoning is unclear. The beneficial effects of the emotional content could be accounted for under an affect-as-information model (e.g. Schwarz & Clore, 1983), which broadly summarised (though discussed in detail above), states that positive mood cues rapid, shallow responding because the positivity of the affect is taken to indicate that the default 'heuristic' responding is 'ok', whereas negative emotions cue more careful, analytic, logical processing because the negativity is interpreted as an indicator that 'something more is needed'. In this case, the 'emotional' content was largely negative, and as such, might be expected to cue more careful processing of the reasoning problems.

Following this work Blanchette et al (2007) report a study in which the content of syllogisms was varied between neutral, negative, and terrorist-related. They found that individuals recently affected by a terrorist attack showed increased logical performance on the terror-related syllogisms, and were less likely to respond based on prior belief, that is, using a heuristic processing style.

Blanchette et al (2007) conclude by suggesting that emotionally relevant material improves logicality, a suggestion which is consistent with earlier related work on conditionals (Oaksford et al., 1996). It is also possible to consider these results in light of the affect-as-information model. Under this account, the terror related content may serve as a cue to more careful processing. However, the mechanism which may underlie this improved logicality is not elaborated by the authors, and there are potential confounds between the logical validity of the responses and the syllogism structures used.

These explanations which focus on the informational value of emotions are supported by more recent work presented by Goel and Vartanian (2011). In their study, they present data which suggests negative emotions can moderate the belief-bias effect found in syllogistic reasoning, which essentially summarises as negative content reduces reliance on heuristics. Their work develops the belief-bias paradigm to include emotional content, an approach which is taken in Chapter 5, and controls for confounds introduced by Blanchette et al (2007, discussed later). By presenting individuals with syllogisms whose conclusions varied in validity, believability, and between neutral and negative content, Goel and Vartanian (2011) show that although the typical belief-bias effect is found with neutral content, in terms of what is relevant to the current paradigm, that is a higher reliance on prior beliefs, they found that this was reduced when the content of the problems was negative. They explain these findings with reference to the Affect Infusion Model (detailed in section 2.4.1), suggesting that the negative content leads to 'more vigilant, systematic scrutiny of beliefs' (p. 121). However, the picture becomes somewhat more complicated when the results of these three studies are more carefully compared. Blanchette and Campbell (2005) divided their emotional content into specific and general categories, and only found higher rates of logical responding on the specific-emotional problems. The general and neutral conditions did not differ in their level of logical accuracy.

Blanchette et al (2007) also included a positive content condition, and found that in general, positive and negative content led to worse logical performance than neutral content. The improvement in accuracy was specific to individuals who had experienced the impact of a terrorist attack when they reasoned about terrorist related content.

Only the work of Goel and Vartanian (2011) presented a reasonably clear result. However, it is unfortunate that neither they, nor Blanchette and Campbell (2005) include positively valenced content. By focusing only on negative stimuli, the finding that this leads to improved logical performance relative to neutral stimuli, although interesting, is less informative in relation to distinguishing between different models of how emotion and reasoning interact. This relates back to the proposition that positive and negative emotions may have different effects, and thus both cases need to be included in any studies on mood effects.

In this limited selection of studies, negative content has been shown to both increase and decrease relative rates of logical responding on syllogistic reasoning, a conclusion which was also reached by Blanchette and Richards (2010) in a recent review of the wider literature. This provides little consistent support for the effects of emotional content on reasoning tasks. Although some evidence appears to be in favour of emotional states driving one or another type of reasoning strategy, its benefit or otherwise depending on the task at hand, other evidence seems to suggest that any emotional state or emotional content reduces reasoning performance. Although these two ideas can potentially be combined, as outlined by Schwarz and Clore (Clore & Huntsinger, 2007; Schwarz & Clore, 1983, 2003; Storbeck & Clore, 2005, 2008), or the more recent affect infusion model of Forgas (1995), alluded to by Goel and Vartanian (2011), very few theorists or researchers have thus far directly tested predictions with respect to different classes of emotion-reasoning theories.

Another issue related to the lack of direct predictions about *content*, is that although emotive content may be expected to moderate responses by inducing mood states, this has not been empirically tested, and at present, the leap from content to emotion to mood-based theories is not supported by empirical evidence. This is understandable, given the nebulous nature of subjective emotional experience and the debate over what constitutes an ‘emotion’, yet this is one of the additional aims of this thesis: to investigate mood effects as well as content effects; that is, the effects of a person being in a positive or negative mood state whilst reasoning about neutral content, and the effects of a person in a neutral mood state reasoning about positive and negative content. Having now defined emotion, reasoning, models of emotion, models of reasoning, methods of investigating the two, and having provided a brief summary of how emotional content and emotional states may affect some of the reasoning tasks outlined above, the following sections outline a selection of models which combine both emotion and reasoning. The aim is to take into account the findings reviewed above and consider further how they may apply to reasoning when emotion is varied by altering the problem content, and the individuals' concurrent mood.

2.4.2 Load and Information Theories

Although the preceding sections have aimed to discuss work which supports one or another specific theory of the relationships between emotions and reasoning processes, two themes have repeatedly appeared. These are the ideas of emotion serving as a source of information in reasoning, judgements, and decision making, and emotion acting as a source of cognitive load and thus altering the processing strategies that can be engaged in such tasks.

Some of these theories have made these mechanisms explicit. In others, they have become apparent when discussion moves beyond the data and tries to answer the question of why particular effects are seen. Both cases have been discussed in light of empirical evidence and keeping in mind issues in emotion research discussed in the previous chapter. For the purposes of developing testable hypotheses and developing our understanding of whether and how emotions impact on reasoning, the two classes of theory will, in this thesis, be referred to broadly as Information Theories and Load Theories. This distinction, although it simplifies the specifics of each individual model discussed, utilises the similarities within those categorised as

Load Theories, and those categorised as Information Theories. This in turn will aid discussion of the hypotheses outlined and the results presented.

Theories which treat affect as information largely argue that the effects they explain are due to emotion serving as a metacognitive cue. Load theories are more varied in their explanations, ranging from appraisals which require cognitive engagement, to redirected attention, to cueing related but irrelevant associations, but the wide range of mechanisms have been discussed in the above review.

2.5 Summary: Emotion and Reasoning

To summarise, emotion is usually seen as the opposite of reasoning, but there are times that emotions can be of benefit. Emotions are typically considered irrational, but formal logic isn't always a rational approach, so, although this research adopts formal normative responding as a measure of accuracy, it does so only in order to evaluate relative performance on the given tasks, and does not intend to make judgements about what the 'best' approach to everyday problems may be.

As with emotion, many different definitions and models of reasoning have been proposed, which vary in how they explain common phenomena found in reasoning tasks. Different brain structures have been investigated with respect to both emotion and reasoning, and a number of different psychological constructs have evolved to aid definition and support theories, such as working memory and the different types of processing. This research will aim to focus on the cognitive component of emotion as it relates to reasoning, as this commonality allows theories from both the emotion and reasoning domain to be combined and tested. Furthermore, this work will adopt cognitive means of manipulating emotions, and so limit its claims to the cognitive realm and those aspects of emotion which overlap with it.

With respect to models of cognition and reasoning, the dual process framework provides specifications of reasoning systems which correspond to those that have been researched in relation to emotion, and the different types of strategies that have been variously named in the literature can be equated with the analytic and heuristic processes. In relation to this, mental models theory provides an explanation of how the cognitive systems are engaged and has been applied to a range of reasoning tasks, specifically those of syllogistic and conditional reasoning used in current work. This affords a detailed model of what patterns of responding are typically expected under certain conditions, and why, which allows for any deviation from these caused by emotion to be detectable, and provides the basis for beginning to understand why any variations that are found have occurred.

The models of how emotion and cognition interact which have been proposed largely fall under two types; Load Theories and Information Theories. Both of these, in relation mainly to social judgements, are supported by empirical evidence, but little research has investigated their relative explanatory power in relation to non-social reasoning such as syllogisms. This is where the current work adds a novel contribution.

It would be expected that if emotions required cognitive resources for generation and maintenance, and led to depletion of other cognitive resources through reallocation of attention, as suggested by the load theories, then both positive and negative mood would deplete cognitive resources. Given that analytic processing required to respond logically to reasoning tasks is cognitively demanding, then both positive and negative emotions would likely lead to reduced logical accuracy.

Information theories on the other hand suggest that emotions alter processing by acting as cues to either analytic or heuristic responding, rather than by limiting the available resources. This leads to the expectation that negative moods, which cue bottom-up processing, will encourage processes such as searching for additional mental models in order to generate logical solutions to problems. Positive mood however, would be expected to cue heuristic responding, such as less fully developed model searches or reliance on properties such as believability, leading to lower rates of logical responding when these are in conflict with the logically correct answer. The aims of this thesis are therefore to compare the explanatory power of load and information theories in relation to non-social reasoning, and develop a better understanding of whether and how emotions affect reasoning.

Chapter Three

Necessity, Possibility, and Mood Effects

3.1 Introduction (Experiment 1)

One interesting distinction that is drawn within the thinking and reasoning literature is that between conclusions which are necessary, and those which are possible. Necessary conclusions are conclusions which must follow if the premises are true. Possible conclusions are those which may follow, but which do not always follow from a set of premises. This distinction has been drawn in syllogistic reasoning by many, but of particular relevance to the current work because of its implications, is the work of Evans, Handley, Harper, and Johnson-Laird (1999) and Evans, Handley, and Harper (2001).

In their work with syllogistic reasoning, they first distinguish between syllogisms which are necessary and those which are impossible. Necessary syllogisms are those in which the conclusions follow (are 'true') in every possible representation of the premises that can be constructed. Impossible syllogisms are the opposite; syllogisms whose conclusions do not follow (are 'not true') in any of the possible models. Evans et al. (2001; 1999) then go on to draw a distinction between two kinds of possible syllogism, which they term possible-strong (PS) and possible-weak (PW). This is a distinction which can be used to investigate the effects of emotion on reasoning and how any such effects might occur, but first requires a clear understanding of the difference between PS and PW syllogisms.

Possible-strong syllogisms are those for which people generate an initial, first model of the premises in which the conclusion follows. However, given the time, effort, or inclination to generate them, alternative models of the premises can be constructed in which the conclusion does not follow. Possible-weak syllogisms on the other hand are those for which the conclusion does not follow in the first model generated, but for which alternative models can be generated in which the conclusion does hold. Given these properties of possible-strong and possible-weak syllogisms, it can be seen that if an individual were presented with a multi-model possible-strong syllogism and asked to evaluate the necessity of its conclusion, they would respond differently if they had constructed only one model as opposed to testing a range of alternatives.

Testing different representations of sets of premises is cognitively demanding. The differential cognitive load coupled with the different outcomes generated by single or multiple model testing allows the responses to be used as a proxy for level of reasoning engaged in. Testing only the first model and accepting its result can be considered a cognitively undemanding, relatively automatic (Type One) process. Testing multiple models is cognitively demanding, and requires the initial linguistically cued model to be questioned, and processed in a more effortful, analytic, and systematic way (Type Two processes). In summary, when reasoning about possible-strong and possible-weak syllogisms, and asked to evaluate their necessity and possibility, endorsements might be considered by dual process theorists as measures of the engagement of 'Type One' and 'Type Two' processes, or at least as indicative of different amounts of cognitive effort expended on the task. This is valuable given the distinction drawn between load and information theories of how emotion may impact reasoning, and the information different patterns of response types (type one and type two processing, or high and low effort) will provide for distinguishing between the two theories.

This chapter first discusses the PS-PW further in relation to how the properties of possible-strong syllogisms can be combined with theories of emotion to investigate whether and how emotion and reasoning interact. The exploitation of these properties within the current studies and syllogistic reasoning tasks with different instructional sets is then considered in order to provide a rationale for the following experiments.

3.1.1 The Necessity-Possibility Paradigm and Comparing the Effects of Emotions on Reasoning

Chapter 2 introduced the idea that, when reasoning, individuals may respond based on relatively low-effort strategies, be they simple rules or heuristics. Alternatively, people may engage in elaborated, higher-effort strategies, either in the form of searching for alternative models or applying more complex logical rules. In order to compare the effects of positive and negative moods on the relative use of these two types of strategy it is necessary to use a paradigm which can differentiate between them.

Many tasks, such as those used in the belief-bias paradigm (Evans et al., 1983), those used to investigate effects such as base-rate neglect (Manktelow, 2000), and the many others used to investigate dual-process theories assume dichotomous response options, and operate on the assumption that each type of processing will result in a different kind of response. For example, in the belief-bias paradigm, participants are presented with a series of valid and invalid syllogisms whose content is varied to create conclusions which are valid-believable, valid-unbelievable, invalid-believable, and invalid-unbelievable.

The endorsement rate, that is, the number of conclusions participants respond to as being valid irrespective of logical accuracy, of each class of syllogism is then compared and the results typically show that believable conclusions are endorsed more than unbelievable conclusions. This effect also interacts with the logical validity of the conclusions. Valid and believable conclusions are endorsed more frequently than valid-unbelievable ones, followed by invalid-believable conclusions, and finally, endorsed least frequently, are invalid-unbelievable conclusions. An interaction is also commonly found between validity and believability, such that the effect of validity is larger for unbelievable than believable conclusions. Although this paradigm will be discussed in detail when it is revisited in Chapter 5, it provides here a clear example of the distinction between the two response types. At the simplest level, participants can be thought of as either responding based on the believability of the conclusion, or based on the logical form of the syllogism. The former is a heuristic response, based on the believability heuristic (Type One), the latter an analytic one (Type Two), based on an effortful attempt at applying logical rules.

The paradigm used in this and the following chapter is that of necessity-possibility and is derived from the work of Evans and colleagues (1999). They presented students with all 512 syllogisms, and asked them to either evaluate the necessity or possibility of the conclusions; that is, whether the conclusion must follow, and follows in all possible combinations of the premises, or might follow, holding in at least one of the possible models, but not necessarily all of them. Under necessity instructions, individuals were asked whether the conclusion to each syllogism was necessary or not necessary. Under possibility instructions, the individuals were asked whether the conclusion was possible or not possible. The syllogisms were divided into those whose conclusions must follow logically from the premises (Necessary), those whose conclusions never followed logically from the premises (Impossible), and those whose conclusions could follow, but were not necessitated by the premises (Possible). They found that overall, people endorsed more conclusions when asked if those conclusions were possible than when they were asked if they were necessary. They also found a significant difference in the rate of endorsement between necessary, possible, and impossible conclusions, with endorsement rates dropping in that order.

Interestingly, they found a bimodal distribution of endorsement within the possible conclusions under necessity instructions, with some being endorsed almost always, and others rarely ever. In order to investigate this effect further Evans and colleagues (1999) conducted two further studies which seem to suggest that some ‘possible’ conclusions lead people to construct a first mental model which leads to a ‘valid’ response, which in turn leads to a 'necessary' response, whereas other ‘possible’ conclusions lead individuals to construct first a model which is inconsistent with the conclusion, and the 'Not Necessary' response. The first set, Evans and colleagues (1999) classify as possible-strong, the second set, they classify as possible-weak; the properties of which were outlined in the introduction to this chapter.

The use of possible-strong and possible-weak syllogisms can be extended to investigate the effect of emotion on processes underlying an individual’s responding, and provide an opportunity to investigate the relative merits of load and information theories by including emotion in the design. If participants are asked to evaluate the necessity or possibility of a conclusion, and mood serves as a source of information, altering the extent to which individuals search for alternative models, we would expect different patterns of responding for each of the four syllogism types; Necessary (N), Possible-Strong (PS), Possible-Weak (PW), and Impossible (I).

Firstly, when reasoning about a necessary syllogism, the first model will typically lead to the conclusion being seen as necessary. If the individual is in a positive mood, and mood serves as information, they may be cued to accept this first response, and indicate the conclusion is necessary. If however, they are in a negative mood, they may be cued to search for alternative models. In the necessary syllogism case, all subsequent models lead to the same finding; that the conclusion follows, and so the response remains 'necessary'. There is therefore no difference between positive and negative moods because whether only the first model or all possible alternatives are constructed and evaluated, the conclusion holds. Figure 3.1 illustrates this process and the two outcomes.

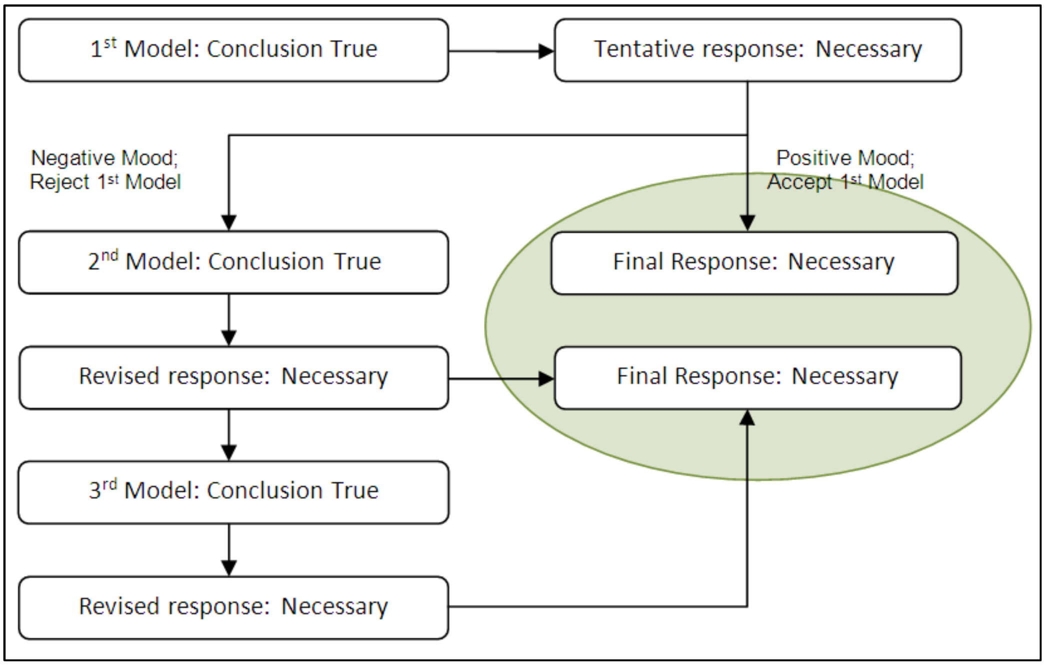


Figure 3.1 Reasoning about a necessary syllogism under necessity instructions if emotion serves as information

As an example, consider the syllogism "(1) All cats are mammals, (2) All mammals have fur, (3) Therefore all cats have fur". Imagine each set (Cats, Mammals, and things with Fur) represented as a circle of variable size like the example used earlier in Chapter 2. These circles can be overlapped in a number of ways to represent the premises and conclusion. You might initially think of three circles of the same size layered one on top of the other such that all cats, mammals and things with fur occupy the same space. In this model, the conclusion holds as all cats are within the same space as is covered by the 'things with fur' set (Model 3A in Figure 3.2). Alternatively, you might imagine a small circle for cats inside a larger circle for mammals, inside a still larger circle for things with fur (3B). In this case, there are some things with fur that are not mammals, and some mammals that are not cats, yet the conclusions still holds as all cats are within the same area as the 'things with fur' set. If all possible models of a conclusion hold, then regardless of whether all or just one model is evaluated, and regardless of in which order this is done, the same judgement is reached.

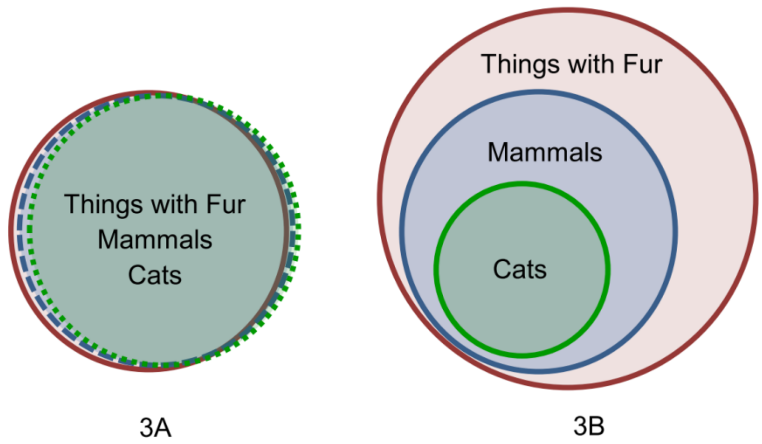


Figure 3.2 Models of Necessity

A similar process occurs when presented with an impossible conclusion. Both positive and negative mood would be expected to lead to the same response, although this time, a 'not necessary' response (Figure 3.3).

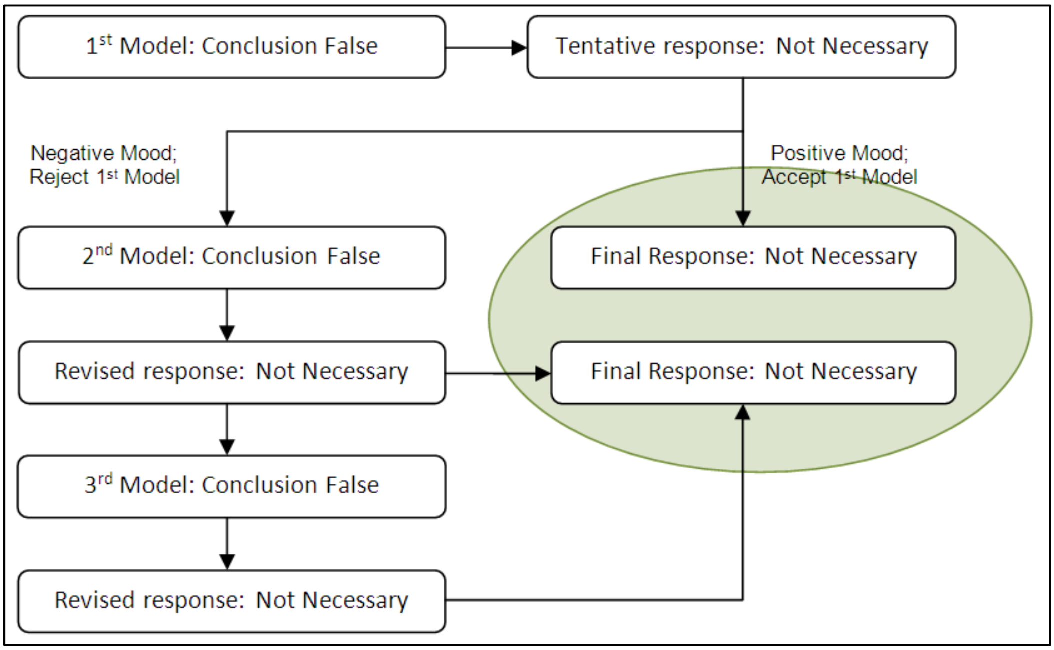


Figure 3.3 Reasoning about an impossible syllogism under necessity instructions if emotion serves as information

Possible-weak and possible-strong syllogisms lead to slightly different processes (shown in Figure 3.4 and Figure 3.5). In possible-weak syllogisms, the subsequent models lead to different deductions, but the final response remains the same under necessity instructions. If the conclusion is not true in the first model, the response made is that the conclusion is not necessary, as it does not follow in all models. If the conclusion is true in subsequent models, it has still been not true in one (the first) model, and so is still not deemed to be necessary. However, under necessity instructions, the interesting case is the possible-strong syllogisms. As can be seen from Figure 3.5, positive and negative moods lead to different responses if negative mood, relative to positive mood, results in more deliberative processing as suggested by information theories.

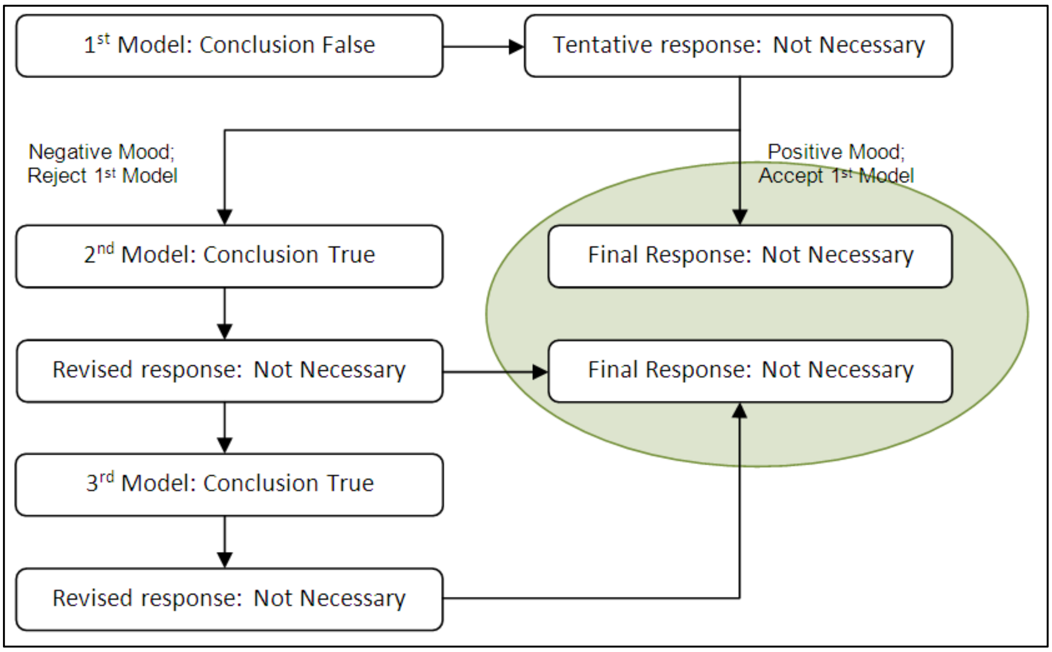


Figure 3.4 Reasoning about a possible-weak syllogism under necessity instructions if emotion serves as information

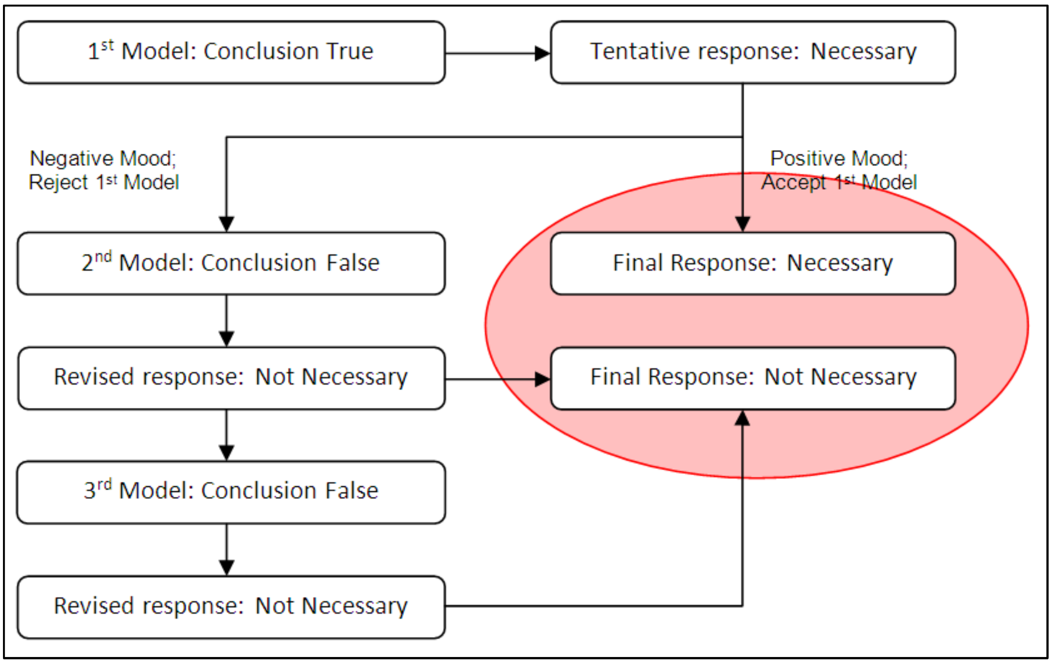


Figure 3.5 Reasoning about a possible-strong syllogism under necessity instructions if emotion serves as information

With possible-strong syllogisms, the initial model leads to a ‘necessary’ response. However, testing alternative models leads to a ‘not necessary’ response. Taking a possible strong example from the materials which will be introduced later, “(1) All Journalists are Bus-Drivers; (2) Some Bus-Drivers are not Professors; (3) Therefore some Journalists are not Professors”, the first model constructed is typically one in which the conclusion holds, such as model 3C in Figure 3.6.

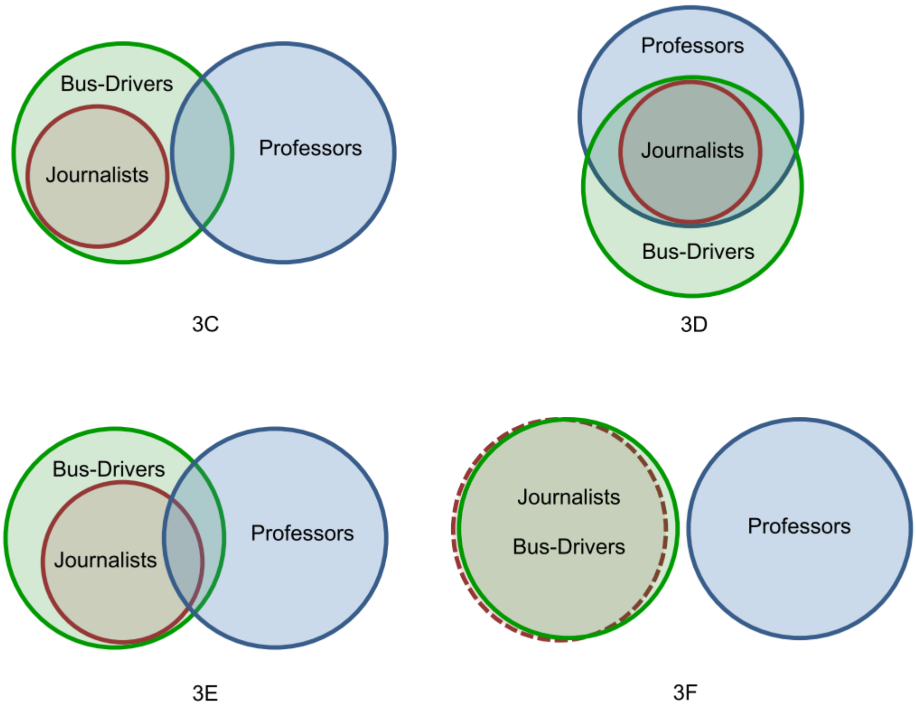


Figure 3.6 Possible-Strong Conclusions

Positive mood, cueing acceptance and low-effort strategies, would lead to this model being the only one evaluated, and thus, when asked if the conclusion was necessary, participants in a positive mood would be expected to respond, incorrectly, that it was necessary; based on this one model holding. Those in a negative mood however, being cued by the emotion to engage in more careful, effortful processing, might then construct one of the alternative models in which the conclusion does not hold, for example, model 3D. Based on consideration of these two models, participants should respond that the conclusion was ‘not-necessary’. Other models may exist in which the conclusion holds, such as models 3E and 3F. Whether these are constructed, and in what order, current theorising on the necessity-possibility paradigm does not comment on. It may be that even in a negative mood an individual who is trying to search for alternatives only finds 3C, 3E and 3F. As such, the paradigm does not provide a perfect measure of engagement in elaborated higher-effort processing, and these additional models may add noise to the data. However, for the purposes of understanding how emotions interact with reasoning, and combined with measures of response time and confidence which to some extent provide proxy measures of effort, the paradigm provides a useful tool.

As positive and negative mood, if acting as a source of information, cue these one versus multiple model approaches, rates of necessary and not-necessary responses provide a means of testing information theories as an explanation of how emotion affects syllogistic reasoning. The diagrams above show what would be expected if mood served as information; where the decision to accept the first model or search for alternatives is required, mood is included as the determining factor. If the individual is in a positive mood, this may cue acceptance of the first model. If the individual is in a negative mood, this may cue a search for alternatives.

However, mood might also act as cognitive load. In this case, both positive and negative mood would lead to acceptance of the first model, as checking one model is cognitively less demanding than checking multiple models, and due to the emotion, the individual only has limited resources available. Only individuals in neutral moods would have the resources necessary to search for alternative models. To summarise, when reasoning about possible-strong syllogisms under necessity instructions, if mood served as information, positive and negative moods would lead to different rates of necessary responses; if mood served as load however, both positive and negative moods would lead to higher rates of 'necessary' responses than neutral moods as not enough cognitive resources are available to efficiently and effectively search for alternative models.

Similar patterns, based on the mental models explanation of the differences in endorsement rates between conclusion types (Evans et al., 2001; Evans et al., 1999), would be expected to appear under the possible-weak conclusion type when the instructions are changed to require judgements of possibility rather than necessity. This allows a second way to investigate mood effects on deliberative versus shallower, lower effort strategies. The cases for processing possible-strong and possible-weak syllogisms under possibility instructions are shown in Figure 3.7 and Figure 3.8.

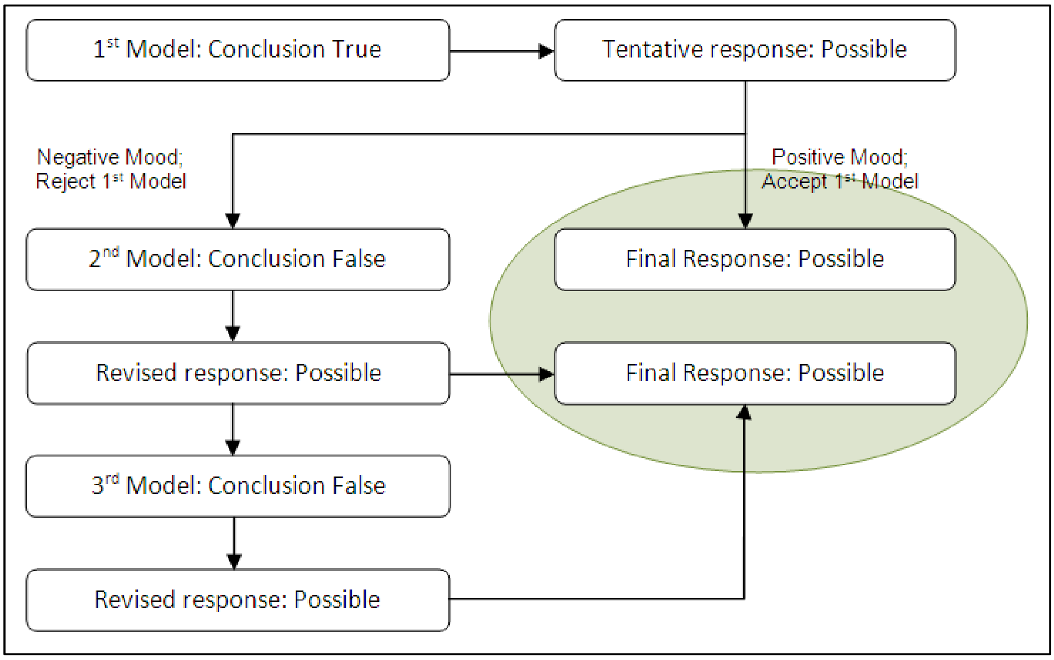


Figure 3.7 Reasoning about a possible-strong syllogism under possibility instructions if emotion serves as information

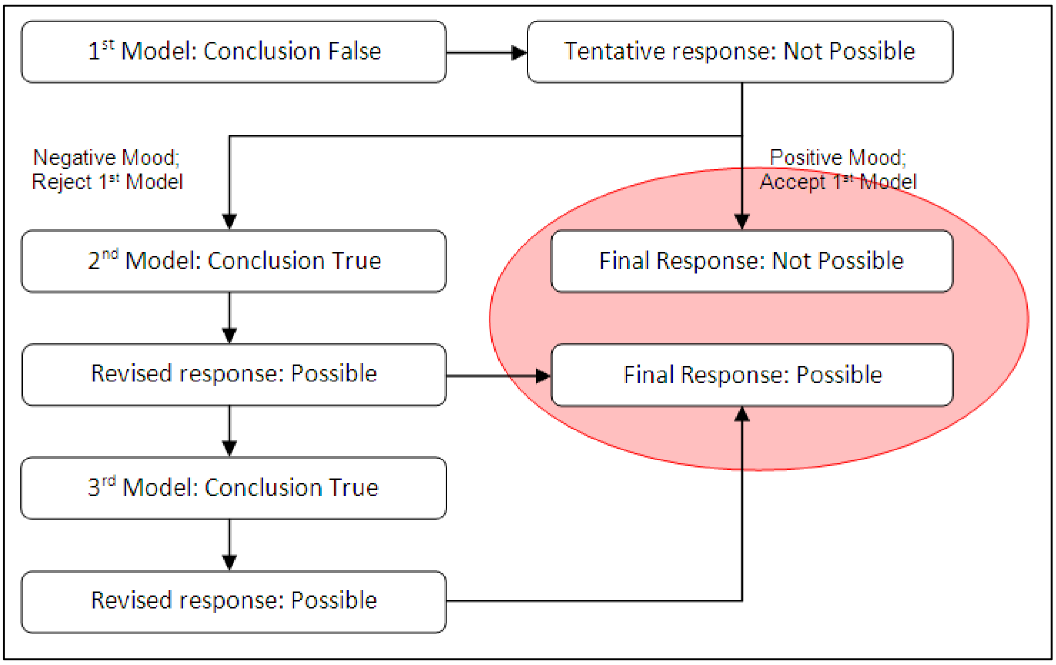


Figure 3.8 Reasoning about a possible-weak syllogism under possibility instructions if emotion serves as information

The same distinction between mood-as-load and mood-as-information can be included in these models as well. To summarise what would be expected: under necessity instructions, if mood served as information, positive mood should lead to higher rates of 'necessary' responses than negative moods on possible-strong syllogisms. If mood serves as load, then both positive and negative emotion should lead to higher rates of 'necessary' responses on possible-strong syllogisms, relative to a neutral condition. Under possibility instructions, if mood served as load, positive moods should lead to higher rates of 'not possible' responses than negative mood on possible-weak syllogisms. If mood served as load, positive and negative mood should lead to higher rates of not-possible responses than neutral moods on possible-weak syllogisms. As such, the studies reported in this chapter aim to investigate mood effects on syllogistic reasoning under both necessity and possibility instructions. The hypotheses outlined above are elaborated on in the following section.

3.1.2 Expected Endorsement Rates under Necessity and Possibility Instructions

Based on previous findings relating to the effects of necessity and possibility instructions (Evans, 2002a; Evans et al., 2001; Evans et al., 1999), high rates of endorsement are expected for necessary syllogism conclusions under both necessity and possibility instructions across all mood conditions. In such cases, as outlined above, no matter how many or few models are constructed, the conclusions will always be judged as necessary (under necessity instructions) or possible (under possibility instructions). The inverse applies for impossible syllogism types. Regardless of how many models are tested under either instructional set, all of the models will lead to not-necessary or not-possible responses.

Under necessity instructions, different patterns of responding between mood conditions on possible-strong problems will provide an indication of whether or not mood serves as information or cognitive load. Similarly, under possibility instructions, it is response patterns on possible-weak problems which will provide this discrimination. If mood serves as information, negative mood would be expected to cue more deliberative processing, leading to lower rates of 'necessary' responses on possible-strong problems than positive mood, under necessity instructions. On possible-weak problems, negative mood would be expected to lead to higher rates of possible responses, than positive mood, under possibility instructions.

If however mood states, both positive and negative, serve as cognitive load, reducing the resources available to a search for alternatives, both positive and negative mood would be expected to result in higher rates of necessary responses to possible-strong conclusions (under necessity instructions) and lower rates of possible responses to possible-weak conclusions (under possibility instructions). The patterns expected under each eventuality are shown in Table 3.1. Where no direct predictions are made, dashes have been entered. The comparisons of interest have been shaded. They form four 'boxes' of values, within which the patterns will be examined to assess any differences in endorsement rates between mood conditions, and within which interactive effects of mood and syllogism type will provide information regarding the relative merits of load and information theories. These comparisons will inform the structure of the analyses conducted, which will be outlined in more detail in the methods section.

Table 3.1 Expected Endorsement Rates Under Different Theories

			Endorsement by Syllogism Type			
Theory	**Instruction**	**Mood**	**N**	**PS**	**PW**	**I**
Information	Necessity	Positive	High	High	-	Low
		Control	High	Mid	-	Low
		Negative	High	Low	-	Low
	Possibility	Positive	High	-	Low	Low
		Control	High	-	Mid	Low
		Negative	High	-	High	Low
Load	Necessity	Positive	High	High	-	Low
		Control	High	Med	-	Low
		Negative	High	High	-	Low
	Possibility	Positive	High	-	Low	Low
		Control	High	-	Med	Low
		Negative	High	-	Low	Low

In terms of testable hypotheses, shaded cells in (A) predict that under necessity instructions, PS syllogisms will be endorsed less by those in a negative mood than by those in a positive mood. The shaded cells of (B) represent PW syllogisms being endorsed more by those in negative moods than those in positive moods under possibility instructions.

The cells in (C) reflect higher rates of necessary responses to PS syllogisms by those in both positive and negative moods, relative to those in control moods under necessity instructions. Finally, the cells in (D) represent lower rates of possible responses for PW syllogisms for participants in positive and negative moods, relative to control, under possibility instructions.

In terms of assessing whether Load or Information theories provide a better explanation of the relationship between emotion and reasoning, if the data shows patterns similar to (A) and (B), this supports Information theories, whereas if the data show patterns resembling the patterns in (C) and (D), then Load theories would be more supported

3.2 Method

3.2.1 Participants

The participants in this study were 168 (27 Male, 141 Female) psychology students from Plymouth University. Participants were aged from 18 to 49 years (*M* = 20 years, *SD* = 5 years).

3.2.2 Materials

Each section of the experiment described below was programmed into a locally downloadable executable file using Microsoft Visual Basic. The program was installed onto the PCs in the laboratory, and the experimental conditions were set by the experimenter prior to the arrival of the participants. Each section required participants to respond using either a keyboard or mouse to make selections from drop-down menus or radio button arrays. The different sections were progressed through using the mouse to click 'continue' buttons after completion of each task. Copies of all materials referred to in this chapter can be found in Appendix A.

Mood Manipulation

The mood manipulation task used in this study was a shortened version of that used by Brand and colleagues (2007), and required participants to type for ten minutes about either a particularly happy or sad life event (Tamir & Robinson, 2007). In addition to positive and negative mood conditions, a control condition was included in order to provide a baseline against which to compare any change in mood, reasoning, response times and confidence ratings.

The inclusion of a control condition also allows for an analysis of any changes caused by positive and negative mood to be conducted not only relative to the other mood condition, but relative to a baseline, allowing for assessments of differences between moods and differences 'from normal', which enables this experiment to assess whether positive and negative mood alter performance in the same way, in different ways, or not at all. This is an element typically overlooked in the emotion literature, as discussed previously.

The instructions given to participants in each of the mood conditions were kept as similar in structure as possible, with only the key happy-sad words and examples being changed. Each set of instructions had the same opening paragraphs explaining that as part of a future study, short descriptions of life events would be used, and that the purpose of this section was to provide materials for the future study. This cover story was included following research which has suggested that the manipulation is more effective when participants are less aware of the true purpose of the task (Brand et al., 2007). The true reason for the writing task was explained to participants during debriefing.

The same paragraph asking participants to write for ten minutes was also used, and the closing paragraph asking participants to contact the experimenter with any questions before beginning was also kept identical across conditions. The key differences in the mood related sections of the instructions are shown below.

Positive Instructions

Please try to recall a particularly happy event in your life. It may be, for example, receiving good results on a difficult test, an unusually fun and memorable night out with friends, or a joyful family occasion such as a birthday or wedding that made you happy. When you have decided on a memory, please write in the box below everything you can remember about the event, describing the event briefly, and then focusing on your thoughts, feelings, and reactions

Control Instructions

Please try to recall an occasion on which you used one of the library services; for example, book loaning, computing and printing facilities, or room booking. When you have decided on a memory, please write in the box below everything you can remember about the event, describing the event briefly, and then focusing on what you noticed about your surroundings

Negative Instructions

Please try to recall a particularly sad event in your life. It may be, for example, failing an important test, the death of a loved relative or pet, or the break-up of a relationship that made you sad. When you have decided on a memory, please write in the box below everything you can remember about the event, describing the event briefly, and then focusing on your thoughts, feelings, and reactions

The mood of participants was measured before and after the manipulation. This provided a pre-manipulation measure for use as a base-line to control for starting mood, and provides information regarding mood change. The post-manipulation measure of mood allows for a manipulation check, and both pre-manipulation, post-manipulation, and change in mood ratings may be used in correlational analyses comparing mood and endorsement rates.

In order to measure mood, participants were asked to complete the PANAS, which was presented with instructions designed to measure state rather than trait affect. That is, participants were asked to what extent they were experiencing each emotion presently, as opposed to recently or over the previous days or weeks. As discussed above in Section 1.4, this scale provides a measure of both positive (PA) and negative affect (NA), which has theoretical advantages over analogue measures of mood state. Firstly, it does not assume that the positive and negative factors are opposites, and allows an investigation of the structure of the moods generated by the manipulation. Secondly, it allows for the separation of the effects of positive and negative affective factors on syllogistic reasoning. In order to prevent participants leaving the study in a negative mood, the study included as its final section a series of jokes which participants were asked to rate before they left the laboratory. Ratings for each joke were made along a seven-point Likert-scale anchored at '*Not funny at all*' and '*Extremely Funny*'.

For both PANAS sections of the study (pre- and post-manipulation), participants were presented with all twenty emotion words, and for each word had to make a mouse click response to a series of labelled radio buttons. The options were labelled, from left to right on screen, as 'Slightly or not at all', 'A little', 'Moderately', 'Quite a bit', and 'Extremely'. PA scores were calculated as the sum of ratings across positive items, and NA scores were calculated as the sum of ratings across negative items.

To allow a comparison of the effectiveness of the manipulation in the current study with similar manipulations used elsewhere, '*Happy*' and '*Sad*' items were embedded in the PANAS items to be rated as analogue scales of mood. Furthermore, if these are highly correlated with PA and NA measures, they may provide a mood manipulation check which is shorter than the PANAS for subsequent studies.

Syllogisms

The syllogisms used in the current study are taken from those used by Evans and colleagues (1999). In order to maximise differences between possible-strong and possible-weak syllogism conclusions, the possible-strong syllogism structures with the highest endorsement rates were chosen, and the possible-weak syllogism structures with the lowest endorsement rates were chosen. The endorsement rates for the chosen syllogisms recorded by Evans and colleagues (1999), along with their content are shown in Table 3.2.

Overall, participants were presented with sixteen three-term syllogisms with arbitrary content; four with necessary conclusions, four with possible-strong, four with possible-weak, and four with impossible conclusions.

Each syllogism was presented separately. For each syllogism, the two premises and the conclusion were each on a separate line, but all three lines were presented simultaneously. Providing a conclusion for evaluation overcomes problems of interpretation and individual differences in ability to generate conclusions, discussed by Ford (1994) in relation to conclusion-generation paradigms. This also allows close control of the conclusion type and structure, which is a critical part of the design given its interest in evaluating logical accuracy across content types.

Participants in the necessity condition were required to indicate whether they thought that the conclusion was necessary or not-necessary. Participants in the possibility condition were required to indicate whether they thought the conclusion was possible or not-possible.

Table 3.2 Syllogism Details

Conclusion	A-B B-C A-C	Code	Mood	Endorsement Rate
Necessary	All Architects are Bankers All Bankers are Cooks All Architects are Cooks	A1.1	AAa	73
	All Accountants are Builders No Builders are Cleaners No Accountants are Cleaners	A1.2	AEe	83
	Some Taxi-drivers are Engineers All Engineers are Climbers Some Taxi-drivers are Climbers	A1.3	IAi	87
	Some Lawyers are Priests No Priests are Students Some Lawyers are not Students	A1.4	IEo	83
Impossible	All Nurses are Runners No Runners are Lecturers All Nurses are Lecturers	B1.1	AEa	3
	All Musicians are Babysitters No Babysitters are Surgeons Some Musicians are Surgeons	B1.2	AEi	7
	Some Astronauts are Scientists All Scientists are Carpenters No Astronauts are Carpenters	B1.3	IAe	10
	Some Chemists are Surfers No Surfers are Teachers All Chemists are Teachers	B1.4	IEa	0
Possible-Strong	All Journalists are Bus-drivers Some Bus-drivers are not Professors Some Journalists are not Professors	C1.1	AOo	90
	Some Canoeists are Zoo-keepers Some Zoo-keepers are Policemen Some Canoeists are Policemen	C1.2	IIi	80
	Some Clowns are not Sailors All Sailors are Judges Some Clowns are not Judges	C1.3	OAo	83
	Some Soldiers are not Magicians Some Magicians are not Electricians Some Soldiers are not Electricians	C1.4	OOo	87
Possible-Weak	Some Waiters are Managers Some Managers are Caterers No Waiters are Caterers	D1.1	IIe	3
	Some Pilots are not Divers Some Divers are Painters No Pilots are Painters	D1.2	OIe	3
	Some Plumbers are not Writers No Writers are Bikers All Plumbers are Bikers	D1.3	OEa	3
	Some Artists are not Salesmen Some Salesmen are Cobblers All Artists are Cobblers	D1.4	OO	7

Response times in milliseconds for these choices were recorded for each syllogism. This measure was included to allow an analysis of the effects of emotion on reasoning by comparison of reasoning time as well as by logical accuracy. Although response time measures in computer programs can be affected by network connection speeds and network load, the program for the current study overcomes this limitation by running the program locally. Data was saved locally and to a server upon completion of the study. Although other DirectX-based programs, such as Slide Generator (Tucker, 2007) specifically designed for high-precision response time recording may provide slightly more accurate measures of response times, given that reasoning times are typically in the order of seconds rather than milliseconds for syllogistic reasoning tasks (Thompson et al., 2003), and that in this case, there will be variability introduced by differences in reading time, the level of accuracy obtained using milliseconds and the current program was deemed acceptable.

After making these judgements about possibility and necessity, a seven-point Likert-scale was presented anchored at '*Not confident at all*' and '*Extremely confident*', on which participants indicated their level of confidence in their answer. This measure was included to investigate the possibility that differences found between mood conditions may be due to differences in confidence.

3.2.3 Design and Procedure

The current study adopted a 3 Mood (Positive, Control, Negative) x 2 Instruction (Necessity, Possibility) x 4 Syllogism Type (N, PS, PW, I) mixed ANOVA design. Although this analysis is broken down into smaller analyses in order to assess each of the individual hypotheses, this initial structure allows for checks of the materials by replicating those of previous work, albeit with the addition of a mood condition.

At the recruitment stage participants could select a preferred time slot to participate. Upon arrival, participants were seated at a computer, on which the test program had been installed and set to a particular experimental condition (Instructional Set and Mood Condition). Participant ID numbers were entered by the experimenter, and the fields for age and gender were completed by participants. Participants were then presented with a paper copy of the brief, which they were asked to read. Following this if they consented to participate in the study they were asked to click 'consent' on the screen and sign a paper consent form.

Upon clicking consent, participants were presented with instructions for the first PANAS task. They were asked to read these and click continue when they were ready. The program then presented the list of PANAS items with a rating scale next to each which participants were asked to complete and then click continue.

The next screen presented the instructions for the mood manipulation task, which was followed, upon clicking continue, by a blank text box into which participants were required to type for ten minutes about a particularly happy or sad life event. Participants in the control condition were asked to type about the last time they visited the university library. After ten minutes, the instructions to the second PANAS task were presented, again followed by the list of words to be rated.

After completing this task and clicking continue, participants were presented with the instructions for the reasoning task, which were followed by the reasoning problems. Participants had to indicate their response to each problem as described above, followed by their confidence in that response. The program moved on to the next reasoning problem automatically after each confidence rating.

Following the final reasoning problem, instructions for the joke-rating task were presented, and participants worked through each of the jokes reading them and providing ratings of how funny they found them.

Upon rating the final joke, participants were presented with an on-screen and paper copy of the debrief, which contained the experimenter's details, the project supervisor's details, and the contact details of the student counselling services. Clicking finish on this screen wrote the data to the spreadsheet and server. Participants were then asked if they had any further questions, thanked for their time, and told they could leave when ready.

3.3 Mood Data Results

As can be seen from Figure 3.9 and Figure 3.10, A 2 Rating ('Happy', 'Sad') by 3 Condition (Positive, Control, Negative) ANOVA on post-manipulation mood ratings shows the patterns that might be expected (Happy: [$F(2,117) = 15.46$, $p < .001$, $\eta_p^2 = .20$], Sad: [$F(2,117) = 24.43$, $p < .001$, $\eta_p^2 = .30$]). Participants in the positive condition reported higher levels of happiness than those in the control ($p < .01$) and negative conditions ($p < .001$), and those in the control condition reported higher levels of happiness than those in the negative condition ($p = .03$). Similarly, participants in the negative conditions report higher levels of sadness than those in either the positive ($p < .001$) or control conditions ($p < .001$). Participants in the positive and control conditions showed no difference in their ratings of sadness. This pattern is also present in the PA [$F(2,117) = 10.73$, $p < .001$, $\eta_p^2 = .16$] and NA ratings [$F(2,117) = 7.52$, $p = .001$, $\eta_p^2 = .12$], although the differences between the control and negative conditions were less pronounced. Participants in the positive condition reported higher levels of PA than those in the control ($p = .01$) and negative conditions ($p < .001$), and those in the control condition reported higher levels of PA than those in the negative condition, though this did not reach statistical significance ($p = .12$). Similarly, participants in the negative conditions report higher levels of NA than those in the positive condition ($p < .001$) and those in the control condition, though this latter comparison did not quite reach statistical significance (p = .07). Participants in the positive and control conditions showed no significant difference in their ratings of NA, though NA was lower for the positive than the control group.

Given that no significant differences were found between conditions on pre-test ratings of any of these measures, the mood manipulation task appears to have been successful in causing the groups to diverge in their ratings.

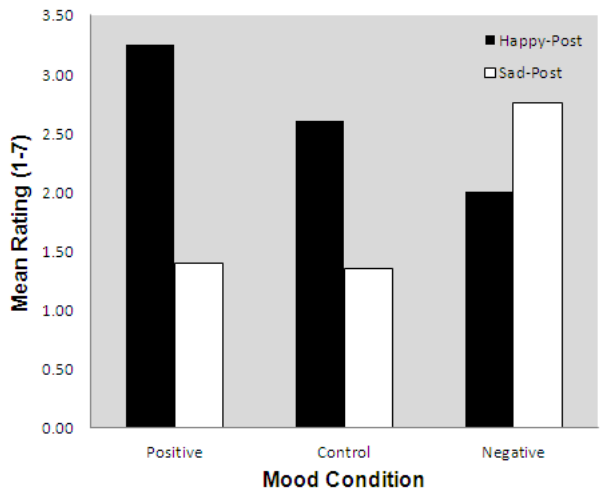


Figure 3.9 'Happy' and 'Sad' post-manipulation ratings

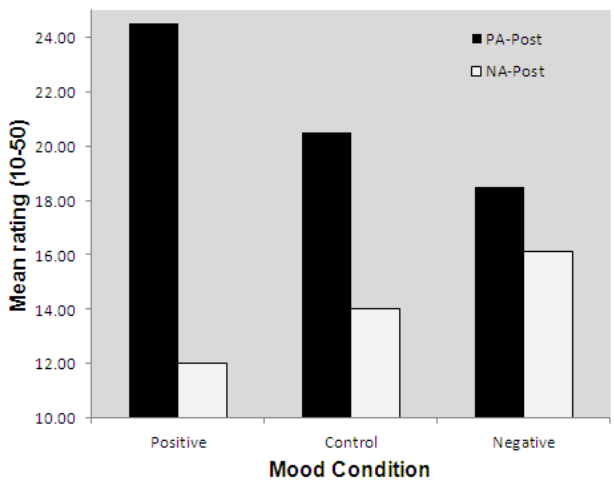


Figure 3.10 PA and NA post-manipulation ratings

As can be seen from Figure 3.9 and Figure 3.10, the patterns of PA and Happy, and NA and Sad scores are very similar. To provide some indication of the level of association, the correlations between post-manipulation Happy, Sad, PA and NA ratings are shown below in Table 3.3.

Table 3.3 Correlations between Post-Manipulation Mood Measures

	Correlation Coefficients		
Measures	Happy-Post	NA-Post	Sad-Post
PA-Post	.65**	-.16	-.26**
Happy-Post		-.33**	-.38**
NA-Post			.76**

** p<.001

3.4 Reasoning Results

Table 3.4 shows the mean endorsement rates, as percentages, by instructional set, mood condition, and syllogism type. Under necessity instructions, these represent the percentage of 'necessary' responses, as opposed to 'not-necessary'. Under possibility instructions, these represent the percentage of 'possible' responses as opposed to 'not-possible' responses.

Table 3.4 Endorsement Rates by Instructional Set and Syllogism type (SD parenthesised)

		Endorsement Rate (%)			
Instruction	**Mood (*N*)**	**N**	**PS**	**PW**	**I**
Necessity	Positive (31)	79.0 (28.2)	62.9 (30.9)	0.8 (4.5)	2.4 (9.9)
	Control (25)	81.0 (25.3)	65.0 (31.5)	7.0 21.1)	5.0 (10.2)
	Negative (31)	74.2 (27.0)	64.5 (32.1)	2.4 (7.5.)	2.4 (9.9)
Possibility	Positive (31)	90.3 (15.4)	93.5 (12.9)	16.1 (22.9)	6.5 (11.1)
	Control (20)	88.8 (25.0)	85.0 (17.0)	10.0 (18.8)	6.3 (17.9)
	Negative (30)	94.2 (12.6)	87.5 (18.3)	26.7 (27.8)	8.3 (15.2)

From the shaded cells in the top half of the table, it would appear that positive and negative moods lead to consistently lower endorsement rates than control mood, and that negative mood leads to lower endorsement rates than positive mood on necessary syllogisms. Under possibility instructions, positive and negative moods would appear to lead to higher endorsement rates than control moods, with negative mood leading to higher endorsement rates than positive moods. These patterns are analysed statistically in the following sections.

3.4.1 Endorsement Rates

As can be seen from Figure 3.11, a 2 Instruction (Necessity, Possibility) x 3 Mood (Positive, Control, Negative) x 4 Syllogism Type (N, PS, PW, I) ANOVA reveals the patterns of endorsement rate to be similar for each type of syllogism across the two instructional conditions. These patterns replicate the findings of Evans and colleagues (1999). The main effect of syllogism type [$F(3,486) = 734.00$, $p < .001$, $\eta_p^2 = .82$] shows that individuals can differentiate the types of syllogism conclusion, and can be taken as evidence that the materials largely behave as would be expected. All pairwise comparisons are statistically significant ($p < .001$). There was also a main effect of instructional set [$F(1,162) = 65.01$, $p < .001$, $\eta_p^2 = .29$], possibly driven by the fact that more conclusions are endorsed under possibility than necessity instructions, replicating the previous work of Evans and colleagues (1999), amongst others. Syllogism type and instructional set show a small statistically significant interaction, suggesting different response patterns across syllogism types between the two sets of instruction [$F(3,486) = 7.49$, $p < .001$, $\eta_p^2 = .04$], as would be expected given the anticipated differences between PS and PW within each condition. Finally, endorsement rates in this combined analysis show no effect of mood [$F(2,162) = .28$, $p = .76$, $\eta_p^2 < .01$], nor does mood interact significantly with syllogism type or instructional set. The three-way interaction between mood, instructional set and syllogism type was also non-significant. Having established the general behaviour of the materials, the differences between mood conditions within each instructional set can be considered.

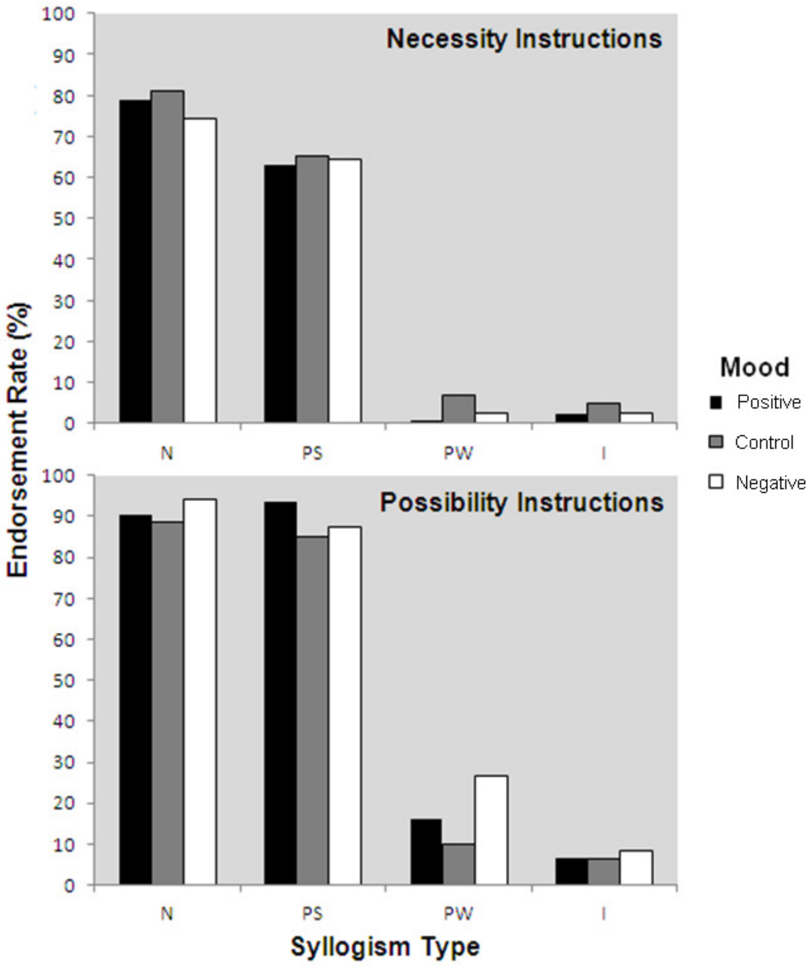


Figure 3.11 Mean endorsement rates across instructional sets by syllogism type and mood

In order to assess the patterns across the groups of interest (See Table 3.1, p127), the analysis was separated by instructional set. Figure 3.12 and Figure 3.13 show graphical representations of the output from two ANOVAs, one 2 Problem Type (N, PS) x 3 Content (Positive, Control, Negative) x 2 Instruction (Necessity, Possibility), and the other 2 Problem Type (PW, I) x 3 Content (Positive, Control, Negative) x 2 Instruction (Necessity, Possibility).The main differences of interest under necessity instruction, those between mood conditions on PS syllogisms did not approach statistical significance, and showed a negligible effect size [$F(2,84) = .04$, $p = .97$, $\eta_p^2 < .01$]; compare the bars labelled A, B, and C in Figure 3.12.

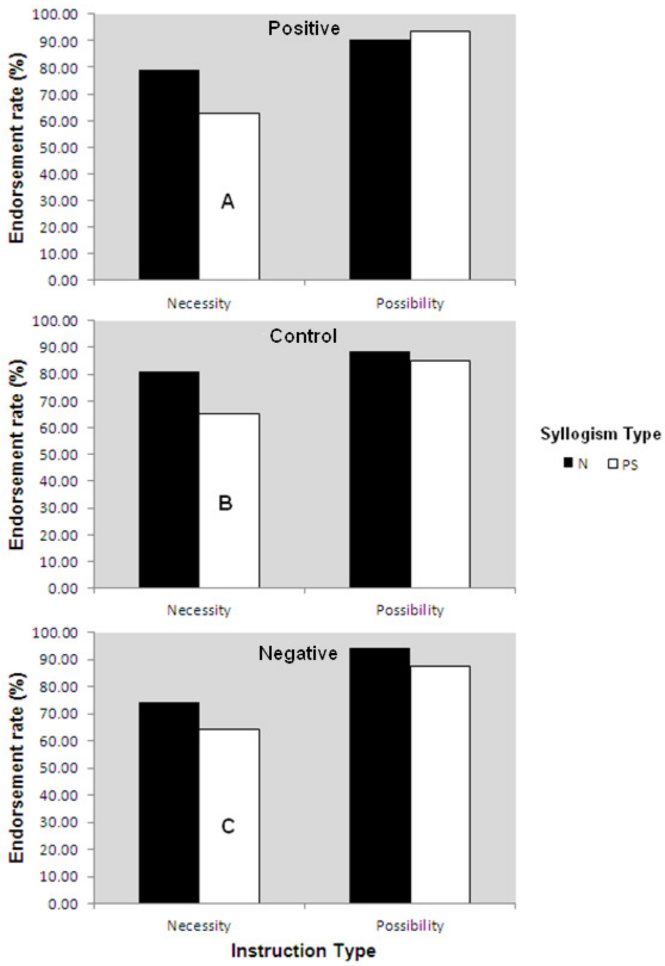


Figure 3.12 Endorsement rates for N and PS by instructional set and content type

Comparing across mood conditions within each syllogism type for possibility instructions reveals no effect of mood on N or PS conclusion endorsement rates. However, of particular interest to the hypotheses outlined earlier are the differences in endorsement rates between mood conditions on the PW conclusions under possibility instructions; compare bars D, E, and F in Figure 3.13.

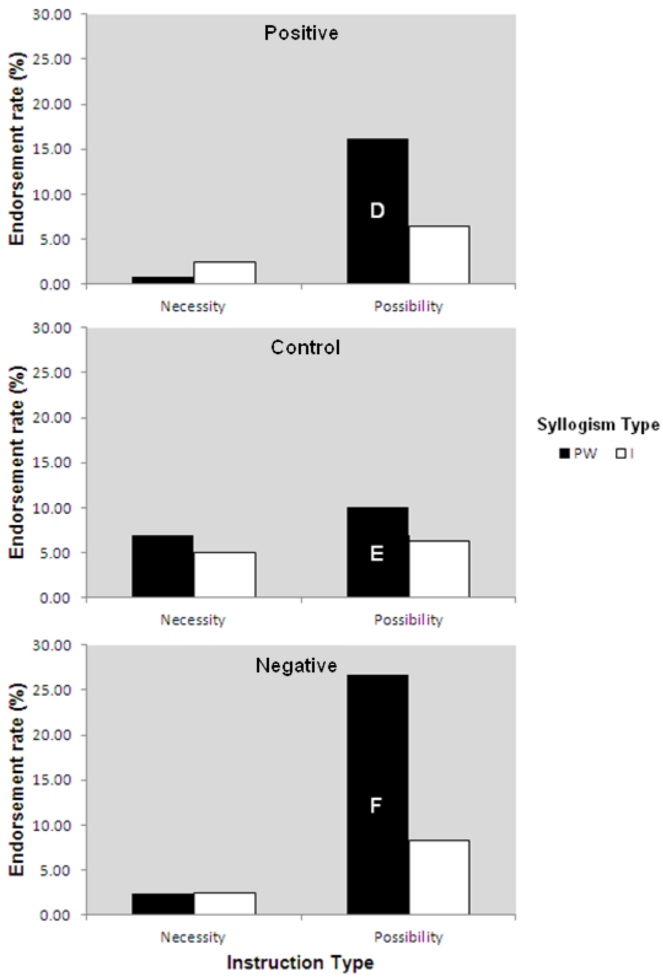


Figure 3.13 Endorsement rates for I and PW by instructional set and content type

On PW conclusions, a statistically significant effect of mood is found [$F(2,78) = 3.15$, $p = .05$, $\eta_p^2 = .075$]. Pairwise comparisons show this effect is primarily driven by those in the control condition endorsing fewer conclusions than those in the negative condition (E versus F; *p* = .02), although the difference between positive and negative conditions also begins to approach significance (D versus F; *p* = .09). Positive and control groups show little difference in their mean endorsement rates (D versus E, *p* = .38).

In terms of effect size, the difference between control and positive content is small (*d* = .30), the difference between positive and negative content is on the borderline between small and medium (*d* = .41), and the difference between control and negative content is medium to large (*d* = .70).

3.4.2 Confidence Rates and Response Times

Mean confidence ratings by instructional set, mood condition, and syllogism type are shown in Table 3.5 along with standard deviations.

Table 3.5 Confidence Ratings (%) by Instructional Set and Syllogism type (SD paranthesised)

		Confidence Ratings (%)			
Instruction	**Mood (*N*)**	**N**	**PS**	**PW**	**I**
Necessity	Positive (31)	70.7 (21.4)	65.8 (19.1)	69.8 (21.5)	71.8 (22.3)
	Control (25)	74.4 (17.7)	65.6 (17.4)	69.1 (18.0)	73.9 (18.3)
	Negative (31)	79.7 (14.7)	73.8 (14.5)	78.8 (14.5)	83.5 (18.9)
Possibility	Positive (31)	78.7 (11.9)	66.9 (13.9)	65.7 (15.5)	79.4 13.0.)
	Control (20)	79.1 (14.7)	70.2 (13.8)	66.1 (14.2)	79.5 (14.9)
	Negative (30)	82.1 (11.3)	72.0 (17.1)	68.0 (16.6)	80.5 (14.1)

Overall, the results of a 2 Instruction (Necessity, Possibility) x 3 Mood (Positive, Control, Negative) x 4 Syllogism Type (N, PS, PW, I) show a main effect of syllogism type [$F(3,486) = 57.96$, $p < .001$, $\eta_p^2 = .26$], which seems to reflect the higher confidence for N and I conclusion types than for PS and PW types. Pairwise comparisons showed no significant differences between N-I and PS-PW, but all other comparisons between these sets are significant at p < .001. As with endorsement rates, this main effect of syllogism type is indicative of participants' ability to draw a distinction between the syllogism categories. It also seems to suggest that N and I conclusions are subjectively easier to evaluate. This pattern broadly holds across instructional set. No main effect of instruction was found, although syllogism type and instructional set showed a small significant interaction [F(1,162) = 4.89, p = .03, η_p^2 = .03]. This is possibly driven by confidence ratings for PW and PS changing across instructional sets, and the higher confidence reported for N and I syllogism types when reasoning under possibility instructions. A 2 Syllogism Type (PW, PS) by Instructional Set (Necessity, Possibility) ANOVA revealed a significant interaction supportive of the first possibility [F(1,166) = 15.98, p < .001, η_p^2 = .09]. Furthermore, post-hoc comparisons of the significant syllogism type main effect under possibility instructions [F(3,240) = 52.52, p < .001, η_p^2 = .40] support the second possibility; significance values for each pair are shown in Table 3.6.

Table 3.6 P-values for pairwise comparisons of confidence ratings across Syllogism type (under possibility instructions)

	p-values		
	PS	PW	I
N	<.001	<.001	.83
PS		.031	<.001
PW			<.001

Across instructional sets, a main effect of mood was found, [F(2,162) = 3.05, p = .05, η_p^2 = .04]. Pairwise comparisons showed the main difference to be that individuals in the negative condition were significantly more confident in their responses than those in the positive condition (p = .020), and that those in the control condition were less confident in their responses than those in the negative condition to an extent which approached significance (p = .08). Participants in the positive and control conditions did not differ in their confidence ratings (p = .70). This main effect of mood overall reduces when assessed separately for necessity and possibility [F(2,84) = .88, p = .06, η_p^2 = .06 and F(2,78) = .47, p = .63, η_p^2 = .01 respectively], only holding marginally for necessity instructions with participants in the negative condition (M = 79.0, SD = 15.7) being more confident in their responses than those in the positive (M = 69.5, SD = 21.1, p = .03) and control conditions (M = 70.8, SD =17.9, p = .07). Mood and instructional set did not interact with respect to confidence rates [F(2,162) = .92, p = .40, η_p^2 = .01].

After LOG-transforming the response time data for each syllogism, means and standard deviations were derived, shown in Table 3.7, which were then subject to comparisons across mood conditions and syllogism type as in the above consideration of confidence ratings.

Table 3.7 Response Times (LOG(MeanRT)) by Instructional Set and Syllogism type (SD paranthesised)

		Response Times (LOG(MeanRT))			
Instruction	Mood (N)	N	PS	PW	I
Necessity	Positive (31)	3.94 (.18)	4.01 (.23)	4.00 (.22)	3.93 (.23)
	Control (25)	3.97 (.14)	4.09 (.19)	4.01 (.17)	4.00 (.17)
	Negative (31)	3.96 (.15)	4.08 (.12)	4.04 (.18)	3.96 (.15)
Possibility	Positive (31)	3.97 (.17)	4.08 (.18)	4.12 (.16)	3.96 (.16)
	Control (20)	3.94 (.11)	4.08 (.16)	4.08 (.16)	4.02 (.17)
	Negative (30)	3.97 (.14)	4.06 (.17)	4.13 (.18)	3.97 (.15)

Conducting the same initial three-way ANOVA on response time data reveals few significant effects. The most pronounced is a main effect of syllogism type [F(3,486) = 52.90, p < .001, η_p^2 = .25]. This appears to be driven by N and I (determinate) problems being responded to faster than PS and PW (indeterminate) problems. This is supported by planned comparisons which show participants under necessity instructions responded faster to determinate (*M* = 10624ms, *SD* = 3653ms) than indeterminate problems, (*M* = 13330ms, *SD* = 5558ms), [$t(86) = -7.09$, $p < .001$, $d = .58$]. This pattern also holds for possibility instructions, in which determinate problems (*M* = 10802ms, *SD* = 3498ms) are responded to faster than indeterminate ones (*M* = 14773ms, *SD* = 5617ms), [$t(80) = -9.00$, $p < .001$, $d = .85$].

There was also an interaction between syllogism type and instructional set [$F(3,486) = 3.06$, $p < .028$, $\eta_p^2 = .019$], based on the 4 Syllogism Type x 3 Mood x 2 Instructional Set ANOVA detailed above, which reflects an increased difference in responses times between determinate and indeterminate problems under possibility instructions relative to necessity instructions.

The comparison of PS response times across mood conditions under necessity instructions shows that there is no statistically significant effect of mood on response times [$F(2,84) = 1.77$, $p = .18$, $\eta_p^2 = .04$]. Similarly, PW response times under possibility instruction showed no effect of mood [$F(2,78) = .12$, $p = .89$, $\eta_p^2 < .01$]. Finally, no pairwise comparisons reached statistical significance.

3.4.3 Reliable Change Index

An alternative way of assessing the effectiveness of the mood manipulation is to calculate reliable change index (RCI; Jacobson & Truax, 1991) scores for each individual. What the RCI essentially does is provide a measure of the direction in which an individual's score changes, and whether that change is over and above what would be expected given the test-retest reliability of the measure being used (Zahra & Hedge, 2010). This allows for a person-by-person analysis of the effect of the manipulation, and enables those for whom the manipulation had no effect to be removed. This not only allows some indication of the effectiveness of the mood manipulation in terms of the proportion of people who showed a 'true' change in mood, which is interesting in itself, but also means that any subsequent analysis will utilise only those individuals for whom the manipulation was effective outside the measurement error of the mood scale. The results of the RCI analysis on the complete dataset for Experiment 1 are shown in Table 3.8 (See Appendix F for equations).

Table 3.8: Reliable Change Index Analyses

Condition	Instr.	α*	SD**	N	Change (%) Up	Down	None	Reliable Change (%) Up	Down	None	#RC in desired direction
Positive	Nec.	0.90	6.11	31	71	16	13	29	0	71	9
Control	Nec.	0.90	6.11	25	28	56	16	4	24	72	17
Negative	Nec.	0.90	6.11	31	16	71	13	0	29	71	9
Positive	Poss.	0.83	6.11	31	48	35	16	10	3	87	7
Control	Poss.	0.83	6.11	20	15	70	15	0	10	90	18
Negative	Poss.	0.83	6.11	30	20	77	3	0	30	70	9

* PA-Pre and PA-Post in the control condition for Necessity Instructions, and PA-Pre and PA-Post in the control condition for Possibility Instructions
** SD from control participants within control condition, combined necessity and possibility

Running the analyses outlined above with only those individuals whose mood changed in the expected direction yields the following results. These participants are those who fall into the shaded cells in the table. Prior to analysis, participants showing no reliable change (RCI < |1.96|) or in an unintended direction were excluded. The number of participants remaining in each of the conditions is shown in the final *#RC in desired direction* column of the table.

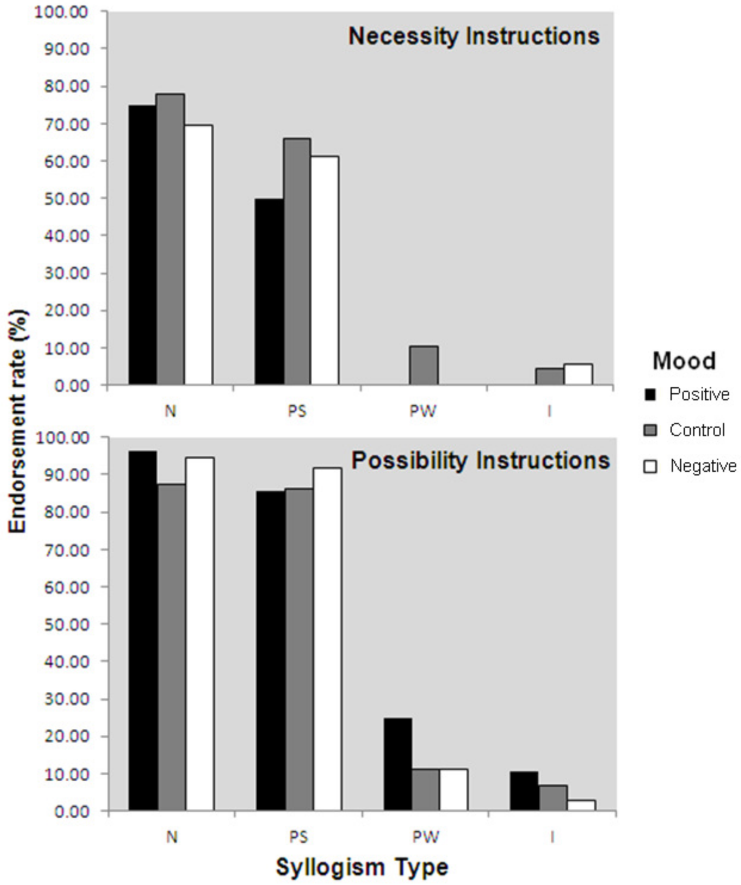


Figure 3.14 Mean Endorsement Rates by Instruction, Mood, and Syllogism Type based on only those individuals whose moods showed reliable change in the expected directions

By comparing Figure 3.14 with Figure 3.11 presented earlier, the general pattern is still visible. As with the analyses above, of particular interest is the difference between mood conditions on possible-strong syllogisms under necessity instructions, and the difference between mood conditions on possible-weak syllogisms under possibility instructions.

Univariate ANOVAs and post-hoc comparisons across mood conditions for these two cases reveals that although mood appears to have some effect on endorsement rates, none of these differences reached statistical significance. However, it should be noted that the analyses reported in this section were based on relatively small samples. Considering again the effect size for these differences, using Hedge's $\hat{g}$ which corrects d for the small sample sizes, and g^* which estimates the population effect size (Appendix F), the values shown in Table 3.9 were found. These can be interpreted in the same way as d-values.

Table 3.9: Hedge's $\hat{g}$ *(and g*)* effect size measures for comparisons between mood conditions based on only those individuals who showed reliable mood change.

		Hedge's ĝ (and g*)	
Condition	**Mood**	**Negative**	**Control**
Necessity, PS	Positive	.304 (.290)	.479 (.463)
	Negative	-	.135 (.131)
Possibility, PW	Positive	.321 (.303)	.315 (.306)
	Negative	-	.022 (.021)

Despite this lack of statistically significant findings and relatively small effect sizes, it is promising that when more stringent criteria are used to assess membership of each mood category, the patterns revealed are similar to those in the full sample. This suggests that although some of the variation in the PANAS measured between mood groups may be due to variation in the measure, and that not all changes in mood caused by the induction are necessarily reliable, it is promising that the general pattern of results reported in the main analyses still remain.

3.5 Discussion

Patterns of Endorsement

In relation to the predicted patterns shown in Table 3.1, the findings from Experiment 1 (Table 3.4) do not show clear support for either the Load or Information theories outlined previously. However it appears that the manipulation of instructional set was successful, given the replication of patterns found in previous research. In addition, individuals seem capable of discriminating between the different problem types based on their responses to critical items under each instructional set. Overall, participants typically endorse necessary and possible-strong conclusions at high rates, and only rarely endorse possible-weak and impossible conclusions.

Although little support was found for load or information theories in the study as a whole, closer inspection of the data when considered across instruction type reveals some patterns suggestive of support for information as a potential explanation of the interaction between emotion and reasoning. Under necessity instructions, positive and negative moods lead to lower endorsement rates than the control condition, whereas under possibility instructions, positive and negative moods lead to higher endorsement rates than the control condition. When considering the problem types of interest, mood condition shows no effect on the endorsement rates of PS syllogisms under necessity instructions. However, under possibility instructions, mood appears to impact endorsement rates of PW syllogisms. Participants in the control condition showed significantly lower endorsement rates than the negative condition, and, although not statistically significant, the positive condition showed lower endorsement rates than the negative condition, with an effect size bordering on medium. This pattern of Positive < Negative is more supportive of the information theories than load theories

Despite the relative weakness of this support for information theories, performance on PS items after excluding individuals who did not show reliable mood changes (Section 3.4.3) shows that after removing the variability of the mood measure and focussing the analyses on only those individuals who can be said to have shown reliable change on the mood manipulation check, the difference in endorsement rates between mood conditions is increased, though these differences still do not reach statistical significance. This is the case for both PS syllogisms under necessity instructions, and PW syllogisms under possibility instructions, and suggests that more careful analysis and consideration of 'noise' in the data is important when investigating the effects of emotion.

To summarise, there is some support for information theories from the finding that negative mood increases confidence ratings and the rate of PW endorsement under possibility instructions relative to positive mood, this will be revisited below. However, it would seem that mood has only a small impact on syllogistic reasoning in this paradigm, though it provides a tool which can be developed, as will be done in the following chapter through altering how emotion is included as a variable.

Response Time and Confidence

From the response time and confidence-rating data, it seems that determinate problems are responded to faster than indeterminate ones, and that people are more confident about their responses to determinate problems. This pattern of faster and more confident responding to determinate problems is found across both instructional sets and all mood conditions, which suggests reasoning time and confidence are unlikely to be the cause behind the effects of instruction and mood.

Although response times show some difference between mood conditions, they do not show the negative > control > positive pattern that might be expected if negative mood cued more careful processing than control or positive moods. Mood also seems to be only marginally relevant when making judgements about confidence. It would appear that negative moods lead to higher confidence ratings when individuals are asked to evaluate their responses. This may be due to participants being aware that having been in a negative mood, they have reasoned more carefully, and are thus more confident in their responses.

Considering response times, confidence and endorsement rates together, although moods have little effect on these measures, it is interesting that individuals spend longer thinking about the indeterminate problems. This provides some evidence that people are aware of potential alternative models, even if this extra effort does not necessarily result in higher logical accuracy or confidence rates, and if confidence ratings are unrelated to accuracy (Shynkaruk & Thompson, 2006).

Mood

The mood manipulation used in the study appears to have been effective, based on the analysis of the PANAS scores. Although on occasion the differences in reported mood between the conditions did not quite reach statistical significance, that broadly similar patterns in reasoning were found on the problem types of interest after applying the more stringent RCI-based inclusion criteria is promising. Also of interest is the finding that PA and NA scales are highly correlated with the individual 'Happy' and 'Sad' ratings. This suggests that in future studies, or where a shorter measure of mood is needed, these two items can be used in place of the full PANAS.

Information and Load Theories

In relation to the previous literature discussed at the start of this chapter, the patterns bear some resemblance to previous findings. Namely, that there is a difference between control and negative moods, and that there is a difference, although not quite reaching statistical significance, between positive and negative, provides some support some for the idea that mood acts as information in syllogistic reasoning. That is, under possibility instructions with PW syllogisms, negative mood increases endorsement rates relative to positive and control conditions. Increased endorsement of PW conclusions is equivalent to an increase in logical responding, possibly due to increased engagement of type two processes; negative mood serving to increase logical responding, possibly by cueing more careful processing and a search for alternative models.

However, as discussed above, the size of the effect is relatively small and the effects of concurrent moods on syllogistic reasoning are fragile, as evidenced by them not appearing in all analyses. One possible explanation for the small effect size under possibility instructions is that participants were aware of the purpose of the writing task. If information theories are correct, then knowing that the writing task was intended to alter mood may lead to a discounting effect, whereby participants are aware of, but remove, emotion as a source of information when reasoning (Clore & Huntsinger, 2007; Schwarz & Clore, 1983, 2003). Although the inclusion of a manipulation check may have alerted participants to the purpose of the writing task, its value in assessing the effectiveness of the manipulation outweighs this potential cost, and provides support for the use of the manipulation task in future studies without the need for the manipulation check.

Although reducing this discounting effect was the purpose of removing references to emotion in the brief and instructions, no explicit measures of the effectiveness of these precautions were included, nor indeed would this be easy to implement without drawing attention to the white bear. Future studies might include a simple 'What did you think the study was about?' question, or alternatively, subconscious emotional primes might be adopted as a means of inducing mood without incurring any risk of discounting effects, although the efficacy of subconscious priming is more debateable than that of writing tasks.

In relation to the particular mood states that are induced, and the effects that positive and negative mood were predicted to show under the load and information hypotheses, it is worth noting the comment by Westermann and colleagues (1996) that mood manipulations are unlikely to elicit specific moods, but will rather induce a diffuse mood state which might be classified by the individual as any one of a range of emotions if they are asked to label it. Arguably though, diffuse positive and diffuse negative moods are roughly comparable to specific positive and specific negative states, and the effects of the two are unlikely to overlap. After a more thorough investigation of the effects of these general 'positive' and 'negative' effects which is the aim of this thesis, more targeted and specific induction of narrower moods such as anxiety, anger, joy or a feeling of success might be developed to differentiate more clearly the effects of emotion on reasoning. This will be returned to in Chapter 10, after consideration of the results from the remaining experimental chapters, but is of particular importance as different, though both broadly 'negative' moods might lead to different effects that could mask the differences between emotions in primarily positive-negative paradigms such as this one.

Having established some small effects of mood using the necessity-possibility paradigm, but obtained promising results with alternative ways of analysing the data generated, it will be a useful next step to investigate whether these patterns are similar when emotion is introduced through manipulation of the problem content, as opposed to the manipulation of the participants' mood state. This is based on the broad divide in the literature between mood effects found across different problem content types and differences found between individuals induced into different mood states, and provides the starting point for the following chapter. In addition, it is hoped that by investigating integral mood in comparison to incidental mood, if the effects found were small because of discounting cued by any aspect of the task, this should be minimised by using a manipulation of integral emotion.

Furthermore, factors which may influence the impact of emotion on reasoning which were omitted from the current chapter will be introduced. These include the extent to which individuals attend to their emotions, the clarity with which emotions are perceived, and their ability to repair negative emotions. Including measures of these variables along with a manipulation of integral mood will hopefully provide a better understanding of any relationship, however small, between confidence ratings, logical accuracy, and emotion which build on the findings of the current chapter.

Chapter Four

Emotional Content, Necessity, and Possibility in Syllogistic Reasoning

4.1 Introduction (Experiment 2)

Chapter 3 investigated the effects of a written mood manipulation on syllogistic reasoning. The results provided some support for information theories as an explanation of how emotions affect reasoning, though the effects found were small. The current chapter builds on these findings and adopts a similar paradigm, though rather than investigating emotion by manipulating it with a writing task, the current experiment varies the emotional valence of the terms in the syllogisms people are asked to reason about. This will provide data to investigate whether and how emotive *content* affects syllogistic reasoning, as well as allowing a comparison of valence effects across written manipulations of emotion and manipulations of problem content.

Although recent research on the effects of emotions has relied on mood manipulations which are separate from and external to the reasoning tasks employed, there is a body of interesting research which has investigated the effects of problem content on reasoning, and recently, the work of Isabelle Blanchette has brought some of these methods and ideas to the fore again. The existing literature suggests that content can both improve and impair reasoning in terms of logical accuracy. This is demonstrated nicely by Blanchette and Campbell's (2005) study on war veterans, in which war-related content led to greater logical accuracy, when it is contrasted with the work of Blanchette, Richards, Melnyk, and Lavda (2007) on terrorist-related content, which found that general emotional and terrorist-related content impaired logical performance. However, comparisons between positive, negative, and control materials are important in understanding these effects; an aspect which is not always included (e.g. Blanchette et al., 2007). This makes work comparing changes in reasoning due to emotion difficult to interpret in relation to 'normal' reasoning.

In cases where content is manipulated, the emotion element originates from the materials, rather than from the person. That is, rather than the emotional states being generated by internal reflective processes such as recalling and describing emotional life events, factors internal to the stimuli provide the emotional component. Whether these responses to content valence are automatic, controlled, conscious, unconscious, or somewhere in between is a contentious issue, yet it is still worthwhile considering the possibility that the two types of emotion have different effects on reasoning processes. Related to this is the distinction between mood states being directly created and manipulated by the use of an external task, and whether or not emotive stimuli have an effect by creating similar emotional experiences or altering how the material is processed.

In order to clarify the discussion of results across studies which manipulate mood states and those which manipulate content, it will be useful to introduce terms to distinguish between the two. Following the example of Blanchette and Richards (2010), where mood states are created externally to the task, these moods will be referred to as 'incidental', in that the mood state is not directly related to the task. Where the content of a reasoning task has been manipulated to elicit an emotional state or reaction, these states will be referred to as 'integral'. The terms incidental and integral are intended as neutral with respect to any philosophical debate about the nature of subjective emotional experiences, and speak only to whether mood is manipulated by a separate procedure, or the emotional valence of the content.

As mentioned above, whether emotive content (integral emotion) has an effect on reasoning by generating a mood state that is similar in nature to the mood states created by incidental emotion (as in Chapter 3) or not is open to debate. However, as this is not the main focus of the current experiment, reference to integral mood, integral emotion, or the effects thereof should be taken to mean any effect of integral content manipulations, and not be read as implying anything about the nature of the emotions generated in the individual. If integral content manipulations have an effect, these effects of integral mood may be a result of an emotional state having been created in the individual, or they may be the result of the valence of the content altering processing styles without altering the subjectively experienced mood state. In either case, the results will shed light on the relationship between content valence and reasoning, and serve to inform future research.

In summary, the current chapter aims to develop the necessity-possibility paradigm used in Chapter 3 which looked at the effect of incidental mood on reasoning. This will be achieved by manipulating the emotional valence of the problem content, shifting the focus to integral mood effects. Before discussing how emotional content can affect reasoning however, it is informative to review the literature so far. Much of this has already been introduced, but key findings and how they relate to the current experiment will be considered in more detail next.

4.1.1 Necessity, Possibility, and Emotive Content

From the few studies which have looked explicitly at emotive content in syllogistic reasoning, a number of issues can be identified which the current experiment will aim to address whilst building on the work of the previous chapter. Firstly there is the issue of a lack of comparison between positive, negative, and control content. This is important because in order to evaluate the relative merits of existing theories, it is necessary to devise tests for which the different emotions would be expected to have different results relative to control (Chapter 3). The load and information theories, which are the main targets for the current work, differ in their expected patterns of results for positive and negative emotions. These different expected patterns have been outlined in relation to incidental mood manipulations previously, but can be extended to include integral emotion, and as such, positive, negative, and control content will be included in the current study. The inclusion of a control group is important as it provides a base-line against which the impact of positive and negative content can be compared.

Although the predictions of load and information theories might be expected to generalise from incidental to integral mood, the idea has not yet been explicitly tested in the literature. As discussed previously, little work has been conducted on the effects of integral emotion relative to incidental emotion. By building on the work in the previous chapter which utilised the necessity-possibility paradigm with an incidental mood manipulation, comparison of patterns across studies will go some way towards supporting or refuting the generalisation from incidental to integral emotion. By extending the paradigm of the previous study to investigate integral emotion, if the patterns are similar to those found using other paradigms, a stronger case can be made for the robustness of the effects of emotion on reasoning. This in turn would provide a replicable set of results on which to develop theories about the relationship between emotion, content, and reasoning. The literature of interest in a comparative sense here is the seemingly contradictory work of Blanchette and colleagues outlined above. Their work has found improvements in logical accuracy as a result of war-related negative emotive content, as well as reduced logical responding as a result of terrorism-related and generally emotive content. However, limitations of the materials used in this latter study (Blanchette et al., 2007) have been outlined earlier (Section 2.4.1) and there is also the fact that the structure of the problems varies across the validity conditions. All valid syllogisms are of the form AAa, all invalid syllogisms are of the form AIa (See Table 2.3). This is controlled for in the current chapter. Although Blanchette et al. (2007), when manipulating the content valence of syllogisms, found negative content to lead to more logically accurate responses in personally relevant cases, as did Blanchette and Campbell (2005) when investigating reasoning in veterans; Blanchette and Richards (2004), when investigating conditional reasoning, found that both positive and negative emotional content reduced logical accuracy relative to neutral content. These contradictory findings may be explained by the lack of control in the syllogism structures of Blanchette and colleagues (2007). Although the majority of their analyses focus on an 'overall' logical accuracy, in which an average is taken across valid and invalid syllogisms (which as noted above, differ in their structure), controlling the structure of valid and invalid syllogisms would allow a clearer comparison of valid and invalid arguments without this confound. Blanchette and Campbell (2005) provide no list of their materials, so their design may suffer from the same confounded structure which again highlights the need for tight control of experimental materials in order to make claims about the effects of emotive content on reasoning.

In relation to drawing testable predictions, it is possible to relate the aims of the previous chapter to the current use of integral emotion. By aiming to investigate the same elements as were considered with incidental emotion, the relationship between mood and content effects can be assessed, whilst simultaneously investigating any effect of integral emotions. There is some support in the literature for both the load and information models as outlined in Chapter 2, and the necessity-possibility paradigm allows an assessment of the extent to which content alters engagement on the task, namely, the search for alternative models. By presenting individuals with syllogisms with necessary, possible-strong, possible-weak, and impossible conclusions, and varying both the content and instructional set, the extent to which alternative models are searched for can be assessed in the same way as in Chapter 3.

To give an overview (though see section 3.1.1 for full details), necessary problems are those in which all possible models of the premises support the conclusions. In possible-strong problems, the conclusion holds in the first model, but in subsequent models the conclusion does not hold. Possible-weak problems are the opposite, in that their conclusion holds in the first model, but not subsequent models. Finally, impossible problems are those in which the conclusion never holds in any possible model of the premises.

When asked to evaluate whether a conclusion is necessary or not-necessary, that is, reasoning under necessity instructions, the problems of interest are the possible-strong set. Responding based on only the formulation of the first model will lead to more 'necessary' responses, as the first model returns a valid conclusion. If this is the only model assessed, it would be assumed that the conclusion is valid and therefore necessary. However, if alternative models are sought, the conclusion will be seen to be valid in only some cases, and invalid in others, and hence only possible, not necessary. When responding on the basis of necessity instructions, this search for alternative models would be expected to reduce the number of 'necessary' responses.

Adding integral mood effects to this prediction, and in line with the predictions of Chapter 3, if content serves as information, negative content would be expected to cue a more considered analysis of the problem, and thus the search for alternative models, which in turn would be expected to lead to lower endorsement rates (fewer 'necessary' responses) on possible-strong problems. Positive mood on the other hand would be expected to cue acceptance of the first solution, and hence higher rates of endorsement as necessary. This is *relative to negative content*, and highlights the need for positive-negative comparisons in emotions research.

If, however, emotive content loaded the cognitive system, in both positive and negative cases there would be a reduction in resources available to search for alternative models, and hence both would be expected to show increased rates of endorsement of PS problems *relative to control problems*. This is where the importance of including a control group for comparison to positive and negative content becomes most important.

Under possibility instructions, the problems of interest are those with possible-weak conclusions. With this instructional set, people are asked whether the conclusions are possible, as opposed to necessary. Possible-weak problems would be expected to be responded to as 'not-possible' if only the first models are considered, as the conclusions in the first models don't hold. If extra effort is expended by the individual to search for alternative models, conclusions which are valid will be found, and hence the responses made should be 'possible'. Therefore, searching for alternative models will lead to higher rates of 'possible' endorsements than relying on only the first model.

With respect to mood-as-information, negative content would again be associated with more careful analysis and use of alternative models, leading to higher 'possible' endorsement rates. Positive content on the other hand might be expected to cue acceptance of the first model, which has an invalid conclusion, and thus reduce endorsement rates as the majority of individuals should respond 'not possible'. The justification for the load and information theories is dealt with in the previous chapters following a review of the relevant literature, but a summary of the predicted patterns is shown in Table 4.1.

Table 4.1: Expected Endorsement Rates Under Load and Information Theories

		Predicted Problem Type Endorsement	
Theory	Content	PS under Necessity	PW under Possibility
Load	Positive	High	Low
	Control	Mid	Mid
	Negative	High	Low
Information	Positive	High	Low
	Control	Mid	Mid
	Negative	Low	High

In addition to these proposed patterns of endorsement rate, given the interesting findings in the previous experiment that confidence ratings are higher for determinate problems, a measure of the participants' confidence in their responses will also be included in the current experiment. This will allow the replicability of the effects of problem type and instructional set to be evaluated, as well as provide data for a comparison of integral and incidental mood effects on confidence.

4.1.2 Trait Meta-Mood

The possibility that individuals may differ in their attention to emotions was raised when discussing the previous findings (Section 3.5). In order to address this issue the experimental design in the current chapter is supplemented by the inclusion of a measure of 'attention to emotions'. How people's emotions guide their responses to situations is embodied in the concept of factors related to emotional intelligence, largely irrespective of which conceptualisation of emotional intelligence is considered (Fitness & Curtis, 2005; Mayer, Salovey, & Caruso, 2008; Warwick & Nettelbeck, 2004). These include, but are not limited to, factors such as meta-cognitive processing of emotional experience, source monitoring, and an appreciation of affective forecasting and its limitations (Goleman, 2004b; Song et al., 2010). One dimension of particular interest that may vary between individuals and affect the experimental results is emotion regulation (Fitness & Curtis, 2005; Salovey, Mayer, Goldman, Turvey, & Palfai, 1995). More specifically, the extent to which people attend to their emotions and the strategies they deploy in response to them (e.g. Extremera, Durán, & Rey, 2007).

The Trait Meta-Mood Scale (TMMS) is a 48-item questionnaire designed to measure three factors of emotional experience: attention to emotions (Attention), clarity of emotions (Clarity), and mood repair (Repair), which make up three subscales of the TMMS. A shortened 30-item version also exists, but the discussion that follows applies to both (Salovey et al., 1995), and the scale is correlated with longer measures of mood which have been validated in clinical and non-clinical samples such as the Hopkins Symptom Checklist, PA r = .74, NA r = -.19; Beck Depression Inventory, PA r = .74, NA r = -.19 and the State-Trait Anxiety Inventory, PA r = .74, NA r = -.19 (Watson et al., 1988).

The Attention factor provides a measure of the extent to which individuals notice and respond to their emotions. Clarity provides a measure of how clearly distinct an individual finds each of their emotions; their ability to distinguish between different feelings. Finally, Repair provides a measure of how well the individual recovers from negative emotions and maintains positive emotions. Each item is responded to using a five point Likert scale, with the options defined as agree, somewhat agree, neither agree nor disagree, somewhat disagree, and disagree (all items, scoring order, and subscale memberships can be found in Appendix B).

Including the TMMS in the current study allows an investigation of how the three factors might moderate the relationship between emotion and reasoning. If different emotionally valenced stimuli can attract different levels of attention, and emotional cues have been shown to be used as a source of information on judgement tasks, then some measure of the extent to which individuals attend to emotions may be useful for understanding the results. For example, individuals who show higher levels of attention to their emotions might be expected to show larger effects of emotionally valenced content. Additionally, the subscales of the TMMS might be related to differential use of reasoning strategies. Specifically, TMMS scores might shed light on how the three components of emotional experience moderate the effects of emotion on reasoning through altering the use of shallower or more elaborated processes.

4.1.3 Aims and Hypotheses

To summarise the preceding section the current study aims to investigate the effect of emotive content in syllogistic reasoning, and the relationship between attention to emotions, clarity of emotions, and ability to repair emotions. With respect to specific hypotheses, these are outlined in Table 4.1, and are in line with those of Chapter 3 and the findings in the literature discussed previously in this and earlier chapters.

4.2 Method

4.2.1 Participants

Participants for this study were recruited through various online mailing lists dedicated to different areas of psychological and non-psychological research, links posted on social-networking and research websites, and Plymouth University mailing lists. The study was kept live for two months, after which time the links were removed from the websites used and made inactive. At the close of the study, 161 people had participated (78 male, 83 female), with ages ranging from 16 to 60 years

(*M* = 33.60, *SD* = 11.88). Overall, this was a response rate of 5% (based on the scope of recruitment being approximately 3,000 people, as of 29th June 2009).

4.2.2 Materials

Syllogisms

The syllogisms from Chapter 3 were used to provide the control materials for the current study. In addition, a positive and a negative set of syllogisms were created by replacing the neutral terms with emotionally positive and negative terms which have been used in other studies of emotional content outside of reasoning. These permutations create three sets of syllogisms (control, as well as positively and negatively valenced) each with subsets whose conclusions are necessary (N), possible-strong (PS), possible-weak (PW) and impossible (I). Emotive content was varied as a between-participants factor. A full set of the syllogisms used for each content condition can be found in Appendix B, though examples are provided below;

Positive Content

All puppies are fluffy
All fluffy things are cute
All puppies are cute

Control Content

All Architects are Bankers
All Bankers are Cooks
All Architects are Cooks

Negative Content

All cancers are terrifying
All terrifying things are deadly
All cancers are deadly

Piloting

In order to avoid confounding believability or validity with content, the positive and negative syllogism sets were pre-tested. This was achieved by presenting individuals with the conclusions for each syllogism in a random order, and asking them to rate either the positivity of the conclusion, or its believability, on a Likert scale. Positivity was defined as the score on a seven point scale anchored at *'extremely negative'* to *'extremely positive'*, whereas believability was defined as the score on a seven point scale anchored at *'extremely unbelievable'* and *'extremely believable'*. The results of two 4 Syllogism Type (N, PS, PW, I) ANOVAs found no differences in believability [F (3,31) = 1.22, p = .32] or positivity ratings, [F (3,31) = .04, p = .99], between the syllogism types, within content types.

Furthermore, the content manipulation was found to be effective by a 2 Content Type (Positive, Negative) ANOVA on the positivity ratings, [F (1,31) = 3523.41, p < .001]; with positive content being rated as more positive than negative content; but the same ANOVA run using believability ratings showed no difference in believability between positive and negative syllogisms [F (1,31) = .04, p = .85]. The interaction effects between syllogism type and content type on both believability and positivity ratings were found to be non-significant in a 2 Content Type (Positive, negative) x 4 Syllogism Type (N, PS, PW, I) ANOVA. The syllogisms used in the current study thus control for structure, syllogism type, and believability across content conditions.

Properties of the Trait Meta-Mood Scale

The 30-item short form of the TMMS was used in the current experiment. The psychometric properties of the 30-item version are comparable to those of the longer 48-item version (Salovey et al., 1995). The internal reliability of each subscale of the 30-item version has been repeatedly shown to be high. Fitness and Curtis (2005) report Cronbach's alphas' of α = .78, α = .85, and α = .78 for the Attention, Clarity, and Repair subscales respectively, which compare well with the results of Salovey and colleagues (1995) who reported α = .86, α = .86, and α = .82, and Palmer and colleagues (2003) who reported α = .84, α = .87, and α = .71. These figures also accord well with the results of a large scale online study to assess the psychometric properties of the TMMS in the student population conducted by Zahra, Bailey, Hedge, Wyles, and Sanders (2012 in press); α = .85, α = .85, and α = .71. Convergent and discriminant validity have also been shown to be acceptable, and the scale has been relatively widely adopted in emotion research (Salovey et al., 1995).

4.2.3 Procedure

Individuals clicking on links to the study were randomly allocated to a content and instruction condition, and taken to a page containing the text of the brief and option to indicate consent. This was followed by the reasoning task.

Each syllogism was displayed on a separate page, and for each problem participants were required to judge either the conclusion's necessity or possibility (depending on instruction condition), and their confidence in their decision. Confidence ratings were made on a seven-point Likert scale, anchored at '*Not Very Confident*' and '*Very Confident*'. Scores have been converted to percentage confidence ratings to facilitate comparisons across studies.

Following the final reasoning problem, participants were taken to a page containing instructions for the TMMS, to which they were required to respond using the Likert scale options described above. Upon completion, a series of jokes were presented to normalise participants' moods, followed by the debrief.

4.3 Results

4.3.1 Comparisons across Instruction Type

Mean endorsement rates by instructional set, syllogism type, and content type are shown in Table 4.2. Effects were analysed using two mixed-ANOVAs, the first a 2 Problem Type (N, PS) x 3 Content (Positive, Control, Negative) x 2 Instruction (Necessity, Possibility), and the second a 2 Problem Type (PW, I) x 3 Content (Positive, Control, Negative) x 2 Instruction (Necessity, Possibility).

The ANOVA concerned with N and PS problem types revealed a significant main effect of syllogism type [F (1,155) = 33.00, p < .001, η_p^2 = .18], with N problems (M = 92%, SD = 17%) being endorsed more frequently than PS syllogisms (M = 76%, SD = 27%). Instructional set and problem type interacted significantly [F (1,155) = 15.51, p < .001, η_p^2 = .10], representing a larger difference in endorsement rates between N and PS problems under necessity than possibility instructions. There was also a main effect of instructional set [F (1,155) = 14.71, p < .001, η_p^2 = .09], with more problems being endorsed under possibility (M = 89%, SD = 19%) than necessity instructions (M = 79%, SD = 25%). Content showed no main effect, or interaction effects with instructional set or problem type.

To investigate the extent to which content may alter the reasoning strategies adopted by individuals, PS endorsement rates between content conditions were analysed for the necessity instructions using a 3 Content (Positive, Control, Negative) univariate ANOVA. This is following the reasoning that PS syllogisms are those where differences in positive, control, and negative content will be found under necessity instructions (See Chapter 3 for a full discussion). No main effect of content was revealed between PS endorsement rates across content categories [F(2,75) = .75, p = .47, η_p^2 = .02], and no pair-wise comparisons were statistically significant.

Table 4.2 Mean Endorsement Rates (%) by Instructional Set, Syllogism Type and Content Type

Instruction	Content (*N*)	Endorsement Rate (%) N	PS	PW	I
Necessity	Positive (20)	91.3 (23.3)	60.0 (32.8)	15.0 (22.1)	15.0 (26.2)
	Control (28)	95.5 (9.8)	67.9 (30.3)	22.3 (28.3)	12.5 (21.0)
	Negative (30)	89.2 (22.4)	70.8 (30.1)	20.8 (22.8)	9.2 (19.1)
Possibility	Positive (23)	88.0 (16.6)	87.0 (21.1)	26.1 (38.0)	21.7 (28.5)
	Control (30)	89.2 (21.5)	90.0 (23.3)	40.0 (34.5)	6.7 (17.3)
	Negative (30)	96.7 (8.6)	82.5 (25.6)	36.7 (32.0)	8.3 (21.1)

The analysis of variance conducted focussing on PW and I conclusions revealed a main effect of syllogism type [*F* (1,155) = 6.89, *p* = .01, η_p^2 = .04], with PW conclusions (*M* = 27%, *SD* = 30%) being endorsed more frequently than I conclusions (*M* = 12%, *SD* = 22%). There was also a main effect of instructional set [*F* (1,155) = 23.172, *p* = .02, η_p^2 = .04], with possibility instructions (*M* = 23%, *SD* = 29%) leading to more endorsements than necessity instructions (*M* = 16%, *SD* = 23%). There was also a statistically significant interaction between problem type and instructional set [F(1,155) = 26.59, p < .001, η_p^2 = .15]. In this case, the interaction reflects the larger difference between the PW and I conclusions under possibility instructions than under necessity instructions. Content type did not show any main effects or interaction effects with instructional set or problem type.

Similarly, a 3 Content (Positive, Content, Negative) univariate ANOVA showed no difference in endorsement rate across content types for PW problems under possibility instructions, [*F*(1,80) = 1.11, *p* = .34, η_p^2 = .03]; the main area of interest for possibility instructions (See Chapter 3 for a full discussion of why differences would be expected in PW conclusions under possibility instructions). No post-hoc comparisons reached statistical significance.

4.3.2 TMMS findings

In order to assess any impact of Attention, Repair, and Clarity on the problem types of interest, TMMS subscale scores were correlated with PS endorsement rates under necessity instructions (PS-Necessity), and PW endorsement rates under possibility instructions (PW-Possibility). As can be seen from Table 4.3, there are no statistically significant relationships between the extent to which people attend to their emotions, the clarity of their emotions, or their ability to repair and maintain emotions and the rates at which they endorse the conclusions of interest. None of the TMMS subscales were found to correlate with the effects of content type on PS-Necessity or PW-Possibility problems. Given the limited relationships between the TMMS subscales and performance on the reasoning task, the scores were not subjected to any further analyses.

Table 4.3 Correlation coefficients for the relationship between TMMS subscale scores and endorsement rates of PS-Necessity and PW-Possibility problem types

		Correlation Coefficients [*r* (*p*) *N*]	
TMMS	**Content**	**PS-Necessity**	**PW-Possibility**
Attention	Negative	.07 (.72) 29	-.24 (.21) 28
	Neutral	.07 (.73) 26	-.07 (.72) 28
	Positive	-.38 (.10) 20	.23 (.32) 22
	Overall	.010 (.90) 75	-.07 (.56) 78
Repair	Negative	-.14 (.47) 29	<-.01 (.99) 28
	Neutral	.13 (.52) 26	.21 (.28) 28
	Positive	-.09 (.70) 20	.10 (.64) 22
	Overall	-.02 (.84) 75	.09 (.44) 78
Clarity	Negative	-.20 (.30) 29	-.10 (.62) 28
	Neutral	.30 (.13) 26	.24 (.23) 28
	Positive	-.28 (.24) 20	.31 (.16) 22
	Overall	-.02 (.86) 75	.15 (.20) 78

4.3.3 Confidence Ratings

Confidence rates were subject to two 4 Problem Type (N, PS, PW, I) by 3 Content Type (Positive, Control, Negative) ANOVAs; with data from the two instructional sets being analysed separately. Cell means for these designs are shown in Table 4.4.

Table 4.4 Confidence Ratings (%) by Instructional Set and Syllogism type (SD paranthesised)

		Confidence Ratings (%)			
Instruction	**Mood (*N*)**	**N**	**PS**	**PW**	**I**
Necessity	Positive (20)	83.39 (15.16)	79.46 (17.53)	83.04 (13.51)	86.61 (12.09)
	Control (28)	84.57 (19.59)	81.25 (19.55)	78.19 (20.47)	82.65 (19.34)
	Negative (30)	81.79 (15.82)	76.79 (19.19)	75.83 (18.61)	81.07 (18.21)
Possibility	Positive (23)	86.96 (10.96)	79.50 (14.69)	86.96 (11.07)	87.73 (12.78)
	Control (30)	84.29 (19.46)	75.83 (22.54)	83.21 (14.86)	89.29 (15.72)
	Negative (30)	83.21 (21.94)	75.12 (22.40)	83.69 (18.47)	83.57 (20.65)

Under necessity instructions, confidence ratings showed a main effect of syllogism type [F (3,225) = 9.74, p < .001, η_p^2 = .12], but no main effect of content type or any syllogism-content interaction. Pair-wise comparisons revealed a general pattern of higher confidence for N and I conclusions relative to PS and PW; N-PS (p=.003), N-PW (p<.001), N-I (p=.82), I-PS (p=.003), I-PW (p<.001), and PS-PW (p=.59).

Under possibility instructions, confidence ratings also showed a main effect of syllogism type [F (3,240) = 21.96, p<.001, η_p^2 = .22], but no main effect of content or any interaction effects. Pair-wise comparisons revealed broadly the same pattern as under necessity instructions; of higher confidence for N and I conclusions relative to PS and PW; N-PS (p=.003), N-PW (p<.001), N-I (p=.17), I-PS (p=.14), I-PW (p<.001), and PS-PW (p<.001)

Across all mood conditions, under necessity instructions, confidence ratings were correlated with endorsement rates for necessary problems, [r (78) = .47, p < .001], PS [r (78) = -.27, p = .02], and PW problems, [r (78) = -.30, p = .008]. This is similar to the confidence-endorsement correlations found under possibility instructions, which also showed confidence to be correlated with endorsement rate for necessary [r (83) = .23, p = .04], and PW syllogisms [r (83) = .22, p = .05].

In addition, controlling for individual confidence in each response in the previously outlined analysis of endorsement data by including confidence ratings as a covariate does not change the patterns or the levels of statistical significance reached. This suggests that confidence does not explain the effects of instructional set or problem type on endorsement rates.

Overall, these results suggest that under both instructional sets, higher confidence is to some extent associated with higher rates of endorsement (higher logical accuracy) on necessary problems, and with lower rates of endorsement (higher logical accuracy) on possible-strong and possible-weak problems under necessity instructions. Similarly, under possibility instructions, higher confidence ratings are associated with higher rates of endorsement (higher logical accuracy) on necessary and possible-weak syllogisms.

4.4 Discussion

The current chapter builds on the work of Chapter 3 by adapting the necessity-possibility paradigm to incorporate integral mood, manipulated by varying the emotional valence of the terms in each syllogism. Typical effects of problem type were replicated, with necessary problems being endorsed as necessary more than possible-strong, possible-strong more than possible-weak, and possible-weak more than impossible. This pattern also held under possibility instructions when the task was to judge the possibility of each conclusion.

The small effect of mood found previously (Section 3.4.1), whereby negative mood lead to higher endorsement rates on PW problems under possibility instructions, was not found in the current data. There were also no differences in confidence ratings across content types. However, participants were more confident in their responses to necessary and impossible problems in both instructional sets than they were in their responses to possible-strong and possible-weak problem types. This replicates the earlier findings that people are more confident in responses to determinate than indeterminate problems, and along with the main effects of syllogism type on endorsement rates, supports the argument that individuals can differentiate the four problem types to some extent. This highlights the need to consider the different syllogism types when interpreting the results reported in previous research as it is often overlooked; PS and PW, if responded to differently depending on the content valence, may obscure interesting results in syllogistic reasoning if they are treated as a single group.

The existing literature suggests that positive and negative emotive content can both improve reasoning as was shown by Blanchette and Campbell's (2005) study on war veterans or impair reasoning, as shown by Blanchette and colleagues work on terrorist-related content (2007), potentially by focussing attention on logically irrelevant aspects (Janis & Frick, 1943 to take just one example). Yet neither of these effects was found with the current data.

In Experiment 1, the effect of incidental negative emotion was found to be larger than the effect of incidental positive emotion or control conditions. This was seen in higher rates of PW-Possibility endorsement. In the current experiment, with integral emotion, no differences between content types were found for PW-Possibility problems, although increased endorsement for negative content relative to positive and control was found on N-Possibility problems. This provides some further, although weak, support for the idea that negative mood, as well as negatively valenced stimuli, cues more careful and thus logically accurate processing of reasoning problems. Comparison of the predicted patterns for Load and Information theories against the obtained results (Table 4.1 and Table 4.2), however, shows very weak evidence of the expected patterns in the data, and at marginal (at best) levels of statistical significance.

Returning to confidence ratings, similar patterns are found across incidental (Chapter 3) and integral (current chapter) manipulations. In both cases, people are more confident in their responses on necessary and impossible items than they are in their responses to both classes of possible items. However, the differences in confidence ratings in earlier studies have shown that negative mood leads to higher confidence ratings (Section 3.4.2); this pattern is not replicated here. Content valence does not appear to affect confidence judgments when the emotional element is integral to the problem. However, contrary to the relationships found by Shynkaruk and Thompson (2006), confidence is related to some extent to accuracy. This was most pronounced in the correlations between accuracy and confidence under necessity instructions, with the relationships being smaller or in the opposite directions under possibility instructions. Unfortunately, due to the design of the study and the software used, it was not possible to collect response latencies which may shed further light on the relationships between syllogism type and confidence ratings by allowing us to control for thinking time, which may be related to confidence ratings.

The effects found previously with incidental emotion were not found when manipulating integral affect. This may be a result of the salience of the affective cues in the current experiment. Although it was thought that using an integral manipulation should reduce demand characteristics potentially caused by a written mood manipulation, it may be that by moving the affective element to within the reasoning task, any weight it may have had as a source of information may have been discounted. Whereas in the incidental manipulation individuals reasoned about neutral problems after they had supposedly stopped being asked to think about their emotions, in the integral task, reading the emotive terms may make the valence of the items more salient; though the effects in the current study were still small. It is likely that participants in a 'reasoning' study, especially undergraduate psychology students, will have some notion that they are meant to try and ignore any content, not just emotive content, and thus any emotional cues may have been more severely suppressed than they might have been. Other work in the literature which has found effects of integral emotion may not suffer from such a discounting effect because of how they were advertised to participants. It is difficult to tell from the published reports of these studies whether participants were told the studies were investigating reasoning, emotion, or both. Details such as this may aid future researchers by allowing explanations such as this to be supported or ruled out, and in the interests of transparency, all studies reported in this thesis were advertised using variations on 'A study to investigate factors affecting reasoning'.

It could be argued that this discounting would require the expenditure of additional cognitive effort, and that the results would be expected to show the pattern of effects predicted by load theories. It may be that the additional load is of little consequence given the already demanding nature of the task. This explanation of the findings suggests that the paradigm adopted may not be sufficiently sensitive to discover any differences caused by either the content or the additional load. It would therefore be profitable in future work to develop more sensitive measures of reasoning. With respect to theories of whether and how emotion and reasoning interact, and in particular the load and information theories, the current data do not show any clear support for either account, and are not consistent with the findings of Blanchette and colleagues, outlined above, or Goel and Vartanian (2011), outlined in Chapter 2 which support information theories. Taking into consideration the points raised above, this may be due to the nature of the task and its relative difficulty. The high rates of endorsement for PS under necessity instructions, and low rates of endorsement of PW conclusions under possibility instructions provide little evidence that people search for alternative models. If only few people search for alternatives, then the potential for observing differences as a result of the emotional content may be limited.

Summary

Experiment 2 replicates the typical effects of problem type and instructional set (e.g. Evans et al., 1999) but fails to find any statistically significant differences between content types on the critical problems. Positive, Control, and Negative content lead to rates of endorsement on PS problems under necessity instruction and PW problems under possibility instruction which were statistically similar. For PS-Necessity problems, there is some suggestion that positive content led to lower endorsement rates, so possibly more effortful processing and assessment of more possible models. Similarly, for PW-Possibility problems negative mood seems to lead to more effortful processing; though these differences did not reach statistical significance, and are not reliable enough to make a strong case for emotion effects, the reduction in endorsement may be indicative of the search for alternative models.

However, this evidence is limited. Endorsement rates for PS-Necessity problems were high across content types, and endorsement rates for PW-Possibility problems were low across content types. It is possible that the difficulty of these problems and the resultant ceiling and floor effects – that is, necessity problems being perhaps too easy, and the search for alternative models in the key conditions being too difficult - make any effects of content difficult to detect in the current paradigm which seeks differences in the levels of analytic processing. That is, the hypothesised differences between content types on the critical problems would be due to different amounts of 'searching for alternative models'. Whereas Experiments 1 and 2 have been seeking differences in levels of this type of effortful processing, an alternative approach would be to consider differences in the relative use of high- and low-effort strategies; differences in the relative use of analytic processing and heuristics. Experiments 3 and 4 in the following chapter make use of the belief-bias paradigm in order to do this.

Chapter Five

Belief Bias and Affective Content

5.1 Introduction

Experiments 1 and 2 utilised the Necessity-Possibility paradigm to investigate the effect of incidental and integral mood on syllogistic reasoning. The results from these experiments suggest that the effects of emotion are small or non-existent. A number of possible explanations, such as the paradigm's complexity and sensitivity have been discussed at the end of Chapter 4, and the current chapter aims to address the issue of which reasoning processes are measured by adopting the belief-bias paradigm. As previously outlined, the Necessity-Possibility paradigm is designed to measure the extent to which effortful, analytic responding is used, and the previous findings would appear to suggest that there is little difference in performance as a function of the emotional content of the conclusions and limited influence of induced emotion. The Belief-Bias paradigm however allows an investigation of differences in the relative use of these analytic processes, and lower-effort heuristic processes.

In the Necessity-Possibility paradigm the distinction between cursory and more extensive processing was based on the assumption that responses can be made based on either single initial mental models or by these and an additional search for alternative models. This might be considered different amounts of analytic processing. The belief-bias paradigm however considers both analytical responses based on problem structure, and lower effort strategies such as reliance on belief, typically considered more akin to heuristic processing. Belief-Bias therefore provides a means of assessing the relative use of analytic versus heuristic processing by relying on problem properties to determine response strategies. This paradigm takes advantage of the ability to cross logical validity with believability in syllogisms, such that by orthogonally rotating validity and believability, four problem types can be created; those with logically valid and believable conclusions (VB), those with logically valid but unbelievable conclusions (VU), those with logically invalid but believable conclusions (IB), and finally, those with logically invalid but unbelievable conclusions (IU). Examples of each are shown below.

Table 5.1 Examples of Syllogism Conclusion Types
created by crossing Validity and Believability

		Believability	
		Believable	*Unbelievable*
Validity	*Valid*	No silver things are mechanical Some mechanical things are cars Some cars are not silver	No vehicles are blue Some blue things are cars Some cars are not vehicles
	Invalid	No trains are planes Some planes are owned by Virgin Some trains are not owned by Virgin	No cats are dogs Some dogs are mammals Some cats are not mammals

Presenting individuals with a series of syllogisms which are drawn from each of these four categories and asking them to indicate whether they think the conclusions follow allows a comparison of endorsement rates across the four types of conclusion. This in turn enables us to determine whether individuals accept conclusions on the basis of their logical validity, on the basis of their believability, or are influenced by both.

Typically, what is found is that both validity and believability have a main effect on endorsement rates; valid conclusions are endorsed more than invalid ones, and believable conclusions are endorsed more than unbelievable ones. Furthermore, validity and believability are typically found to interact such that VB conclusions are endorsed more frequently than VU conclusions, which are in turn endorsed more frequently than IB conclusions, which are endorsed more frequently than IU conclusions, furthermore the difference between IB and IU problems types is typically found to be larger than the difference between VB and VU types (e.g. Evans et al., 1983).

The validity by believability interaction found using the Belief-Bias Paradigm (Chapter 2), has been widely replicated, and researchers have used the paradigm to measure the relative use of logic and belief when reasoning about a syllogism's conclusions, as well as to investigate factors besides emotion which they propose affect the relative engagement of each reasoning system. For example Evans and Curtis-Holmes (2005) used the paradigm to investigate the effects of a speeded task, and found that reducing the time in which a response had to be made increased reliance on prior beliefs, and Quayle and Ball (2000) adopt the paradigm to investigate the impact of working memory on belief-bias, showing that increasing WM load increases belief-bias. There are other researchers however who have argued that the belief-logic interaction, often considered evidence of motivated reasoning; more engaged reasoning when the conclusion is unbelievable; is merely a response bias (Dube et al., 2010), and does not reflect differential analytic and heuristic processing, and others who explain the interaction in terms of selective processing theory (Ball et al., 2006; Klauer, Musch, & Naumer, 2000). However, the underlying theory is less important than the fact that the logic-belief distinction still provides a useful tool for investigating the interaction of emotion and reasoning.

Although little work has used the belief-bias paradigm to investigate the effects of integral mood on reasoning specifically, as discussed in earlier sections on historical and contemporary research on content effects (Section 2.4.1), Zahra (2008) reports a small-scale study in which participants were presented VB, VU, IB and IU syllogisms in which content was varied to be either neutral or anxiety-related. The results reflected the standard main and interaction effects, as well as main and interaction effects of content type which showed that anxiety content exaggerated the believability by validity interaction relative to neutral content. That is, the difference between endorsement rates of believable and unbelievable syllogisms being greater in valid than invalid conclusions with anxiety content than the difference between these syllogisms found with neutral content. These patterns were considered in terms of anxiety-related content reducing the availability of central executive resources, and the nature of the content leading attention to be directed away from the structure of the syllogisms towards the believability of the thematic content. However, the study was conducted as part of a larger research project investigating the effects of eating-disorder related content and assessment anxiety. These conditions were collapsed to form the anxiety-related content items, so whether the effects were specific to any sub-type of anxiety related content is unclear.

More recently, Goel and Vartanian (2011) have utilised a similar approach to investigating the effects of control and affective content on syllogistic reasoning. They found that the standard belief-bias effects were present with neutral content, but that negatively valenced content lead to less reliance on prior beliefs. They use the AIM (Section 2.4.1) to explain this pattern in terms of negatively valenced content cueing more careful processing of the problem. In explaining the increase in logical accuracy found with negative content, they argue that the negative content cues a more careful and systematic processing style, which they support with response time data. However, they did not consider positively valenced content. As discussed earlier, although emotion-specific content should provide the basis of future work in this area, at this stage, general affective classes may prove more informative when other variables such as form and believability are controlled. This is especially the case given the subjectivity of 'specific' emotional content (Section 1.3). That is, generally positive and negative content classes have been used in previous work, and the comparison of positive to negative is important, but as Goel and Vartanian's study shows, direct comparison is often omitted.

Given these findings, and those of Blanchette and Campbell (2005), Blanchette and colleagues (2007), and the other studies using emotive content outlined in the introduction to Chapter 4 which have found both improved and impaired logical responding with emotive content, the Belief-Bias paradigm provides an opportunity to extend the literature beyond more commonly used tasks such as the Iowa gambling task (e.g. Blanchette, 2006; Ikegami, 2002; Shackman et al., 2006), and provide a more detailed investigation of whether and how emotion affects reasoning. This is achieved by the careful control of syllogism properties in the Belief-Bias paradigm in order to assess the relative use of analytic and heuristic processes, and the comparison of incidental and integral affect. Although a sizeable body of work has investigated the effects of incidental and integral mood in situations such as gambling and generally found negative emotions to impair performance (Miu, Heilman, & Houser, 2008), quite possibly due to their more apparent practical applications in the clinical domain, understanding how affect alters reasoning on syllogistic tasks within the Belief-Bias paradigm provides a much clearer test of the load and information theories. This is achieved by allowing much more control of problem structure whilst also allowing the use of established effects to be used as measures of analytic versus heuristic processing. In the case of belief-bias effects, these are the main effects of validity and believability, and the interaction between the two, as well as indices of logic versus belief, which can be computed using equations derived from the early work on these effects (discussed below, but see also Lefford, 1946). These provide a measure of an individuals' reliance on logical structure and their reliance on the believability of the conclusions when responding, and can be thought of as measures of analytic versus heuristic responding (Chapter 2).

This experiment aims to investigate the effects of syllogism content on the relative reliance on logical structure and prior beliefs by developing the Belief-Bias paradigm to include an additional factor, emotive content, as a way of manipulating integral affect. Based on previous findings from research on integral emotion, the results reported here focus broadly on replicating the standard belief-bias effects, and analysing the extent to which they differ as a function of content valence. Although previous research has shown limited effects of integral emotion the Belief-Bias paradigm provides a more direct measure of the two reasoning systems proposed by dual process theories. This chapter will begin by using a web-based approach to increase sample size and statistical power, followed by a smaller scale laboratory follow-up to assess the replicability of any effects found. In relation to the information and load theories which have so far provided a framework for investigating the impact of emotion, the following hypotheses can be outlined. If integral emotion serves as information then individuals would be expected to show higher reliance on beliefs when the problem content is positive, and higher reliance on logic when the content is negative relative to control content. If, however, affect serves as cognitive load, both positive and negative content would be expected to increase belief-based but reduce logic-based responding relative to control content.

5.2 Online Experiment (Experiment 3)

Having established the Belief-Bias paradigm as a useful tool for investigating the impact of integral emotion on reasoning, the next considerations concern its implementation. The paradigm, as discussed above, and as will be outlined in more detail below, provides a measure of the relative use of logic- and belief-based processing, or more specifically, indices of the reliance on logical form and conclusion believability when responding to syllogisms. This is a more direct measure of which type of reasoning process is engaged than the Necessity-Possibility paradigm. As such, although the primary aim of the online version of this study is to investigate the impact of integral emotion on the belief-bias effect, it also aims to investigate differences in the reliance on logical form versus prior beliefs when content valence is varied. This second objective addresses the issues raised in the discussions of previous chapters and those outlined at the beginning of the current chapter regarding the need to measure the relative use of low and high effort processing rather than just differing levels of high-effort processing.

5.3 Method

5.3.1 Materials

Syllogisms

The syllogisms constructed for this study were matched for mood, structure, form, and difficulty (three models) based on figures provided by Johnson-Laird and Byrne (1992). This avoids the possible confounds caused by figural effects and difficulty (e.g. Garnham & Oakhill, 1994). Content was chosen based on previous work in the area of emotion, with terms appearing in the literature as positive and negative being used to create emotive syllogism sets. Subsets of these emotive-content syllogisms were then selected for use based on pilot data. The believability categories were also validated by piloting as described below.

Piloting of Materials

In order to validate the believability and mood categories, two small-scale pre-tests (Believability: N = 14, 3 male; Mood Categories: N = 12, 3 male) were conducted. Participants asked to assess believability were shown the syllogism conclusions in a random order and asked to rate how believable they thought each one was. Participants asked to assess the mood categories were shown the syllogisms in a random order and asked to rate each on how positive, overall, they thought the content was. Responses for each task were made on a seven-point scale, anchored at *Negative* and *Positive* for the positivity rating task, and *Unbelievable* and *Believable* for the believability rating task.

A 2 Content (Positive, Control, Negative) by 2 Believability (Believable, Unbelievable) repeated measures ANOVA on believability ratings showed a main effect of believability [$F(1,13) = 151.30$, $p < .001$, $\eta_p^2 = .92$], in which 'believable' conclusions (M = 6.33, SD = .46) were rated as much more believable than 'unbelievable' ones (M = 3.16, SD = 1.01). No main effect of content type was found on believability ratings, nor did content type and believability interact.

The same repeated measures ANOVA conducted on positivity ratings showed a main effect of content type [$F(2,22) = 49.36$, $p < .001$, $\eta_p^2 = .81$]. Post-hoc comparisons revealed this to be due to significant differences in ratings between control (M = 4.23, SD = .65) and negative items (M = 2.12, SD = .61, $p < .001$); control and positive items (M = 5.41, SD = 1.18, $p < .001$), and positive and negative items ($p < .001$). No main effect of believability was found on positivity ratings, nor did content type and believability interact.

The intraclass correlation for believability ratings across the fourteen participants' ratings, after applying the Spearman-Brown correction formula (See Appendix F) was $\alpha = .99$, which provides an estimate of the reliability of the believability ratings averaged across participants. The corresponding value for positivity ratings across the twelve participants who rated each syllogism was also α = .99. These values suggest positivity and believability are consistent across individuals. The final set of materials can be found in Appendix C, but examples are provided below.

Positive, Valid, Believable

Some bright things are presents,
No surprises are bright,
Therefore some presents are not surprises

Control, Invalid, Believable

Some orange things are metal,
No metal things are vegetables,
Therefore some vegetables are not orange

Negative, Valid, Unbelievable

Some types of nuclear radiation are deadly,
No deadly things are dangerous,
Therefore some types of nuclear radiation are not dangerous

Questionnaire

The data in this study was collected using an online form created using Google Documents beta©. Different forms were created, with the content of the syllogisms and the order of presentation varying randomly between participants. Each form consisted of the title of the study, the text of the brief and instructions, followed by the first item which asked participants to check a tick-box after having read the brief and instructions if they gave their consent to participate.

Following this, an open text box was provided for participants to enter a memorable date, and it was explained that this was so that their data could be identified and withdrawn if they wished at a later date whilst allowing them to remain anonymous. Participants' right-to-withdraw was explained, and they were informed that they could do so by closing the browser window. To allow participants the chance to ask questions, the experimenter's contact details were provided, along with instructions to contact them if they had any questions before completing the experiment.

The memorable date question was followed by the sixteen syllogisms presented in a random order. For each item, participants had to select one of two radio-buttons, labelled 'Valid' and 'Invalid'. Upon completion of the study and clicking a 'submit' button all responses were saved along with a time-stamp so that time of completion could be monitored and multiple successive submissions could be detected.

Design

The design of this study was a standard Belief-Bias paradigm with an additional content factor, resulting in a mixed 2 Validity (Valid, Invalid) x 2 Believability (Believable, Unbelievable) x 3 Content (Positive, Control, Negative) ANOVA design, with content being a between-participants factor.

To provide measures of the relative reliance on logical structure and prior beliefs, indices of logic and belief were also computed based on endorsement rates as follows (subscripted 'end' denotes endorsement);

$$\text{Logic Index} = (VB_{end}+VU_{end})-(IB_{end}+IU_{end})$$

$$\text{Belief Index} = (VB_{end}+IB_{end})-(VU_{end}+IU_{end})$$

These measures allow the use of logic and beliefs to be compared across the levels of the content factor in two 3 Content (Positive, Control, Negative) univariate ANOVAs.

5.3.2 Participants and Procedure

Potential participants were contacted by email and social networking websites, and those wishing to participate were emailed hyperlinks to a randomly allocated test form. The procedure was structured as outlined above. The final sample for the study consisted of 159 participants. Age, gender, and other demographic information was not recorded.

5.4 Results

5.4.1 ANOVAs

Mean endorsement rates (%) by syllogism type and content valence are shown in Table 5.2. The 2 Validity (Valid, Invalid) x 2 Believability (Believable, Unbelievable) x 3 Content Type (Positive, Control, Negative) mixed-ANOVA found a main effect of validity, with more valid (*M* = 67.29, *SD* = 30.06) than invalid (*M* = 46.60, *SD* = 32.69) conclusions being endorsed [*F* (1,155) = 64.16, *p* < .001, η_p^2 = .29]. The analyses also found a main effect for believability, with more believable (*M* = 63.77, *SD* = 29.33) than unbelievable (*M* = 50.13, *SD* = 33.41) conclusions being endorsed [*F* (1,155) = 24.52, *p* < .001, η_p^2 = .14].

In addition, a main effect of content type was found [*F* (1,155) = 5.58, *p* = .01, η_p^2 = .07], where positive (*M* = 59.66, *SD* = 29.41) and negative (*M* = 61.18, *SD* = 30.80) conclusions are generally endorsed more frequently than control conclusions (*M* = 50.00, *SD* = 33.91; *p* = .02, *d* = .53 and *p* = .008, *d* =.59 respectively).

Table 5.2 Mean Endorsement Rates (%) by Syllogism Type and Content Valence for the Belief-Bias paradigm with emotive content (Online Setting)

Syllogism Type		**Content Valence (*N*)**			
		Positive (55)	Control (52)	Negative (52)	Total (159)
VB	*M*	71.36	59.31	86.54	72.41
	SD	25.19	26.91	20.69	24.26
VU	*M*	63.18	63.24	60.10	62.17
	SD	30.37	42.43	34.75	35.88
IB	*M*	57.73	48.04	59.61	55.13
	SD	31.87	37.70	33.63	34.40
IU	*M*	46.36	29.41	38.46	38.08
	SD	30.21	28.59	34.11	30.97

Believability and content type interacted significantly [F (2,155) = 3.43, p = .04, η_p^2 = .04], whereby believability increases endorsement rates across all conditions, but particularly so when the content is negative. Validity and Believability also showed a significant interaction [F (1,155) = 4.21, p = .04, η_p^2 = .03], in the directions that would be expected based on previous research; valid conclusions being endorsed more than invalid ones, believable ones being endorsed more than unbelievable ones, and the difference between believable and unbelievable being larger for invalid conclusions (Means for each category are included in Table Table 5.2). The results also indicated a highly significant three-way interaction between validity, believability, and content type [F (2,155) = 6.03, p = .003, η_p^2 = .07]. This is shown in Figure 5.1, and partly extends the findings of Goel and Vartanian (2011); their reduced validity-believability interaction with negative content is also found with positive content.

Univariate ANOVAs entering belief and logic indices as dependent variables and content type as the independent variable found no significant effect of content type on use of logic [F (2,155) = 1.18, p = .31, η_p^2 = .02], but did find a significant effect of content type on the belief index [F (2,155) = 3.43, p = .04, η_p^2 = .04]. Post-hoc comparisons show that the negative (M = 23.80, SD = 34.50) content significantly increased reliance on belief relative to positive (M = 9.77, SD = 26.86, p = .04, d = .46) and control content (M = 7.35, SD = 41.85, p = .02, d = .43), but that there was no significant difference between the control and positive content. Plots of indices by content type are shown in Figure 5.6, p207, and are returned to later.

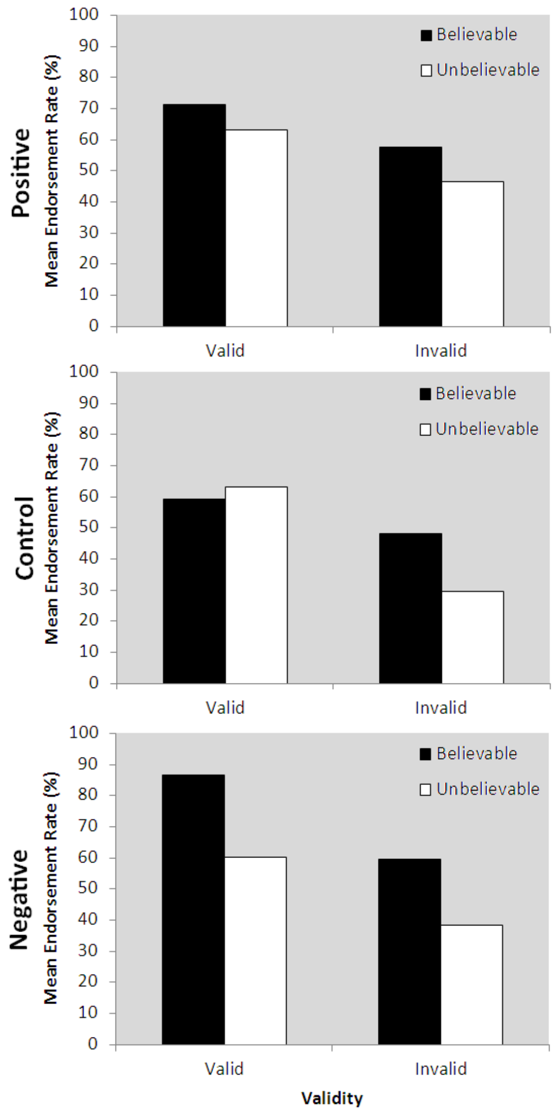


Figure 5.1 Validity by Believability interactions by Content Type; Online Data

5.4.2 Correlations

To obtain a general overview of patterns within the data, Logic and Belief Indices were correlated with each other and with problem content, with the three conditions sequentially ordered Positive-Control-Negative, to provide a valence continuum. Content type was positively correlated with the belief index, indicating that negative content increases reliance on belief as a cue in responding [r (158) = .16, p = .04, d = .33]. In addition, the logic and belief indices were negatively correlated [r (158) = -.35, p < .001, d = .75], suggesting a tendency for participants to rely on either logic or belief as a basis for their responses as opposed to trying to integrate the two.

5.5 Discussion of Experiment 3

The main effect of content type suggests that problems with positive and negative content are endorsed more than control problems. This suggests that regardless of problem validity or believability, those which have emotive content are more likely to be rated as valid than those whose content is neutral. Although interesting, it is in combination with validity and believability that the effects of content are most relevant to evaluating the strength of the load and information explanations of how emotion impacts reasoning. When these additional factors are considered, it can be seen that believability and content interact in such a way that believability increases endorsement rates across all types of content. Furthermore, this believability-driven increase in endorsement is greater for problems with negative than positive or control content. This suggests that believability is consistently used as a cue to endorsement regardless of content, but that it is relied on more heavily when the content is negative. One possible explanation of this is that negative content loads WM more severely than positive or control content, forcing a reliance on heuristic processes.

Differential WM load across content types is also interesting in relation to the validity by believability by content interaction, which seems to show that the validity by believability interaction component is reduced to a large extent when the content is emotive. If both types of content load WM, under a dual process interpretation, it would be attention to logical structure that suffered first, and a reduction in the effect of logic would be expected with positive and negative content. This is because if WM were reduced to the extent that responses were made solely on believability, little difference would be expected in endorsement rates between valid and invalid syllogisms.

However, that there was no validity by content interaction appears to rule out this explanation. However, it might be possible that enough resources remain for an individual to adopt a logical approach to the problems, or a belief based strategy, yet not have enough resources to integrate the information. Limited WM may prevent individuals from detecting and resolving conflict between logic and belief based responses, leading them to adopt one or the other approach. This would explain the reduced interaction between validity and believability found with emotive content. Alternatively, the reduced interaction with emotive content may be indicative of a reduction in motivated reasoning. Emotive content, be it positive or negative, leads individuals to either use logic, or use belief, and integrate the two less; possibly because of increased load or reduced motivation to reason accurately based on all available information.

An alternative explanation of these findings would be from an individual differences perspective, whereby some individuals, when faced with emotive content, choose to adopt a logical strategy, maybe because the content cues them to the structure, and thus ignore the believability of the conclusion; whereas others adopt a belief-based strategy, ignoring structure altogether, possibly because of reduced cognitive resources or a misapplied focus on content.

Alongside the novel results outlined above, the results of Experiment 3 show that the current materials and procedures behave in a similar fashion to those used previously in the literature. This is evidenced by the broad replication of validity and believability main and interaction effects. In relation to the aims of the current thesis, this shows that the paradigm is working as expected, and provides a basis from which the effects of content can be considered.

When considering the index scores, it is interesting that content has no effect on reliance on logic, whereas reliance on belief is increased on problems with negative, but not positive or control, content. This would seem to support the independence of the two reasoning systems, but is difficult to reconcile with load or information theories. One possible explanation is that affective content serves as cognitive load, but that negative content loads WM more severely than positive emotion. However, neither load nor information theories are clearly supported. Having used an online study to generate a larger sample to improve the design, and having considered the effects under such circumstances, the following Experiment 4 aims to replicate these findings under laboratory conditions.

5.6 Laboratory Experiment (Experiment 4)

In order to validate the findings of Experiment 3, the same design, materials, and procedure were used in a laboratory based version of the study. This also enables an investigation of the reliability and validity of online versus laboratory methodologies. The hypotheses are therefore the same as in Experiment 3.

5.7 Method

5.7.1 Materials

The materials for Experiment 4 were identical to those used in Experiment 3. Participants in the laboratory were seated at personal desktop computers with internet access, on which one of the forms (positive, negative, or control conditions) was displayed.

5.7.2 Design

This study utilised the same mixed 2 Validity (Valid, Invalid) x 2 Believability (Believable, Unbelievable) x 3 Content (Positive, Control, Negative) ANOVA design as Experiment 3. Indices of logic and belief were also computed as in Experiment 3.

5.7.3 Participants and Procedure

Participants were 56 Psychology undergraduate students at Plymouth University. Age, gender, and other demographic details were not recorded. Upon entering the laboratory, each participant was seated at a computer terminal and asked to read the on-screen instructions and sign a consent form if they agreed to participate. They were then asked to work through the questions as per the instructions in their own time, and told that they were free to leave when they had finished. Paper copies of the debrief were made available to all participants.

5.8 Results

5.8.1 ANOVAs

Mean endorsement rates (%) by syllogism type and content valence are shown in Table 5.3. The 2 Validity (Valid, Invalid) x 2 Believability (Believable, Unbelievable) x 3

Content Type (Positive, Control, Negative) mixed-ANOVA found a main effect of validity, with more valid (*M* = 71.62, *SD* = 21.77) than invalid (*M* = 37.40, *SD* = 29.83) conclusions being endorsed [F (1,53) = 80.66, p < .001, η_p^2 = .60]. No effect of believability was found, although the general pattern of believable conclusions being endorsed more frequently than unbelievable conclusions is replicated. However, the VB and VU cell means for control content show the opposite pattern; VU conclusions are endorsed more frequently than VB conclusions..

Table 5.3 Mean Endorsement Rates (%) by Syllogism Type and Content Valence for the Belief-Bias paradigm with emotive content (Laboratory Setting)

Syllogism Type		**Content Valence (*N*)**		
		Positive (20)	Control (16)	Negative (20)
VB	*M*	68.75	50.00	88.75
	SD	25.49	18.26	15.12
VU	*M*	65.00	73.44	83.75
	SD	26.16	30.91	14.68
IB	*M*	35.00	40.63	40.63
	SD	31.83	31.83	30.10
IU	*M*	42.50	34.38	31.25
	SD	24.47	34.00	26.75

There was also a main effect of content type [F (2,53) = 3.23, p = .05, η_p^2 = .11], with negative content (*M* = 61.10, *SD* = 21.66) leading to more endorsements than positive (*M* = 52.83, *SD* = 27.00, approaching significance at *p* = .07, *d* = .65) or control content (*M* = 49.61, *SD* = 28.75, *p* = .02, *d* = .79), but no significant difference in endorsement rates between positive and control content. These results replicate the previous experiment.

Validity and content interacted significantly [F (2,53) = 4.21, p = .02, η_p^2 = .14], showing that valid conclusions are endorsed more frequently across all content types, but that valid conclusions are endorsed at still higher rates when the content is negative than when it is positive or control. There was no interaction effect found between validity and believability, unlike in Experiment 3 (See Figure 5.2). As in Experiment 3, there was also a significant three-way interaction between validity, believability, and content type [F (2,53) = 4.01, p = .02, η_p^2 = .13]. This interaction is shown in Figure 5.3.

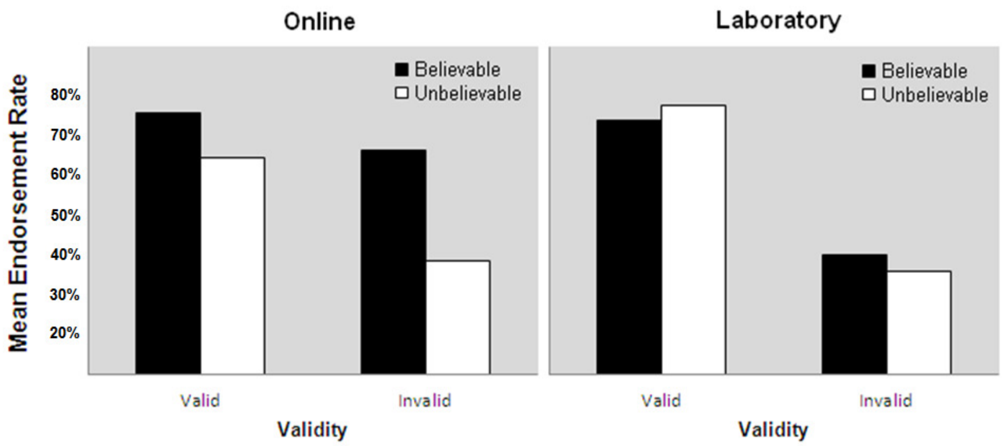


Figure 5.2 Validity by Believability interactions for On-line and Laboratory Data

Univariate ANOVAs identical to those conducted for the logic and belief indices in experiment one this time show a significant effect of content type on the logic index [F (2,53) = 4.21, p = .02, η_p^2 = .14]. Post-hoc comparisons show that only the difference between negative (M = 48.75, SD = 32.16) and control content (M = 24.22, SD = 27.94) reached statistical significance (p = .05, d = .73), with negative content increasing use of logic. No effect of content type on use of belief was found.

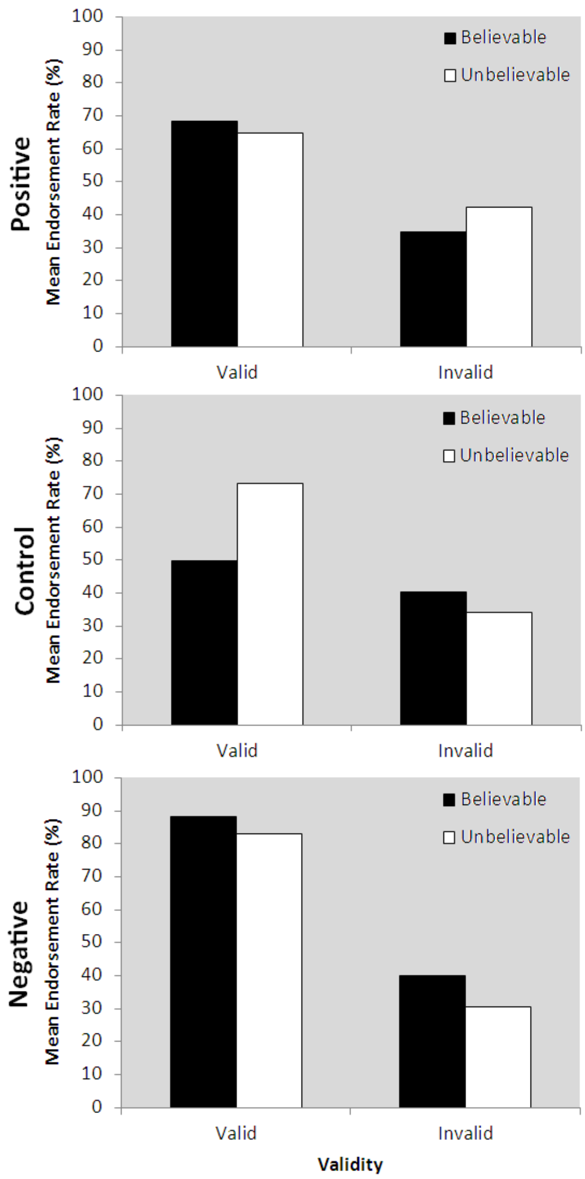


Figure 5.3 Validity by Believability interactions by Content Type; Laboratory Data

5.8.2 Correlations

Correlational analyses conducted as in Experiment 3 show a significant positive correlation between content type and use of logic [r (56) = .30, p = .03, d = .62], indicating that negative content increases reliance on logic. No other significant correlations were found, although, as with the online data, content and belief show some positive relationship [r (56) = .18, p = .20], and logic and belief show a negative relationship [r (56) = -.17, p = .21].

5.9 Discussion of Experiment 4

In the laboratory data, the most notable point is that only the main effect of validity was found to be consistent with typical belief-bias findings. However, although the believability main effect and validity-by-believability interactions did not reach statistical significance, they were in the directions that would be predicted by the previous work. The three-way validity by believability by content interaction still reached statistical significance, though comparison of Figure 5.3 with Figure 5.1 shows that although there is a reduction in the validity by believability interaction for positive and negative content, the interaction within the laboratory control condition, and online control condition are very different. Control VB and VU items are endorsed comparably in the online data, but VU items are endorsed more frequently than VB items in the laboratory data. This might be suggestive of a general reduction in validity-by-believability interaction caused by emotive content, or the laboratory setting reducing the motivated reasoning which might underlie such an interaction.

Interestingly, validity showed a similar interaction with content as did belief in the online data, and furthermore, the logic index showed an interaction with content in the current dataset which is similar to that for the belief index and content in the online dataset. This suggests it is possible that the laboratory setting cues people to apply their knowledge of logic when engaging in the reasoning task; yet without these environmental cues, people default to belief; possibly because in more natural online settings, beliefs have served them well – consider the discussion of pragmatic reasoning in Chapter 2 – whereas in the less natural laboratory setting people have certain perceived expectations. One of these may be the need to try and reason logically. In relation to the data, this supports an explanation of the results based on the content valence modifying the dominant strategy and the data thus appears to fit an information model of emotion and reasoning interaction better than a load model, though the mixed effects discussed earlier should also be kept in mind; Negative content leads to higher reliance on logic than positive or control content.

The explanations outlined in this and the previous discussion section regarding content potentially serving as load may be reconciled by considering the interaction of reasoning strategy with the environment in which reasoning takes place, or it may be a product of different mechanisms operating under different settings. However, the same general patterns in relation to validity and believability main effects are found in the laboratory and online data, with only the points of statistical significance differing. The interaction, however, differs as outlined above.

5.10 Combining Online and Laboratory Data

In order to compare the laboratory and online data directly, a 2 Validity (Valid, Invalid) x 2 Believability (Believable, Unbelievable) x 3 Content Type (Positive, Control, Negative) x 2 Location (Laboratory, Online) mixed-ANOVA was conducted to assess the impact of location. Although no significant main effect of location was found, location did interact significantly with validity, $F(1,208)=7.06$, $p<.01$, and with believability, $F(1,53)=7.83$, $p<.01$. As depicted in Figure 5.4, the laboratory setting appears to increase the effect of validity and decrease the effect of belief. This provides some support for the idea that reliance on logical structure is primed by the laboratory environment. However, as the effect sizes of these interactions are relatively small, η_p^2 = .03 and η_p^2 = .04 respectively, the online and laboratory data were combined to explore the overall effects with a larger data set. The results of analyses of variance on this combined data set are reported in the following section.

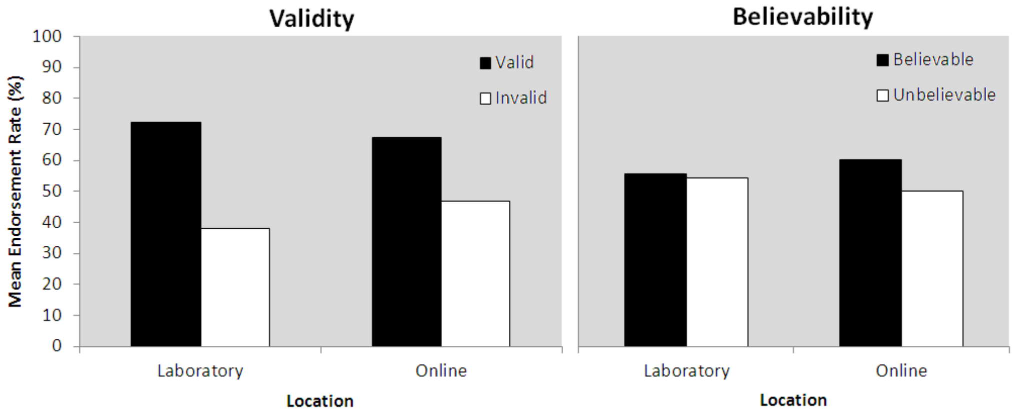


Figure 5.4 Validity and Believability by Location Interaction Effects

5.10.1 ANOVAs

The following results from the combined sample should be interpreted in light of the above mentioned validity-location and believability-location interactions. A main effect of validity was found, showing valid (*M* = 68.49, *SD* = 28.52) conclusions to be endorsed more frequently than invalid (*M* = 44.26, *SD* = 32.32) conclusions, [F (1,211) = 122.69, p < .001, η_p^2 = .37]. Mean endorsement rates by syllogism type and content valence are shown in Table 5.4. A main effect of believability was also found, showing that believable conclusions (*M* = 61.34, *SD* = 28.82) were endorsed more frequently than unbelievable ones (*M* = 51.40, *SD* = 32.02) [F (1,211) = 19.50, p < .001, η_p^2 = .09]. Believability and content type interacted significantly [F (2,211) = 4.75, p = .01, η_p^2 = .04], indicating that believability increases endorsement rates across all content conditions, but especially when the content is negatively valenced (Table 5.4).

Table 5.4 Mean Endorsement Rates by Syllogism Type and Content Valence for the Belief-Bias paradigm with emotive content (Combined Data)

Syllogism Type		**Content Valence (*N*)**		
		Positive (75)	Control (68)	Negative (72)
VB	*M*	70.67	57.09	87.15
	SD	25.13	25.30	19.22
VU	*M*	63.67	65.67	66.67
	SD	29.15	40.08	32.23
IB	*M*	51.67	46.27	55.21
	SD	33.22	35.95	34.07
IU	*M*	45.33	30.60	36.46
	SD	28.68	29.78	32.21

Validity interacted significantly with believability, in the directions that would be expected and that are typical of the belief-bias paradigm, namely that he difference between believable and unbelievable problems is larger when the conclusion is also invalid than when it is valid [F (1,211) = 6.39, p = .01, η_p^2 = .03]. There was also a significant three-way interaction between validity, believability, and content type [F (2,211) = 8.42, p < .001, η_p^2 = .07], the effects of which are shown in Figure 5.5. This again shows, as in Experiments 3 and 4 treated individually, that the validity by believability interaction is different, and reduced, for positive and negative content relative to control content.

A main effect of content type was found [F (2,211) = 7.64, p = .001, η_p^2 = .07], whereby positive (M=57.84, SD=29.05) and negative (M=61.37, SD=32.78) content lead to higher rates of endorsement than control content (M=49.91, SD=29.43, p=.008 and p<.001 respectively). No difference was found between endorsement rates on positive and negative conclusions.

Comparing logic and belief index scores of the combined data across conditions in a 3 Content Type (Positive, Control, Negative) univariate ANOVA shows no effect of content type on use of logic, but does show a significant effect of content on the use of beliefs [F (2,211) = 4.75, p = .01, η_p^2 = .04]. Post-hoc comparisons again show that negative content (M = 19.61, SD = 30.96) increases use of belief relative to positive (M=6.67, SD = 27.82, p = .02, d = .44) and control content (M = 3.54, SD = 39.52, p = .004, d = .45), but there is no statistically significant difference between positive and control content.

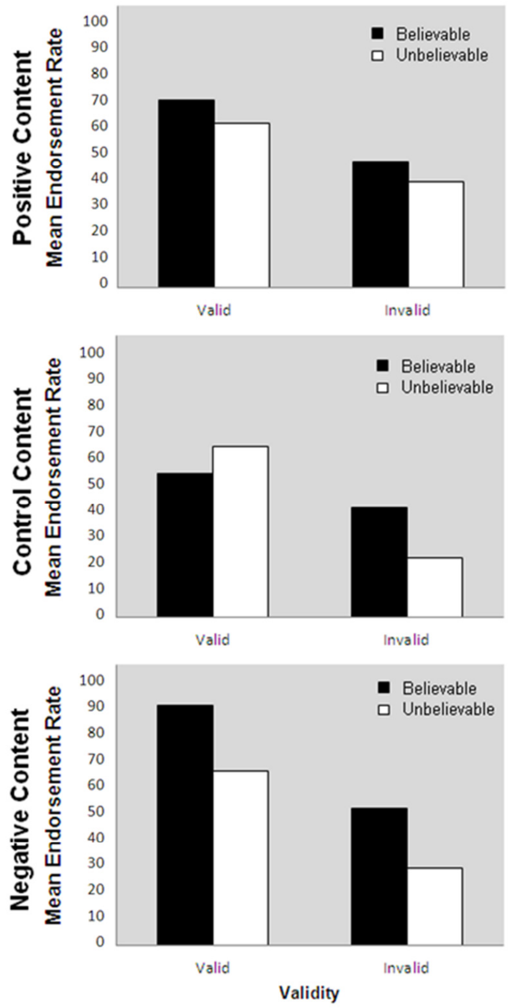


Figure 5.5 Validity by Believability by Content Interaction (Combined Data)

5.10.2 Linear Trends Analysis

In order to further investigate the effects of content type on logic and belief, mean scores on the logic and belief indices for each condition were plotted against content. These are shown for the combined data, as well as for the laboratory and online data separately, in Figure 5.6. Line graphs have been used to clarify general overall directions of change, though it should be kept in mind that the x-axis is categorical and technically non-interval, though spanning the positive-negative continuum.

In addition to the logic and belief indices described above, Figure 5.6 shows an interaction index, which is a measure of the extent to which belief affects logic. Higher interaction scores indicate a greater effect of belief on logic, lower scores, a reduced effect of belief on logic. This index is computed as shown below, and allows an investigation of the hypothesis that positive and negative content reduce the interaction of validity and believability by indexing the impact of beliefs on the use of logical validity.

$$\text{Interaction Index} = (IB_{end}+IU_{end})-(VB_{end}+VU_{end})$$

ANOVA linear contrasts indicate a statistically significant linear component in the logic index trend for both the combined [F (1,213) = 5.54, p = .02], and laboratory data [F (1,55) = 5.46, p = .02]. The belief index trend showed a significant linear component in the combined [F (1,213) = 5.69, p = .02], and online data [F (1,157) = 4.39, p = .04]. The linear components for the interaction index were non-significant across all data sets. However, the interaction index showed a statistically significant quadratic component in all data sets; Combined [F (1,213) = 16.82, p < *.001*], Online [F (1,157) = 11.06, p = .001], and Laboratory [F (1,55) = 6.13, p = .017]. These results indicate a belief by validity interaction in the control condition, but not in the positive or negative conditions. A linear components analysis of the belief and logic indices using the formulae in Appendix E revealed no statistical differences between the linear components of the belief index and logic index trends across datasets, suggesting that both linear trends are the same across datasets.

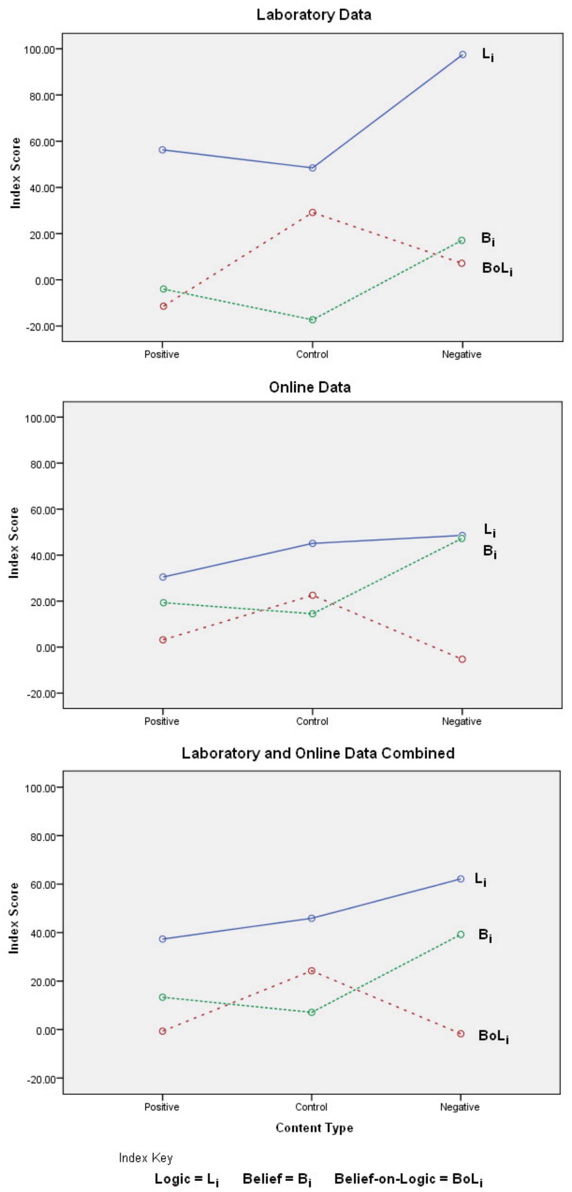


Figure 5.6 Logic, Belief, and Interaction Indices across content types and location

5.11 General Discussion

Experiments 3 and 4 compared the relative use of Type One and Type Two processing as a function of integral emotion, building on the work in Experiments 1 and 2 which assessed the extent to which Type Two processes are utilised as a function of incidental and integral emotion respectively. The results of Experiments 3 and 4 show that valid conclusions are endorsed consistently more frequently than invalid ones, and with the exception of valid-control items, and invalid-positive items in Experiments 4, believable conclusions are endorsed more than unbelievable ones. Furthermore, the difference between believable and unbelievable endorsement rates is, on the whole, larger for invalid than valid syllogism conclusions. What is novel in these findings is that the inclusion of emotive content reveals that conclusions of syllogisms with negative and positive content are endorsed more frequently than those of syllogisms with control content; a finding which replicates clearly across both experiments. Furthermore, the validity by believability interaction also changes depending on content type. Positive and negative content in both experiments show less pronounced validity-by-believability interactions than control content. The combination of the two samples, as well as linear trends analysis across the groups appears to reveal consistent trends: both reliance on logic and reliance on belief increases across positive, to control, to negative content, and the interaction between belief and logic is reduced for positive and negative content.

The increases in both reliance on logic *and* belief with negative relative to positive content neither completely agree with nor conflict with previous work, discussed in Chapter 2, which has shown negative content to increase logical accuracy, or related work which has shown emotive content can decrease logical accuracy (Blanchette et al., 2007). One possible explanation of this is the relevance of the content. Blanchette and colleagues found that when the emotive content was particularly relevant to the individual, logical performance improved relative to neutral content. This highlights the need to consider subjectivity in the use of emotional stimuli, and might be used as an argument for using self-selected stimuli in studies where pre-tests or self-directed incidental manipulations are not possible. The current results have more in common with the work of Goel and Vartanian (2011), who report that with neutral content, the belief-bias effect is present, but that then the content is negative, beliefs have less impact on responses. The current study also finds the belief-bias effect with control content, though less clearly than Goel and Vartanian, and the current data also show a reduction in the impact of belief on logic when the content of the problems is negative. Experiments 3 and 4 also extend the work of Goel and Vartanian by including a positive condition, and finds that the impact of beliefs on logic is also reduced when reasoning about positive content.

With respect to the differences in results found between the current experiments and Experiments 1 and 2, the larger, more consistent effects in the current chapter may be due to the nature of the paradigm. Whereas Experiments 1 and 2 use the Necessity-Possibility paradigm to assess the extent to which Type Two processes are engaged in a search for alternative models, the Belief-Bias paradigm compares the relative use of Type One and Type Two processing. This difference suggests that emotion may impact reasoning by altering the relative use of logic and belief, rather than the extent to which more complex reasoning processes are engaged; it is this latter difference which Experiments 1 and 2 would have been most sensitive to.

In relation to Load and Information, were mood to act as load, belief index scores would be expected to be higher for positive and negative content than for control content as both content types would be expected to reduce the availability of

WM resources necessary for employing logic-based strategies. In addition, logic index scores would be expected to be lower for positive and negative content than for control content. The belief index scores show this pattern; higher for emotive content types than control, albeit not reaching statistical significance. However, the logic indices do not.

The alternative hypothesis set up at the start of this chapter was that integral mood may act as a source of information. Under this model, belief index scores would be expected to be highest for positive content, intermediate for control content, and lowest for negative content. Logic index scores would be expected to show the reverse pattern; being lowest for positive content, intermediate for control, and highest for negative content. The logic scores show some trend towards this pattern; higher for negative content, but the belief index scores do not.

Individual strategy differences might account for these patterns, with emotion acting as load to some individuals and as information to others. This explanation is given some support by the significant quadratic trend in the interaction indices across experiments. Less effect of belief on logic when people reason about emotive content, be it positive or negative, may indicate that people are choosing one or the other strategy to rely on, and this may be driven by whether people incorporate emotion into their reasoning as load or information. However, it seems more likely that the interactions between content type and reasoning system are more complex than can be captured by thinking solely in terms for Load and Information, or Type One and Type Two processes, and moving towards a simpler paradigm may be a useful way of reducing this complexity in order to aid our understanding.

In summary, across the four experiments to this point, it can be seen that incidental emotion has a limited impact on syllogistic reasoning, although negative mood shows some suggestion of increasing the use of Type Two processing. This was explained in terms of negative mood leading to greater engagement, more motivated reasoning, and a greater search for alternative models. This was however only found in very specific conditions, such as on PW-syllogisms under possibility instructions (Experiment 1). These effects were small with incidental emotion (also Experiment 1), and did not reach statistical significance with integral emotion (Experiment 2). Clearer effects were found in the current chapter, with negative mood leading to a consistent increase in use of logic and belief when making judgements about the validity of syllogism conclusions, both in an online (Experiment 3) and laboratory setting (Experiment 4). These results provide some broad support for Information theories, though where the results contradict the patterns expected by Information theories such as increased reliance on belief with negative content, highlight the need to explore the generalisability and robustness of the findings.

As syllogistic reasoning is considered one of the more complex types of reasoning, incorporating further measures of attention to emotions or thinking styles to understand when these apparent contradictions occur would tend to lead to a combinatorial explosion in the numbers of possible interactions. This would, far from clarifying the relationship between emotion and reasoning, only serve to confuse the picture by increasing the number of potential interactions to tease apart. However, some of the simplest arguably even 'innate' reasoning such as drawing Modus Ponens, can be found in conditional reasoning paradigms. Such paradigms are simpler in terms of the processes underlying the logical judgements being made than syllogistic reasoning, especially when focussing on the four main inference types, modus ponens, modus tollens, affirming the consequent, and denying the antecedent, which will be discussed shortly. Furthermore, there is a range of work which has considered the impact of searching for counter-examples in conditional reasoning; that is, considering alternative causes and consequences of assuming certain premises, and this links well to the ideas discussed in this and the previous chapter of searching for alternative models in syllogistic reasoning. It is thus to conditional reasoning that the following chapter turns, in order to compare the effects of emotion across syllogistic and conditional reasoning, and to investigate these effects in a conceptually simpler task.

Chapter Six

Conditional Reasoning and Mood

6.1 Introduction (Experiment 5)

Up to this point, the focus of this thesis has been primarily on syllogistic reasoning. This is largely because syllogisms allow, through the use of the belief-bias and necessity-possibility paradigms, a way of providing measures of analytic versus heuristic processing. Thus they provide a good platform from which to investigate the relative effects of positive and negative integral and incidental emotion on the two types of reasoning outlined by DPT, or the extent to which individuals process the problems based on logical structure versus lower-effort strategies.

Syllogistic reasoning is, however, only one group of reasoning tasks, and many everyday examples of reasoning are centred on conditional statements such as rules and precautions, cause and effect relationships, and social contracts. The current and following chapters extend the work on syllogistic reasoning to consider conditional reasoning, but utilise many of the same manipulations and properties of reasoning tasks discussed previously, such as validity and believability. This allows common metrics of reasoning performance and type of processing to be utilised across the experiments reported in this chapter and the remainder of the thesis.

6.1.1 Conditional Reasoning

Thus far the work reported has focussed on investigating the impact of integral and incidental emotion on syllogistic reasoning. As discussed previously, the absence of strong findings may be due to the complexity of three-term syllogistic reasoning tasks, or their relative difficulty; which leaves little scope for detecting smaller differences in reasoning as a function of emotion. To overcome these issues, the current chapter will investigate conditional reasoning. As outlined in Section 2.3.2, conditional reasoning is primarily concerned with how people process statements such as '*If p then q*'.

Research in this area mainly focuses on four possible inferences that can be drawn in such cases (Evans & Over, 2004). The logically valid inferences are modus ponens (MP), and modus tollens (MT). Given the above rule, *if p then q*, these are equivalent to being given p, and inferring q (MP); and being given $\neg q$, and inferring $\neg p$ (MT). The two invalid inferences are denial of the antecedent (DA) and affirmation of the consequent (AC). These are equivalent to being given $\neg p$ and inferring $\neg q$; and being given q and inferring p. To use a concrete example, consider the statement "If it rains, then the road will be wet". If it has rained (p), you can validly infer that the roads will be wet (q) via MP. If the roads are not wet ($\neg q$), you can validly infer that it did not rain ($\neg p$) through modus tollens. If, however, it has not rained ($\neg p$; denying the antecedent), you cannot make any inference about whether the roads will be wet or not because the statement says nothing about the condition of the roads in the event of 'not rain'. Similarly, if the roads are wet (q, affirming the consequent), you cannot infer anything about whether it has rained or not because the statement says nothing about the state of the weather given the condition of the roads.

Past psychological research has investigated a number of variables which affect the rates at which each of these inferences are drawn, generated, or endorsed. The empirical work has also used rates of endorsement to support different theories regarding how people interpret conditional statements. For example, a range of work, concisely reviewed by Evans and Over (2004), has investigated whether conditionals in everyday speech are interpreted as truth-functional; that is, their truth value is determined entirely by their components. Other researchers have investigated what factors determine whether a conditional is read as biconditional or not; that is, whether *if p then q* is understood as *q if and only if p*, or as equivalent to *if q then p* (Evans & Over, 2004). As a final example of the scope of the research on conditionals, there is also a large body of empirical work and philosophical debate which has focused on developing our understanding of how deontic, causal, and counterfactual conditionals are processed. The current chapter will consider the extent to which individuals rate inferences as 'following' from premises as a measure of the extent to which they endorse the inference. This allows an indication of whether the endorsement rates of valid and invalid inferences alter as a function of incidental mood, which in turn can be used to consider the mechanisms through which mood may have an effect on conditional reasoning as discussed below.

6.1.2 Incidental Mood and Conditional Reasoning

Although there is a growing body of work which has investigated the effects of content type on conditional reasoning (to be discussed in this section), very little has focussed on the impact of incidental emotion. The impact of integral emotion will form the basis of the subsequent chapters, whereas the current chapter focuses on incidental emotion.

The most notable work on the relationship between incidental emotion and conditional reasoning has been conducted by Blanchette (2006), Blanchette and Richards (2004, 2010), and Blanchette and Leese (2011). Between them, these papers cover the most recent and only work specifically concerning incidental emotion and conditional reasoning. In their recent review of the literature on emotion and higher-level cognition, Blanchette and Richards (2010) discuss work related to incidental emotions which has already been reviewed (Chapters 1 and 2 and elsewhere), yet there is very limited research on the impact of incidental emotion on conditional reasoning tasks.

One example of work investigating incidental emotion in conditional reasoning is presented by Chang and Wilson (2004) who had individuals write about autobiographical events where they had either been a victim of cheating or gotten angry, or had been happy or benefitted from someone else's altruism prior to completing variants of the Wason selection task (outlined in Chapter 2). These were the 'cheater detection' and 'altruist detection' versions, where the instructions are altered such that the task is either to check if an individual has cheated the rule, or if an individual is a good candidate for a task. They found that those who had recalled being cheated performed better, that is, selected the correct cards (p and $\neg q$) more frequently, on the cheater variant than the altruism variant; although those who had recalled an altruistic act showed no benefit on the altruism detection variant. Chang and Wilson argue that the emotions generated by the writing task serve to 'facilitate situation appropriate cognition' (p267), or that emotions may serve as a source of information. This is consistent with the hypothesised information mechanisms discussed earlier in that they found better performance overall for the negative emotions (recalling episodes of cheating) than positive emotions (altruism recollection). Similar results were reported earlier by Badcock and Allen (2003) who used depressive and neutral mood inductions on similar variants of the task.

Another such example is the work of Blanchette and Richards (2004), which examined individuals' performance on a conditional reasoning task in which the terms were first substituted for ones with existing emotional connotations, and secondly in which the terms were replaced by originally neutral words that had been conditioned to elicit emotional responses. This paper raises an important point to keep in mind when reviewing previous research in that whereas their Experiment 1 is certainly investigating integral emotion, the focus of Experiment 2 is less clear. Although it could be argued that the conditioned words are part of the conditional statements, and as such the emotional element is integral, it could equally be argued that the conditioned words elicit an emotional state within the person prior to or during the reasoning process which is external to the problem itself. This second experiment thus lies somewhere between the manipulation of integral and incidental emotion. This issue was discussed in earlier chapters in relation to whether emotional content in syllogistic reasoning has its impact through the generation of mood states or whether the nature of the content directs attention, allocation of cognitive resources, or some other mechanism. However, the results can still be used to inform the current work.

Replicating the work of Blanchette and Richards (2004), Blanchette (2006) found that in both cases, with existing and conditioned positive and negative emotional content, people made fewer normatively logical responses, in contrast to the findings of Chang and Wilson (2004) and Badcock and Allen (2003). In relation to how these effects might be generated, Blanchette argues that individuals do not interpret the emotive and neutral conditionals differently, based on similar ratings of necessity, sufficiency, plausibility, and causality across conditions, suggesting that emotional content does not have its effect by altering interpretation, and thus emotion must alter responses by another means. In relation to the expected impact of positive and negative incidental emotion on conditional reasoning, from these results, it might be expected that normative responding would be supressed by both positive and negatively valenced content, and furthermore, as emotion effects are not driven by changes in interpretation, similar effects might be expected with incidental emotion. Blanchette, in her discussion, reports that the reduction in logical responding in the emotive and conditioned materials is similar to effects of incidental mood found elsewhere in the literature (e.g. Oaksford et al., 1996; and literature reviewed earlier). The current work will therefore either replicate the findings with incidental emotion, as opposed to conditioned integral content, or provide evidence to support differential effects of incidental and integral emotion; for example, the work discussed by Blanchette and Richards (2010) which has found incidental emotion to impair logical accuracy across a range of tasks versus the work which has found certain types of integral emotion can improve logical accuracy (e.g. Blanchette & Campbell, 2005).

Following the 2010 review by Blanchette and Richards which concludes more work is needed which compares the effects of integral and incidental emotion, Blanchette and Leese (2011) report a series of experiments which investigated conditional reasoning with emotive content, though with a focus on the physiological relationship between skin-conductance and logical responding. Although using the same conditioning paradigm as earlier work to imbue formerly neutral words with a negative valence, the inclusion in these studies of skin-conductance responses suggests that integral manipulations are likely to create emotions which are to some extent comparable to those induced by manipulations of incidental emotion. Blanchette and Leese report a negative relationship between emotionally driven physiological arousal and logical responding, replicating the earlier findings with skin-conductance measures, and supporting the hypothesised reduction in normative responses under negative mood states.

One important omission from the Blanchette and Leese studies though is a positive emotion condition. The necessity of comparing positive and negative conditions in order to capture any differential impact has been outlined previously, and the current work builds on that of Blanchette and colleagues by extending the investigation not only to explicitly incidental emotion, but also to investigate positive, negative, and control conditions. This is especially important given the contradictory findings of those studies which show that mood should supress logical accuracy, and those which suggest it facilitates it.

6.1.3 Personality Variables: Meta-Mood and Open-Minded Thinking

Previously, the Trait Meta-Mood Scale (TMMS) was incorporated to evaluate the extent to which Attention, Clarity, and Repair are related to the effects of emotional content in syllogistic reasoning. In the current study, two other variables are considered which have been linked to variation in reasoning patterns. These are actively open-minded thinking, and the behavioural approach-inhibition scales. It has been suggested that actively open-minded thinking can improve critical thinking (Baron, 1991; Butchart et al., 2009). Actively open-minded thinking (AOMT) is typically defined as the ability to approach a problem aware of, and actively avoiding, biases such as my-side and confirmation bias (Baron, 1991). Interestingly, AOMT and the avoidance of biases such as belief- and my-side-bias appear to be independent of cognitive ability (Macpherson & Stanovich, 2007; Stanovich & West, 2007). In their work using a teaching syllabus which encouraged AOMT, Butchart et al. (2009) focused on strategies such as looking for alternative explanations and searching for counter-evidence. These are the types of strategies implicitly implied by mental-models theories of reasoning. Similarly, a large amount of work on conditional reasoning focuses on the search for counter-examples, or alternative states of the world in the form of counterfactuals, as well as enabling and disabling conditions (e.g. Cummins et al., 1991). As such, the AOMT scale will be included in the current experiments.

The Behavioural Inhibition Scale - Behavioural Activation Scale (BIS-BAS) also provides a measure of traits which might be expected to influence an individual’s ability or willingness to seek alternative explanations, and in particular, determine how they engage with reasoning tasks when in an emotional state (Carver & White, 1994). The BIS-BAS comprises four subscales. Three of these, related to behavioural activation, are Drive, Fun Seeking, and Reward Responsiveness. The fourth is a single subscale measuring Behavioural Inhibition. Drive is related to an individual’s willingness to engage with and succeed in an activity and is related to perseverance. Fun Seeking is the extent to which an individual attempts to engage in enjoyable activities, and Reward Responsiveness is a measure of the degree to which an individual’s behaviour is influenced by potential gains. Together they provide an overview of an individual’s responsiveness to positive outcomes. Finally, Behavioural Inhibition provides a measure of the extent to which an individual avoids outcomes which are undesirable or aversive (Carver & White, 1994).

Given the many factors discussed in relation to emotion regulation throughout the psychological literature, it is interesting to investigate the BIS-BAS factors in particular given their relation to action potentials. Rather than variables such as whether an individual is oriented to emotion or problem-focused coping, the subscales of the BIS-BAS are more directly related to whether an individual might continue to search for counter examples, or abandon the enterprise given its perceived lack of reward for example. Marrero and colleagues (2008) provide evidence that BIS scores are positively related to strategies on the Wason selection task which are akin to adopting a falisificationist approach, whereas BAS scores are positively related to a tendency to seek affirmation of the rule. Similarly to the potential explanatory function of the AOMT measure, the BIS-BAS will be included in order to investigate these findings in relation to emotions, and as very little work has investigated the BIS-BAS in relation to reasoning (Marrero et al., 2008).

Selecting the *p* and *q* cards in the Wason selection task is a confirmatory response. In the current study, endorsing AC inferences at high levels, where *p* and *q* are presented as major premises, can be considered similar to the affirmation responses outlined by Marrero and colleagues (2008). Selecting the *p* and ¬*q* cards in the Wason selection task however is seen as the ideal falsification strategy. In the current study, this can be equated with high rates of endorsement for MP and MT inferences. Given that both strategies have selection of the *p* card in common, focussing on MT alone provides the clearest indication of a falsification strategy. Although the current study is not set up primarily to attempt a replication of Marrero and colleagues' findings, if BIS and BAS are predictive of MT (falsification strategies) in the current task, and the differences are moderated by mood states, this will provide some clue as to the factors determining reasoning which are affected by emotions.

In order to create a design which is directly comparable to the validity by believability design utilised with syllogistic reasoning in the preceding chapters, not only will the validity of the inferences be varied (MP and MT being valid, DA and AC being invalid), but the believability of the conditional statements will be varied between high and low. Previous work has suggested that participants in experimental studies treat conditional statements as graded beliefs rather than assuming them to be true without exception, even despite instructions to 'assume the statement and premises as true' (Evans & Over, 2004; Over & Evans, 2003; Over, Hadjichristidis, Evans, Handley, & Sloman, 2007). In addition, asking participants to assign probabilities to each inference provides more detailed information on the effects of validity and believability (Evans, Handley, Neilens, & Over, 2009). Previous work has found that inferences are more likely to be drawn when the conditional is believable (Evans, 2007a), in much the same way that syllogism conclusions are more likely to be endorsed when they are believable than when they are unbelievable. The inclusion of believability in an experimental design with conditional statements therefore provides clear grounds for comparison of validity, believability, and emotion effects across these two types of reasoning. Furthermore, in relation to conditional reasoning tasks in which validity and believability are varied, dual-process accounts would argue that initial, heuristic responses will be based on the believability of the conclusions, whereas a careful consideration of alternatives would be considered analytic responding. A corollary of this is that individuals higher in AOMT ability would be expected to search for such alternatives, and exhibit higher levels of logical responding.

It will therefore be interesting to investigate to what extent these individual dispositions and thinking styles interact with emotion and reasoning. If it is found that incidental emotion alters reasoning, but that this is mediated by approach, avoidance, or fun-seeking for example, future work might develop experimental designs to investigate how these factors alter reasoning which in turn will inform us about the factors which determine how and when emotions alter reasoning. However, it is first necessary to investigate the impact of incidental emotion on reasoning before speculating on potential mediators. The aims within this chapter are therefore to investigate whether conditional reasoning is affected by incidental emotion, and if so, in what way. This extends the work previously reported on the effects of emotional states and emotive content in syllogistic reasoning, with the aim of investigating the extent to which emotion effects are found in conditional reasoning. This allows not only a controlled comparison of incidental emotion effects across reasoning tasks, but also develops earlier work on conditional reasoning by including incidental emotion as a factor.

Based on the predictions of load and information theories, if emotions serve as load then logical performance would be suppressed, relative to control, by both positive and negative incidental emotions. Alternatively, if emotion serves as information, logical performance would be suppressed by positive, but improved by negative incidental emotion; again, relative to control. In addition, because the believability of the statements is manipulated alongside validity in the design, logic and belief indices can be compared across the experiments. In order to accommodate the finding that inferences are treated as graded beliefs participants will be required to indicate to what extent they think an inference follows rather than indicating categorically whether they think it follows, does not follow, or is indeterminate. Based on the research discussed above and in earlier chapters, valid inferences would be expected to be rated as more likely to follow than invalid ones, and inferences based on believable conditionals are expected to be rated as more likely to follow than inferences based on unbelievable conditionals. Whether the effects are similar to or different from those found with syllogistic reasoning will allow us to draw conclusions about the impact of emotion on different reasoning tasks.

6.2 Method

6.2.1 Participants

Participants in the current study were 79 undergraduate psychology students (14 male, 65 female) at Plymouth University aged between 18 and 43 years (*M* = 21 years, *SD* = 4 years). All participated for course credit.

6.2.2 Materials

Conditional Statements

The conditional statements used in the current study were taken from previous work by Evans, Handley, Neilens and Over (2009). From these, four conditional statements were selected. Two statements were highly believable, and two had lower believability ratings, creating high and low believability conditionals. Each of these four statements was presented followed by major and minor premises in rotation such that MP, MT, DA and AC inferences were evaluated for each statement. This generates a total of 16 items to be completed by each participant. An example item is presented below (High Believability, MP example):

> Supposing the following:
>
> **If car ownership increases, then congestion will get worse**
> and
> **Car ownership increases**
>
> To what extent does it follow that:
> **Congestion will get worse**

For each of the sixteen premises, participants were asked to rate 'to what extent does it follow that [conclusion]?'. These responses were made on scales ranging from 0 (it definitely does not follow) to 100 (it definitely does follow). The premise-conclusion pairs that were presented following each conditional statement are shown in Table 6.1.

Statements were matched for length, with differences in believability being assessed based on previous work by Evans et al (2009). Presentation order randomised believability and inference types. Conditional statements, along with reasoning task instructions, can be found in Appendix D. Overall, these procedures create eight types of conditional conclusion. These are those which are highly believable and logically valid, as in MP and MT inferences (HMP and HMT); those which are highly believable but not logically valid, as in DA and AC inferences (HDA and HAC); those which are unbelievable but logically valid (LMP and LMT), and finally, those which are unbelievable and not logically valid (LDA and LAC). When referring to problem categories, the first letter denotes the level of believability, high and low; the final two the inference type.

Table 6.1 Premise-Conclusion Pairs presented following the conditional statements

Inference	Premise	Conclusion	Responses
MP	p	q?	0-100
MT	¬q	p?	0-100
DA	¬p	q?	0-100
AC	q	p?	0-100

Mood Manipulation

The mood manipulation in this study was the same as in Experiment 1. For details, see Chapter 3. This manipulation task was completed prior to the reasoning items. Mood was measured using an analogue scale anchored at *Very Happy* and *Very Sad*. Responses were indicated by marking a cross on a line between these two anchor points. On the printed page, the line was 125mm in length. Scores have been standardised to range from 0 (*Very Sad*) to 100 (*Very Happy*), and the reported analyses are based on these standardised scores. This rating of mood was completed after the reasoning task in order to eliminate any cues to the purpose of the mood manipulation or the hypotheses of the study.

Measures of Reliance on Beliefs and Logic

In the same way that validity and believability can be rotated when using syllogistic reasoning tasks, the validity and believability of inferences can be rotated in conditional reasoning. Because the materials include inferences which vary in their logical validity, as well as comprising believable and unbelievable items, the logic and belief indices outlined earlier can be adapted for the current study by substituting the VB, VU, IB and IU terms as follows, where the H and L prefixes indicate high- and low-believability inferences respectively;

Logic Index =
$((HMP+HMT)_{end}+(LMP+LMT)_{end})-((HDA+HAC)_{end}+(LDA+LAC)_{end})$

Belief Index =
$((HMP+HMT)_{end}+(HDA+HAC)_{end})-((LMP+LMT)_{end}+(LDA+LAC)_{end})$

Interaction Index =
$((HDA+HAC)_{end}+(LDA+LAC)_{end})-((HMP+HMT)_{end}+(LMP+LMT)_{end})$

These thus provide a metric that is consistent throughout studies in this thesis which cross validity and believability for the purpose of assessing the similarities and differences in reliance on logic and belief across emotional materials and mood states.

Approach-Avoidance and Actively Open-Minded Thinking Scales

AOMT was assessed using the scale presented by Stanovich (2000), as used by Stanovich and West (2007). The scale consists of 41 items which are responded to using a six-point Likert scale anchored at *Strongly Disagree* and *Strongly Agree*.

Approach and avoidance were measured using the BIS-BAS developed by Carver and White (1994), which is a 24 item scale that provides measures of Inhibition, Drive, Fun-Seeking, and Reward Responsiveness. Each item is responded to on a four point Likert scale anchored at *Very True for Me* and *Very False for Me*. All items and subscale compositions can be found in Appendix D. Scores for each scale in total, and subscales of the BIS-BAS were summed and converted to percentages in order to facilitate comparisons within and across studies. Analyses reported in this chapter are based on these percentage scores.

6.2.3 Procedure

After being briefed and signing a consent form, individuals were provided with a booklet of reasoning problems and a response booklet. The response booklet contained instructions for the mood manipulation task along with space to write about their chosen life event, followed by instructions for the reasoning task along with a page of numbered boxes for recording their responses to each item. These pages were then followed by the mood rating task, the items of the AOMT and BIS-BAS scales along with the relevant response scales. Upon completion of these tasks, participants were debriefed, thanked for their time and allowed to leave.

6.3 Results

6.3.1 Mood Manipulation

A univariate ANOVA of standardised mood ratings revealed no main effect of mood condition, [F (2,76) = 1.06, p = .35, η_p^2 = .03]. However, the differences are in the direction expected, with individuals in the happy condition (M = 65.06, SD = 23.31) reporting more positive moods than those in the control condition (M = 59.64, SD = 22.45, .d = .24), and those in the control condition reporting more positive moods than those in the negative condition (M = 56.94, SD = 19.50, d = .13); the different between positive and negative mood having an effect size of d = .38.

One possible explanation for these reduced emotion effects relative to previous use of this manipulation (Chapter 3) may be the position of the rating task after the reasoning task. Previous work has found that mood normalises over the duration of reasoning tasks similar to those used here (Zahra, 2008 unpublished). Whether this is due to the task, or a natural change over time, the ratings reported here are recorded as this normalisation occurs, and mood ratings begin to converge on pre-manipulation levels. As such, although the mood condition mood ratings differences do not reach statistical significance at this stage of the experiment, that small to medium effect sizes are still found is encouraging, and justifies to some extent the comparison of positive and negative moods, even if not lending strong justification to comparisons involving the control group.

6.3.2 Reasoning

An initial 3 Mood (Positive, Control, Negative) x 2 Believability (High, Low) x 4 Inference Type (MP, MT, DA, AC) ANOVA on mean rates of 'following' (which can be thought of as endorsement rates; see Table 6.2) shows a main effect of believability [F (1,76) = 4.33, p = .04, η_p^2 = .05], and of inference type [F (3,228) = 173.19, p < .001, η_p^2 = .70], as well as an interaction between the two [F (3,228) = 9.23, p < .001, η_p^2 = .11]. Mood condition showed a marginal main effect on 'following' ratings [F (1,76) = 1869.12, p = .07, η_p^2 = .07], but did not interact with believability or inference type, nor was there a three-way interaction.

Post-hoc comparisons of these differences between mood conditions reveal that control mood (M = 48.25, SD = 2.05) leads to higher rates of endorsement than positive mood (M = 45.84, SD = 1.65), and positive mood to higher rates of endorsement than negative mood (M = 42.15, SD = 1.73). The only difference which reached statistical significance was that between negative and control moods (p =

.026, *d* = 3.22). Thus it would appear that positive and control moods lead to similar endorsement rates, whereas negative mood reduces the ratings of following. This is interesting given the small effect sizes revealed in the mood ratings, but supports the assumption that differences in mood rating between conditions were larger after the manipulation but before the reasoning task.

Table 6.2 Mean 'Following' ratings (%) including standard deviations for inference types by believability and mood condition

Inference		High Believability			Low Believability		
		Positive	Control	Negative	Positive	Control	Negative
MP	M	94.16	92.60	94.79	80.13	76.28	70.89
	SD	*10.50*	*8.54*	*10.79*	*27.82*	*31.31*	*32.47*
MT	M	14.40	23.63	16.64	17.35	24.60	15.20
	SD	*15.22*	*20.32*	*24.07*	*19.27*	*24.48*	*22.21*
DA	M	22.90	24.13	26.43	22.23	19.88	17.80
	SD	*24.82*	*23.07*	*24.31*	*26.12*	*24.76*	*26.55*
AC	M	53.81	62.98	40.79	61.74	61.93	54.64
	SD	*32.48*	*26.42*	*34.42*	*28.46*	*28.29*	*35.53*

In relation to believability, highly believable (*M* = 47.27, *SD* = 1.30) conditionals were rated significantly more likely to follow than unbelievable ones (*M* = 43.56, *SD* = 1.46, *p* = .041, *d* = 2.68). Although this is an absolute difference of only a few percentage points, there is little variability within each condition, indicating the difference is relatively consistent.

Across inference types, it appears MP inferences are rated as much more likely to follow (*M* = 84.81, *SD* = 1.98) than MT (*M* = 18.64, *SD* = 2.02), DA (*M* = 22.23, *SD* = 2.41) or AC (*M* = 55.98, *SD* = 2.72) inferences. All pairwise post-hoc comparisons were significant at $p < .001$ with the exception of the difference between MT and DA which was non-significant. The interaction between belief and inference type is depicted in Figure 6.1; MT and DA inferences are rated as less likely to follow than MP and AC inferences, and although high-believability items are seen as more likely to follow for MP inferences, this pattern is less pronounced across other inference types, clearly reversing with AC inferences, though not significantly so.

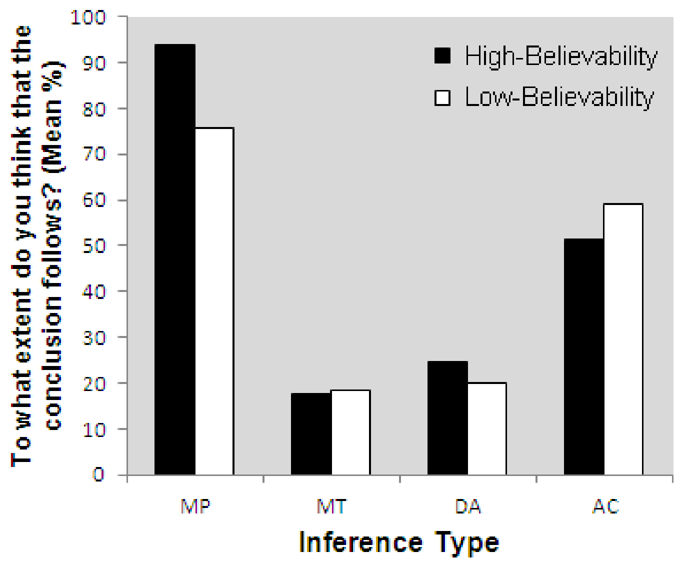


Figure 6.1 Ratings of 'Following' by Believability and Inference Type

Considering differences between mood conditions across inference types and believability conditions, although the overall interaction was not statistically significant, it is interesting that the largest differences on average are found on the problems which typically show the lowest logical performance, MT and AC; this can be seen in Figure 6.2.

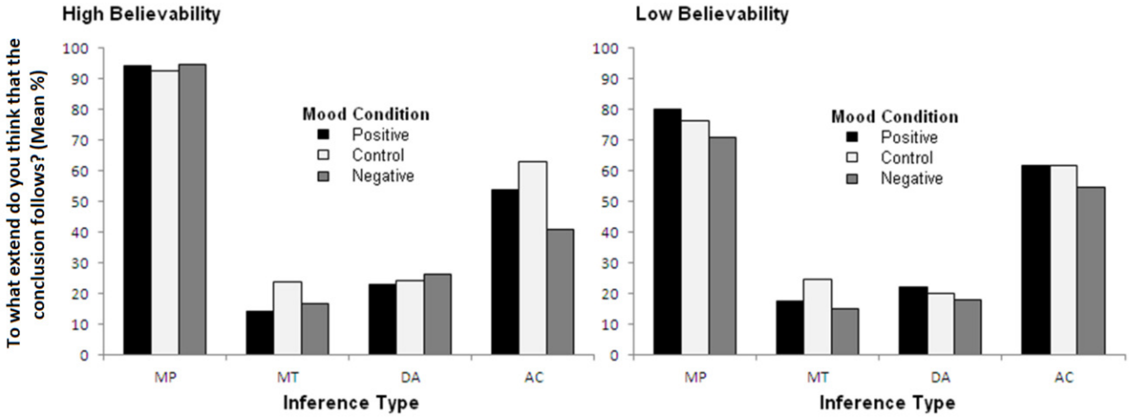


Figure 6.2 Ratings of Following by Mood, Believability, and Inference Type

Univariate analyses showed no significant differences in endorsement rates between mood conditions within each inference type, with the exception of highly believable AC inferences. In this cell, the main effect of mood approaches statistical significance [F(2,76)=, p = .057, η_p^2 = .073], and pairwise comparisons showed the difference in endorsement rates between control and negative conditions to be statistically significant (p = .002).

The differences in index scores across mood conditions are shown in Figure 6.3. Broadly speaking, logic and belief indices increase across positive, control and negative mood conditions. This replicates the patterns found in Experiments 3 and 4. However, none of the pair-wise comparisons between emotion conditions reach statistical significance.

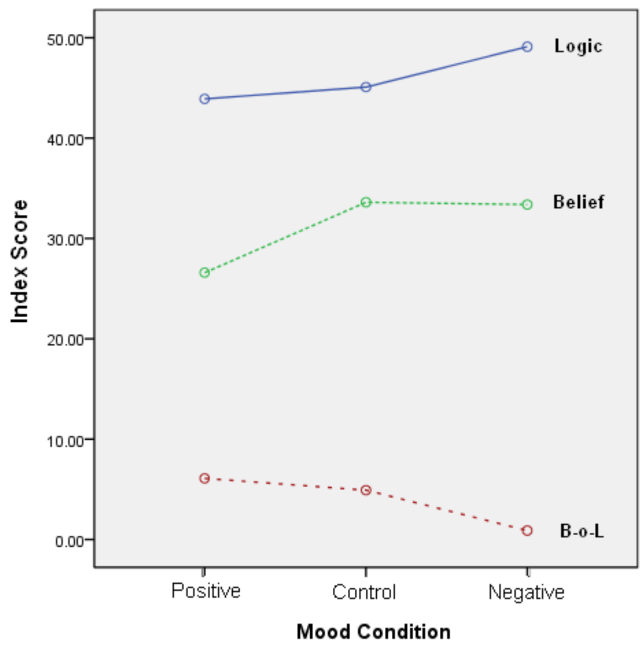


Figure 6.3 Index scores by Mood Condition

6.3.3 AOMT and BIS-BAS Analyses

AOMT showed no relationship with any of the BIS-BAS subscales. All Pearson's correlation coefficients were found to be smaller than r = .15 with p > .18. The relationships between AOMT and each of the index scores were similarly small (all at r < .16 and p > .15). No relationships were found between the rates at which any inference was thought to follow and AOMT scores.

The relationships between the BIS-BAS subscales and index scores were also small. Only reliance on belief appeared to be related, showing significant or marginally significant negative relationships with reward responsiveness [r (79) = -.20, p = .08], fun seeking, [r (79) = -.28, p = .01], and inhibition [r (79) = -.22, p = .06]. This suggests that the more reward-driven, more fun-seeking, and more inhibited an individual is, the less they rely on beliefs when reasoning. These patterns are similar across mood conditions.

6.4 Discussion

The current data would seem to suggest that incidental mood has very little effect on conditional reasoning. Although the differences in mood rating were small between the conditions the lower endorsement of AC-believable conditionals under negative mood relative to control, and small main effects of mood overall on endorsement rates may suggest that the manipulation was effective initially, but that mood normalised during the course of the reasoning task. The lack of any findings in relation to emotion is unlikely to be explained by any unusual properties of the materials as large effects of inference type and believability were found, which replicate previous findings in the literature and shows that individuals can distinguish between the different problem types. Furthermore, the same conditionals were given to participants in each condition.

The lack of relationship between AOMT and the reasoning measures is interesting in that it appears to contradict a growing body of literature that suggests higher AOMT scores should result in more critical evaluation of problems (Butchart et al., 2009) such as conditional arguments. Furthermore, it fails to replicate findings from work which suggests that although thinking dispositions similar to AOMT do not directly predict increased logical performance, they do predict a reduced reliance on belief-based responses (Macpherson & Stanovich, 2007). One reason for this may be that the sample was drawn from a student population. It might be expected that this population are largely very similar in their tendency to engage in AOMT, and that the measure lacks the sensitivity to assess small variations in AOMT. Another explanation may be that the literature the hypotheses were based on has investigated syllogistic reasoning (Macpherson & Stanovich, 2007), and although belief-based reasoning was measured in the same way across tasks (this chapter's investigation of conditional reasoning and previous experiments on syllogistic reasoning), the way that beliefs and emotions are incorporated may differ between the tasks; for example, in easier tasks, more individuals may be capable of applying logical rules, and thus rely less on non-logical features such as believability. The argument could be made that the crossing of believability and validity in the current design is not entirely analogous to that in the traditional syllogistic belief-bias paradigm. One potential issue is that the levels of the belief factor discussed here are based on the believability of the conditional statement; high and low $P(q|p)$, which may not map directly on to the believability of the conclusion. This may explain the relatively small, though statistically significant, effect of believability and the less clear pattern of believability effects across each inference type. However, that believable conditionals are rated as more likely to follow than unbelievable ones is in line with previous work.

Future work which may develop the use of logic and belief indices should be careful to ensure that the believability of the conditional rule also reflects the believability of the inferences being evaluated. Although a conditional rule may be rated as believable (or unbelievable) in pre-testing, the inferences may not have the same level of believability. For example, although the conditional statement 'If Sony releases a new console, then their profits will rise' is believable, the believability of the inference 'Sony release a new console' given that their profits did not rise (MT) is less clear. As such, discussion of the effect of believability in this chapter should be understood as the believability of the conditional, and not the premises or conclusions; and the results relate to the presentation pairs shown in Table 6.1.

The relationships found between the BIS-BAS subscale scores and endorsement rates suggest some association between reward responsiveness, fun-seeking, and inhibition and reliance on beliefs. This supports earlier work which has shown the subscales are related to reasoning strategies similar in nature to falsification (Marrero et al., 2008). However, in relation to testing the relationship between BIS sensitivity and MT endorsement as a proxy of a falsification strategy, no relationship was found. Though the effects of the mood manipulation were small, this may be taken to suggest that the constructs measured by the BIS-BAS do not mediate the effects of emotion on reasoning. Furthermore, as with the necessity-possibility paradigm where the effects of syllogism type were much larger than those of incidental or integral emotion, in conditional reasoning it would appear that the effects of inference type are much greater than the effects of incidental mood.

In summary, very few effects of incidental emotion were found in conditional reasoning. The mood manipulation was marginally effective, though the difference between conditions did not reach statistical significance. As the mood manipulation was found to be effective in other studies in the literature, and in Experiment 1, the effects may have been masked by the position of the mood rating in the current design, which is plausible given previous findings that mood normalises over the duration of the reasoning task.

It is interesting that mood effects seem to be larger when the reasoning tasks are more difficult; as indicated by the larger differences in ratings between positive, control and negative conditions on AC inferences. This may be indicative of emotion having a larger impact on the consideration of alternative causes, as AC inferences have been shown to be affected by this variable (e.g. Cummins et al., 1991), but unfortunately the differences between mood conditions did not reach statistical significance, so no strong conclusions can be drawn. The one exception to this was negative emotion leading people to rate AC inferences as less likely to follow relative to the control group. In addition, mood condition and inference type showed no significant interaction effect which would have supported the suggestion that mood effects are more pronounced on the more difficult problems; difficult in the sense that they are typically responded to with lower rates of logical accuracy. In order to investigate the impact of emotion on conditional reasoning further, and overcome the limited effectiveness of the incidental mood manipulation, Chapter 7 will investigate conditional reasoning with integral emotion. This builds on the current experiment by focusing on emotive content, and allows a comparison of incidental and integral emotion effects in conditional reasoning. Furthermore, a comparison of integral effects in conditional reasoning can be made with the integral effects in syllogistic reasoning reported in Experiments 2, 3, and 4.

Chapter Seven

Conditionals, Emotive Content, and Emotional Images

7.1 Introduction

Chapter 6 found that it was only ratings of how likely AC inferences were to follow that were affected by incidental negative emotion, such that negative emotion reduced how likely people thought it was that the inference followed. Very few other effects were found with incidental emotion, and the current chapter aims to investigate the impact of integral emotion on conditional reasoning. In the existing literature there is relatively little work on the effects of emotive content on conditional reasoning, as we have seen in Chapter 2. Almost all of the work published in this area has been conducted by Blanchette and colleagues (Blanchette, 2006; Blanchette & Leese, 2011; Blanchette & Richards, 2004), whose work has been detailed previously. The most common finding is that emotive content of any type reduces logical accuracy. In the case of Blanchette and Richards (2004), this is seen with happy, sad, and anxiety related content relative to neutral content. In the two studies reported in their paper however, they comment that their work says little about what might cause the effects they report and no mention is made of controlling for the believability of the conditional statements. This is particularly important as believability has been shown repeatedly to affect the inferences which are drawn or endorsed in conditional reasoning tasks, such that believable inferences are endorsed more frequently than unbelievable ones (e.g. Evans et al., 1983;

Morsanyi & Handley, 2011). Emotions, if they serve as load, may impact conditional reasoning through believability. It is therefore important to consider believability when investigating the impact of integral emotion on conditional reasoning.

The experiments reported in this chapter build on the work of Blanchette and colleagues by including believability as a factor in the design of the conditional statements, which allows investigation of the impact of believability as well as logical validity, in the same way as in Experiment 5. This also allows a comparison of load and information theories of emotion, and provides a way to link the current work to previous studies on content effects within a dual-process framework, particularly the work on syllogisms discussed previously (Chapter 5). This is important as although dual-process theorists working in reasoning have not considered emotive content specifically, it provides a framework for assessing and explaining effects of belief and logic in light of any effects of integral emotion.

A large body of work has considered content and context effects in conditional reasoning, though only a few investigate emotional content. For example, the work by Perham and Oaksford (2005) who compare the evolutionary and decision-theoretic models of decision making when the conditional rules are presented as social contracts or as relating to hazards, and the work of Chang and Wilson (2004) outlined earlier which has shown that when the content of a conditional statement relates to a concrete or familiar social situation, logical performance is improved. Whereas the work of researchers such as Chang and Wilson (2004) suggests content serves as a cue to which approaches to adopt in conditional reasoning tasks, although emotions may have a similar effect and be beneficial when appropriate to the context of the conditional rule, they would not provide any benefit when they are incompatible with or inappropriate to the situation.

Whilst this work is interesting in understanding the effect of specific contextual variables on the impact of emotions in conditional reasoning, it is primarily descriptive in its focus and not concerned with why or how emotion and reasoning interact to generate these effects. In the following experiments, as in relation to the emotion-based work of Blanchette and colleagues, by including believability as a variable, this factor can be controlled for, and its impact assessed alongside validity, as outlined above. This provides a way of learning something about how emotion might impact on reasoning, as discussed in earlier chapters, by contrasting load and information based theories. Although no explanatory models of how emotive content interacts with conditional reasoning have been assessed in detail, models have been developed to explain effects found with other content types, although not explicitly with respect to emotive content. As one example, if logical accuracy is suppressed by both positive and negative content relative to control, then this would provide support for load theories. Alternatively, if logical accuracy is suppressed by positive but facilitated by negative emotive content relative to control, this pattern would provide support for the information theories; the reasoning behind these predictions has been discussed previously (e.g. Chapter 1).

In summary, the preceding studies in this thesis have considered integral and incidental emotion in syllogistic reasoning using a variety of paradigms; some investigating the level of high-effort processing, others comparing the use of high and low effort processing. The effects of incidental emotion were then investigated in conditional reasoning, and the current chapter considers the effects of integral emotion in conditional reasoning by adopting the same design as has been used in earlier chapters which varies believability, validity, and emotion. Based on the previous findings, it would be expected that more valid inferences will be endorsed than invalid ones and that believable conditionals will also lead to higher rates of endorsement. In relation to the effects of integral positive and negative emotion compared to control items, if integral emotion has the same effect as incidental emotion, negative content might be expected to improve logical accuracy (lower endorsement rates), but only on believable AC inferences. The directional hypotheses outlined above in relation to load and information theories are the primary interest of the current experiments, and as such, rather than focussing on the rates at which each inference is endorsed, in line with previous work, analyses in this chapter will be concerned with rates of logical accuracy.

7.2 Conditionals with Emotive Content: Within (Experiment 6)

The first experiment reported here utilises the paradigm of Blanchette and Richards (2004), but using conditionals that vary in their believability as well as content valence. This is in addition to the conclusion validity being varied.

7.2.1 Method and Materials

Participants

The sample comprised 42 (36 females) students at Plymouth University, participating voluntarily or for course credit. The sample had a mean age of 21 years (*SD* = 3 years).

Conditional Statements and Design

A set of 48 conditional reasoning problems were constructed, 16 containing positively valenced terms, 16 containing negatively valenced terms, and 16 containing control terms. Statement believability was also varied between high and low based on previous work and pre-test data (Evans, Handley, Neilens, et al., 2009). MP, MT, DA and AC inferences were presented across all content types, generating a 3 Content type (Positive, Control, Negative) x 2 Believability (High, Low) x 4 Inference Type (MP, MT, DA, AC) experimental design. Examples of positive, negative, and control items are shown below; a full list of items can be found in Appendix D.

High Believability Positive Item

If you pass all of your exams then you will graduate

MP You pass all of your exams. Do you graduate?
MT You do not graduate. Did you pass all of your exams?
DA You do not pass all of your exams. Do you graduate?
AC You graduate. Did you pass all of your exams?

High Believability Control Item

If Sony releases a new console, then their profits will rise.

MP Sony releases a new console. Do their profits increase?
MT Their profits do not rise. Did Sony release a new console?
DA Sony do not release a new console. Do their profits increase?
AC Their profits rise. Did Sony release a new console?

Low Believability Negative Item

If you start a fight then you will get stabbed to death

MP You start a fight. Do you get stabbed to death?
MT You do not get stabbed to death. Did you start a fight?
DA You do not start a fight. Do you get stabbed to death?
AC You get stabbed to death. Did you start a fight?

Participants were required to indicate whether each inference followed ('Yes'), did not follow ('No'), or was indeterminate ('Maybe'), in line with the procedure used by Blanchette and Richards (2004). This is different to the 0-100% likelihood of the conclusion 'following' which was used in Experiment 5, in order to force a response which could be coded as logically accurate or not. Responses in the current experiment were therefore scored for the number of logically correct responses to each inference type across believability and content types. This presentation and response format is taken from Blanchette and Richards' (2004) experiment one. The combinations of premises and conclusions are shown in Table 7.1. They are 'non-standard pairings', relative to the typical combinations found in the reasoning research which has not considered emotional content, but have been used here to allow a conceptual replication of earlier work. Alternative presentations of premise-conclusion pairings which are more consistent with the wider reasoning literature, and how they differ from the emotional literature, are considered in the following chapter.

Table 7.1 Non-standard Premise-Conclusion pairs taken from Blanchette and Richards (2004)

Inference	**Premise**	**Conclusion***	**Responses**
MP	P	q?	Y/N/Maybe
MT	¬q	p? (¬p?)	Y/N/Maybe
DA	¬p	q? (¬q?)	Y/N/Maybe
AC	q	p?	Y/N/Maybe

*Where the conclusion is not that which would be typically presented in a reasoning study, the 'standard' conclusion is shown in parentheses. These are discussed in more detail in Chapter 8

Approach-Avoidance Measures

In addition to the conditional reasoning task, participants were asked to complete the BIS-BAS scale in order to provide a measure of approach-avoidance behaviours. The items of this scale can be found in Appendix D, and have been discussed previously (Section 6.1.3).

7.2.2 Results

Reasoning Accuracy

The means and standard deviations for each cell within a 3 Content (Positive, Control, Negative) x 2 Believability (Believable, Unbelievable) x 4 Inference Type (MP, MT, AC, DA) repeated measures ANOVA can be seen in Table 7.2. This analysis showed significant main effects for content type [$F(2,82) = 10.57$, $p < .001$, $\eta_p^2 = .21$], believability [$F(1,41) = 7.30$, $p = .010$ $\eta_p^2 = .15$], and problem type [$F(3,123) = 134.10$, $p < .001$ $\eta_p^2 = .77$].

Table 7.2 Descriptive Statistics for participants' reasoning accuracy (mean %) on conditionals with emotive content (Content varied Within-participants)

			Inference Type			
Content	**Believability**		**MP**	**MT**	**DA**	**AC**
Positive	High	*M*	89.29	76.19	10.71	14.29
		SD	20.76	31.70	23.52	25.39
	Low	*M*	86.90	83.33	19.05	25.00
		SD	24.84	30.58	33.04	37.04
Control	High	*M*	92.86	86.90	22.62	26.19
		SD	17.71	29.34	35.27	35.33
	Low	*M*	88.10	67.86	14.29	17.86
		SD	28.82	37.97	29.81	32.80
Negative	High	*M*	88.10	85.71	44.05	27.38
		SD	24.22	25.39	33.50	35.27
	Low	*M*	84.52	85.71	15.48	28.57
		SD	32.17	29.81	32.17	38.48

Across content type, positive items were responded to less accurately than control items, though this difference did not reach statistical significance. Control items were responded to significantly less accurately than negative items (p=.003), and positive items were responded to significantly less accurately than negative items (p<.001). These patterns suggest that positive content has no effect on logical performance whereas negative content increases logical accuracy relative to control content.

Logical accuracy was also higher for high-believability (M = 55.36, SD = 28.12) than low-believability conditionals (M = 51.39, SD = 32.29).

Participants responded more accurately on MP and MT inferences than DA and AC inferences. In addition, overall accuracy was higher for MP than for MT (p=.002), DA (p<.001), or AC (p<.001) inferences, and higher for MT than DA (p<.001), or AC (p<.001). There was no difference in accuracy between DA and AC inferences. There was also a significant interaction between content type and believability, [$F(3,123) = 13.42$, $p < .001$ $\eta_p^2 = .25$], shown in Figure 7.1. This indicates that for high-believability items, positive content lead to lower accuracy rates than control or negative content, though control and negative content showed only a marginal difference in accuracy rates (p = .07); when the items were low-believability however, positive and negative content showed little difference in accuracy rates, yet both resulted in higher accuracy rates than control content.

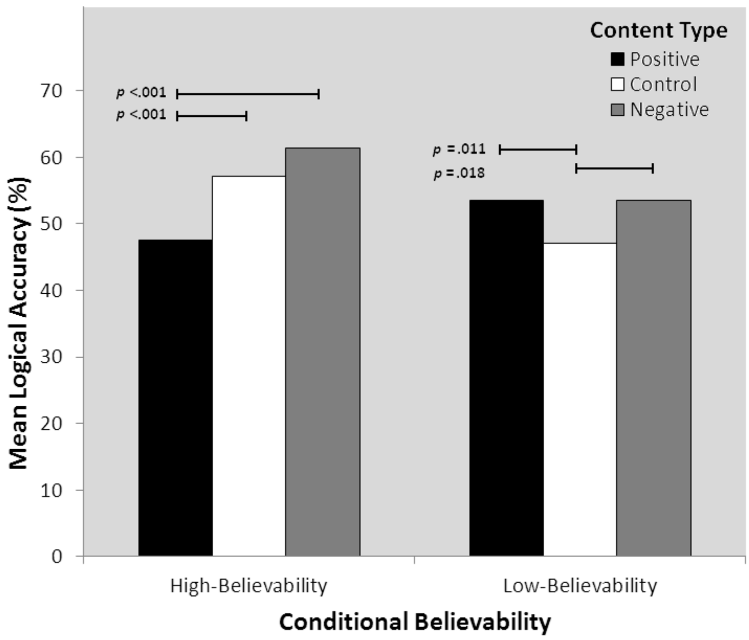


Figure 7.1 Belieavbility by Content type Interaction based on Accuracy

The interaction between content type and inference type was only marginally significant [$F(6,246) = 1.97$, $p = .07$], but is shown in Figure 7.2 for comparison with the following experiments.

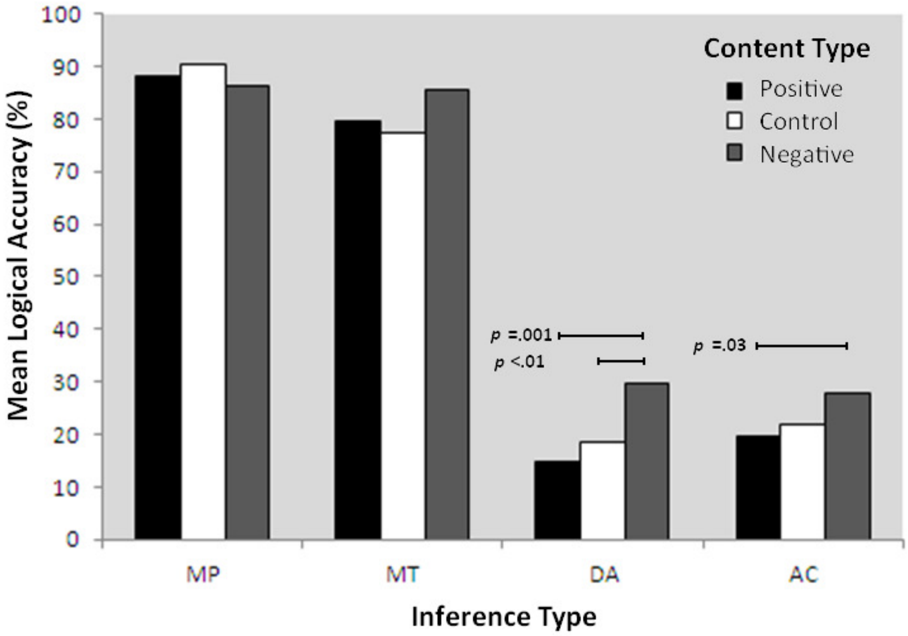


Figure 7.2 Inference type by content type interactions based on accuracy

Finally, a significant three-way interaction was found between content type, believability and problem type, [$F(6,246) = 4.23$, $p < .001$, $\eta_p^2 = .09$]. This is depicted in Figure 7.3. With highly believable content, there seems to be some suggestion that negative content improves reasoning accuracy whereas positive content decreases reasoning accuracy relative to control content. This is generally in line with the information theories of emotion, with negative content cueing more caution and thus less reliance on believability, hence higher accuracy. The results of pairwise comparisons are shown in Table 7.3

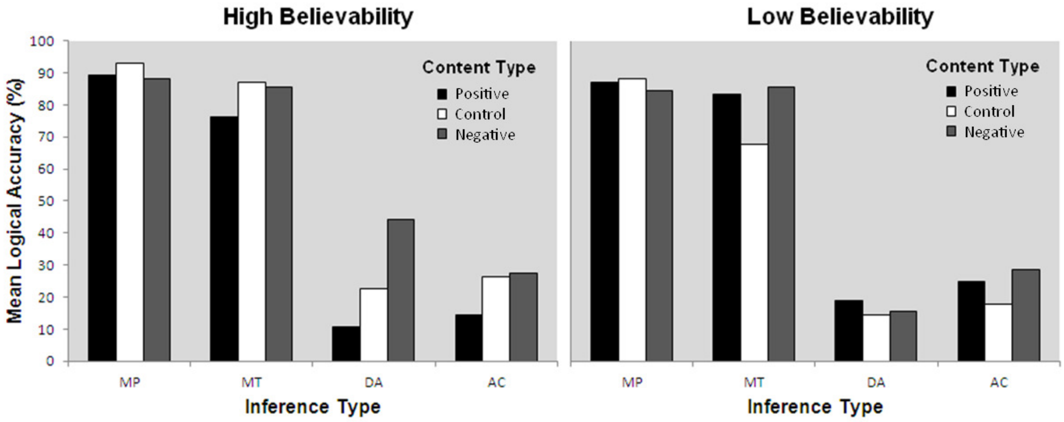


Figure 7.3 Inference type by content type, by believability interactions

Table 7.3 *p*-values for pairwise comparisons split by believability
(P-Positive; C-Control; N-Negative)

		Comparisons		
Believability	**Inference**	***P-N***	***P-C***	***C-N***
High Believability	MP	.743	.262	.323
	MT	.073^{+}	.048*	.812
	DA	<.001**	.049*	.002**
	AC	.020**	.040*	.822
Low Believability	MP	.660	.710	.555
	MT	.675	.008**	.004**
	DA	.519	.377	.785
	AC	.412	.160	.060^{+}

Approach-Avoidance Measures

The subscales of the BIS-BAS did not correlate significantly with any measures of reasoning accuracy. No further analyses were conducted on this portion of the data.

7.2.3 Summary of Experiment 6

The results reveal that valid inferences are responded to more accurately than invalid inferences, and inferences related to believable conditionals are responded to more accurately than those related to less believable ones. Interestingly, believability and content interacted, such that when the conditional was believable, accuracy increased across positive to control to negative content; however, when the conditional was unbelievable, positive and negative content led to higher accuracy than control content. Approach-Avoidance measures showed no effects of interest to the hypotheses under investigation. Content showed a significant main effect such that accuracy increased from positive to control to negative content types, providing support for information theories of the impact of emotion on reasoning. Further analysis of this effect suggests that the impact of content is more pronounced for indeterminate (DA and AC) inferences, suggesting that the effect is perhaps more specific than the general information effect; negative content may cue more careful processing of the problem based on logical rules leading to increased accuracy, whereas positive content may lead to less careful processing and a reliance on strategies not based on logical rules, thus lower accuracy relative to negative content. Before considering these findings in more detail, the extent to which they occur in a between-participants design will be assessed.

7.3 Conditionals with Emotive Content: Between (Experiment 7)

In order to test the robustness of the content effects found in Experiment 6, the same materials and procedures were used as part of a between-participants replication. The rationale for this change to a between-participants design is based on the possibility that varying content within-participants will make it more salient. This in turn raises the possibilities that the impact of emotion will be discounted by the participant (Section 1.5.3), or that the participants may display demand characteristics if they begin to develop their own hypotheses about what the experiment is investigating. Furthermore, although the presentation order of each content block was randomised in Experiment 6, switching from one content valence to another may ameliorate the effects of the second content type above what can be controlled for by randomisation. These possibilities may provide an explanation for the limited main effects of content found when varying content type in a within-participants design, and is addressed by varying content-type between-participants.

7.3.1 Method and Materials

Participants, Design and Procedure

The sample comprised 87 (63 female) volunteers and Plymouth University students participating for course credit, with a mean age of 21 years (*SD* = 4 years). The design and procedure were the same as in Experiment 6 in every detail except that each participant was only presented with one set of conditionals; positively valenced, negatively valenced, or the control set.

7.3.2 Results

Reasoning Accuracy

A mixed 3 Content (Positive, Control, Negative) by 2 Believability (High Believability, Low Believability) by 4 Inference Type (MP, MT, DA, AC) ANOVA was conducted on accuracy rate data. Means for each cell of the design can be found in Table 7.4. Comparisons of these means showed a main effect of believability [$F(1,252) = 11.00$, $p = .001$, $\eta_p^2 = .12$], with high-believability conditionals being responded to more accurately (*M* = 66.27, *SD* = 32.36) than low-believability conditionals (*M* = 59.86, *SD* = 37.40); the same believability effect as was found in Experiment 6. There was also a significant main effect of inference type, which showed the same pattern as for the within-participant design (See section 7.2) [$F(3,252) = 65.47$, $p < .001$, $\eta_p^2 = .44$]. There was also a significant main effect of content type [$F(2,84) = 12.26$, $p < .001$, $\eta_p^2 = .23$], with accuracy increasing across positive, to control, to negative content types. All pair-wise differences reached statistical significance at $p < .03$.

Table 7.4 Descriptive Statistics for participants' reasoning accuracy (mean %) on conditionals with emotive content (Content varied Between-participants)

			Inference Type			
Content	**Believability**		**MP**	**MT**	**DA**	**AC**
Positive (*N*=33)	High	*M*	92.42	81.82	15.15	16.67
		SD	22.08	27.44	31.83	32.27
	Low	*M*	84.85	87.88	18.18	15.15
		SD	36.41	33.14	39.17	36.41
Control (*N*=22)	High	*M*	93.18	65.91	47.73	63.64
		SD	17.56	41.94	39.27	41.35
	Low	*M*	84.09	59.09	43.18	47.73
		SD	32.32	42.64	44.44	39.27
Negative (*N*=32)	High	*M*	96.88	93.75	50.00	78.13
		SD	17.68	24.59	50.80	42.00
	Low	*M*	89.06	84.38	43.75	60.94
		SD	27.63	32.22	43.53	41.61

There was also a significant interaction between content type and believability [$F(2,252) = 3.10$, $p = .05$, $\eta_p^2 = .07$], suggesting that the effect of believability was greater for control and negative items than for positive items, accuracy on which showed relatively little effect of believability. This interaction is depicted in Figure 7.4. It can also be seen that accuracy increases across positive, to control, to negative content, and that these differences are greater when the content is believable than when it is unbelievable. The pattern for high-believability items is the same as that found in Experiment 6, and the relationship between control and negative content is the same as in Experiment 6 for low-believability conditionals, although positive content shows considerably lower accuracy in the current data than in Experiment 6.

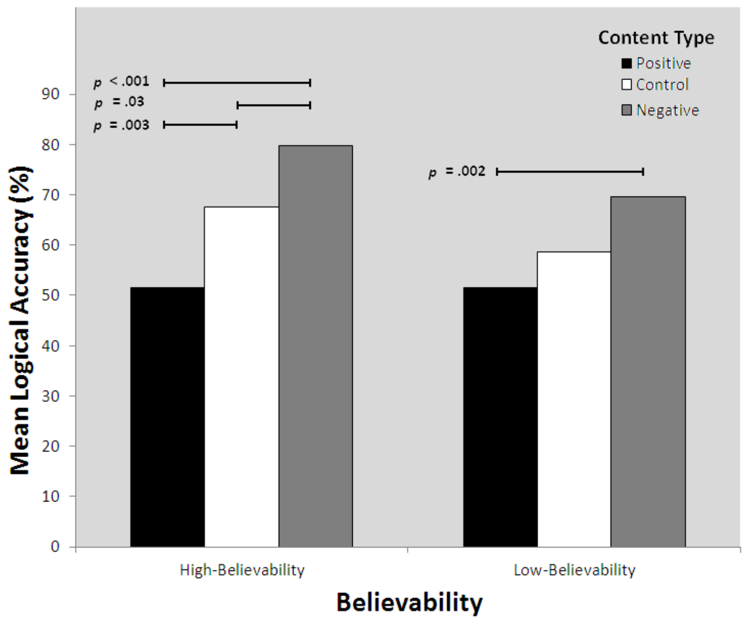


Figure 7.4 Belieavbility by Content Type interactions based on accuracy

Content and inference type showed a significant interaction effect [$F(6,252) = 8.68$, $p < .001$, $\eta_p^2 = .17$]. This is depicted in Figure 7.5, and along with the pair-wise significance values. It would appear that the effect of content is most pronounced when the conclusions are invalid, and that it is primarily a decrease in accuracy on DA and AC problems when the content is positively valenced which is driving this effect. This is similar to the marginal inference type by content interaction found in Experiment 6. The effect seems to be driven by positive content, for which accuracy rates on DA and AC inferences are much lower than for control or negative content; control and negative content having broadly similar accuracy rates in DA and AC inferences.

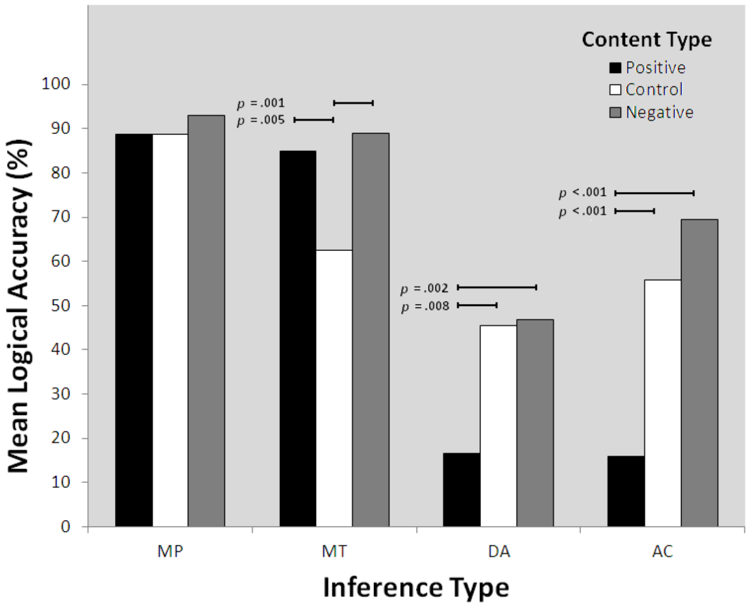


Figure 7.5 Problem Type by Content Type interactions based on accuracy

That the effect is more pronounced when content is varied between participants than it was for the within-participants manipulation supports to some extent the rationale of the current experiment, and provides some evidence that switching between content types may be subject to order effects or discounting. No other interaction effects were found in the data.

Approach-Avoidance Measures

The results from the BIS-BAS scale show that inhibition is positively correlated with reward responsiveness, drive is positively correlated with fun-seeking and reward responsiveness, and fun seeking is positively correlated with reward responsiveness.

In relation to logical accuracy and content type, the BIS-BAS subscales show very few relationships with accuracy across the content types (Table 7.5). Fun-seeking is positively correlated with logical accuracy with control content, but that this is the only relationship suggests further analysis is not warranted. It was thought that increased BIS scores might reflect a more cautious approach to reasoning, and thus be related to higher accuracy scores across content types, whereas BAS scores may be expected to correlate negatively with accuracy scores if they reflect more impulsive, low-effort reasoning. This does not seem to be the case in the coarse analysis shown in Table 7.5, and thus no further analysis is warranted here.

Table 7.5 Correlation coefficients (Pearson's-*r*) showing the relationships between BIS/BAS subscale and reasoning indices (Content varied Between-participants)

		BAS Subscales (N=87)			**Reasoning Accuracy**		
		Drive	Fun Seeking	Reward Responsiveness	Positive (n=33)	Control (n=22)	Negative (n=32)
BIS	r	-.016	.017	.254	-.23	.07	.29
	p	.880	.877	.018	.20	.76	.21
Drive	r		.469	.428	.05	.25	-.12
	p		.000	.000	.78	.27	.52
Fun-Seeking	r			.308	.12	.46	.17
	p			.004	.52	.04	.36
Reward-Resp.	r				-.07	.24	.12
	p				.71	.28	.52

7.3.3 Summary of Experiment 7

Experiment 7 was conducted as a replication of Experiment 6, although varying the emotive content between-participants. This was done to minimise the possibility that content was noticed as a variable, and thus to reduce any demand characteristics or discounting effects. The results largely replicate the findings of Experiment 6, such that valid inferences are responded to more accurately than invalid inferences, and inferences related to believable conditionals are responded to more accurately than those related to less believable ones. This believability effect interacted with the content effect such that the effect of content was larger for believable than unbelievable conditionals. Approach-Avoidance measures again showed no effects of interest to the hypotheses under investigation. Content showed a significant main effect such that accuracy increased from positive to control to negative content types. Further analysis of this effect suggests that the impact of content is more pronounced for indeterminate inferences, and provides further support for information theories of emotion's impact on reasoning.

7.4 Comparing the effects of Verbal and Visual Content (Experiment 8)

Having considered a range of variations on verbal conditional reasoning problems, it is interesting to consider visual representations of conditionals. In the emotion literature, tasks based around emotive words have been used to induce different mood states, and the current series of studies has included emotive verbal content as a manipulation of the emotive valence of the conditionals themselves. However, emotive images have also been used to induce mood states. This raises the question of whether non-verbal emotive content may affect how people process conditional statements. To the author's knowledge, replacing verbal markers for the *p* and *q* terms in conditional statements with images has not previously been investigated, and the current study is presented as a novel methodology.

One large repository of emotive images commonly used in emotion research is the International Affective Picture System (IAPS; Lang, Bradley, & Cuthbert, 2005). These images have all been rated for arousal and valence, and are available to researchers as colour images of reasonable quality. They have been used widely in a range of emotion research to induce mood states and gauge reactions to emotional stimuli (Schaefer, Pottage, & Rickart, 2011; Schimmack, 2005), though some recent efforts have been made to update their content as certain cultural elements in some of the images have become dated. IAPS images contain a range of scenarios and scenes, from flowers and landscapes to injuries and warzones. This broad range of content makes them ideal for substituting into conditional statements as antecedent (*p)* and consequent (*q)* terms as coherent rules can be made which keeps the design much closer in nature to existing work on conditional reasoning.

As this is a novel way of introducing content to conditional reasoning tasks, little is known about how the imagery may affect reasoning. As such, no specific hypotheses were constructed over and above the general questions investigated in the previous experiments; namely, a search for any effect of emotive content, and its interaction with validity and believability. However, to avoid overcomplicating the control of imagery valence and arousal, believability was held constant (based on pre-test ratings of the conditional statements) in the current study, and the investigation is limited to assessing the interaction of integral visual content across inference types.

7.4.1 Method and Materials

Pretesting of Imagery

The pictures used in place of verbal markers were taken from the original IAPS collection. Although an updated set of images were available (Pottage, personal communication, 2010), they had not been rated for arousal and valence using the same system as the original set, so controlling for image properties would be open to criticism. The images chosen were pretested for valence and arousal based on published IAPS ratings (Lang et al., 2005). Mean valence differed significantly across content conditions [$F(2,21)=153.19$, $p<.001$, η_p^2 =.94], with all post-hoc comparisons between the positive (M=7.42, SD=.49), control (M=5.63, SD=.51) and negative (M=2.97, SD=.532) groups being significant at $p<.001$. No significant differences were found between mean arousal scores across content conditions [$F(2,21)=1.14$, $p=.34$,

η_p^2 =.10]. Nor were any pair-wise comparisons between conditions statistically significant (Positive, *M*=4.86, *SD*=.95; Control, *M*=4.79, *SD*=.60; Negative, *M*=5.28, *SD*=.45).

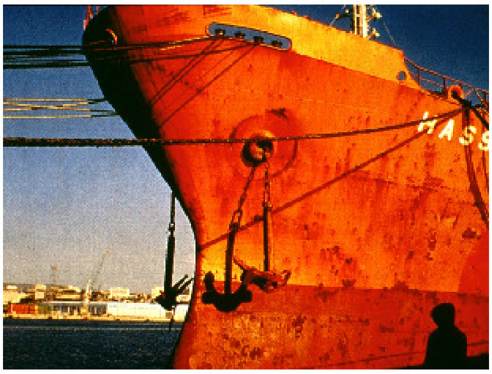
A small group of volunteers (*N* = 7) rated the conditional probabilities of each picture statement of the form "If [*p*-picture] then [*q*-picture]" on a 0%-100% scale, where 0 indicated that it was impossible for the second term to follow given the first, and 100 indicated it was certain that the second term would follow given the first. The same ratings were made for converse probabilities, with the statements presented in the form "If [*q*-picture] then [*p*-picture]" as a way of controlling for the perceived number of alternative possible antecedents. No significant differences in this converse, or the former conditional, probabilities were found as a function of the image valence, nor did any interactions between content conditions and conditional or converse probabilities reach statistical significance. Believability was not varied in this study. That the conditional probabilities are comparable across and within conditions suggests that all statements were comparably believable. A full list of the images used from the IAPS image set, which condition they were allocated to, along with published valence and arousal scores are shown in Table 7.6. Examples of positive, control, and negative pairs of images are show below. The presentation of each trial is discussed shortly under the design and procedure section.

Table 7.6 List of IAPS images used, along with brief descriptions, image identifiers (from IAPS), and their valence and arousal ratings, taken from the IAPS picture set data.

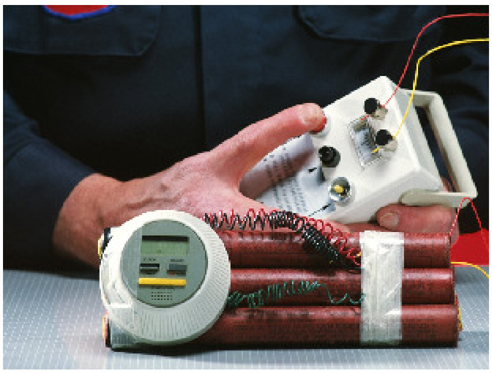
	Brief Description	IAPS#	Valence M	Valence SD	Arousal M	Arousal SD
Positive	Ferrari	8510	7.3	1.7	4.9	2.6
	Gold Bullion	8500	7.0	1.6	5.6	2.4
	Blue sky and clouds	5891	7.2	1.5	3.3	2.6
	Lake and greenery	5780	7.5	1.5	3.8	2.5
	Gymnast	8470	7.7	1.5	6.1	2.2
	Olympic medallists	8540	7.5	1.5	5.2	2.4
	Puppies	1710	8.3	1.1	5.4	2.3
	Woman and dog	2362	6.7	1.3	4.6	2.1
Control	Ship	5395	5.3	1.2	4.2	2.0
	Ship propeller	2575	5.5	1.2	4.2	2.1
	Jet-fighter in flight	6900	4.8	2.1	5.6	2.2
	Jet-fighter firing	6910	5.3	2.3	5.6	2.5
	Whole pizza	7351	5.8	1.7	4.3	2.3
	Slice of pizza	7352	6.2	2.2	4.6	2.5
	Club Scene	2605	6.3	1.5	5.0	2.2
	Dancing Woman	2606	5.9	1.6	4.8	2.2
Negative	Rioter	2691	3.0	1.7	5.9	2.0
	Prisoner in cell	2694	3.6	1.7	5.1	2.2
	Car-jacking	6571	2.9	2.1	5.6	2.5
	Officer with baton	2682	3.7	1.7	4.5	2.1
	Drink driver	2751	2.7	1.9	5.2	2.4
	Car wreck	9903	2.4	1.4	5.7	2.3
	Bomb	2692	3.4	1.6	5.4	2.2
	Dead Bodies	9435	2.3	1.5	5.0	2.0

Positively Valenced Images

Control Images



Negatively Valenced Images



(Images adapted from IAPS; Lang et al., 2005)

Participants

The participants in this study were 69 undergraduate psychology students at Plymouth University who participated for course credit. Age and gender were not recorded.

Design and Procedure

The design and procedure utilised in Experiment 8 were identical in nature to the previously described studies, with the exception of the layout of the reasoning task and examples. Content was varied between-participants. Reasoning problems were presented as shown in Figure 7.6. Response options were 'Yes', 'No' and 'Maybe', as can be seen in Figure 7.6. A copy of the instructions presented to participants prior to practice trials can be found in Appendix D.

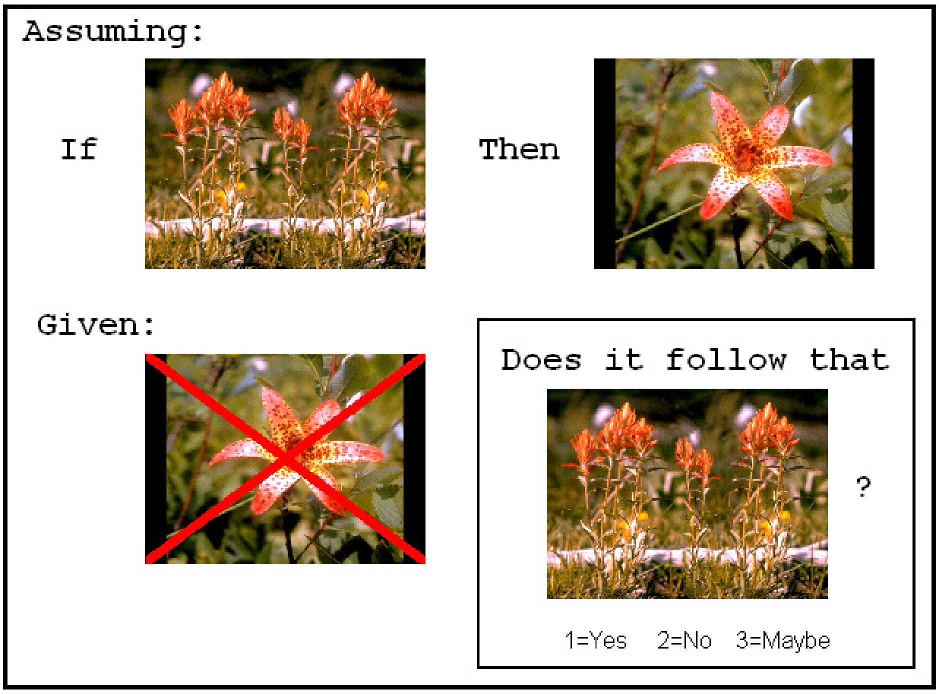


Figure 7.6 Presentation of Visual Conditionals

7.4.2 Results

In order to provide a consistent set of results for comparison across experiments, a 3 Content (Positive, Control, Negative) x 4 Inference Type (MP, MT, DA, AC) mixed ANOVAs was conducted on accuracy rates. Mean accuracy rates for each cell are shown in Table 7.7.

Table 7.7 Mean accuracy rates (%) by inference and content type

		Inference Type (Mean Accuracy, %)			
Content		**MP**	**MT**	**DA**	**AC**
Positive	*M*	91.67	65.63	11.46	16.67
(*N*=24)	*SD*	15.93	28.37	22.09	21.70
Control	*M*	95.83	72.22	22.22	18.06
(*N*=18)	*SD*	9.59	29.57	33.09	20.66
Negative	*M*	94.44	62.96	23.15	45.37
(*N*=27)	*SD*	10.59	33.52	27.67	38.00

The results from the accuracy data revealed a main effect of inference type [$F(3,198) = 134.25$, $p < .001$, $\eta_p^2 = .67$], with all pairwise comparisons being significant at $p<.001$, except the difference between DA and AC which was still significant, but at $p=.031$. MP inferences were responded to most accurately (94%), followed by MT (67%) inferences. DA (27%) and AC (19%) were significantly lower than both MP and MT, with AC showing marginally higher accuracy rates than DA.

There was also a significant inference by content interaction [$F(6,198) = 2.95$, $p = .009$, $\eta_p^2 = .08$]. This interaction is driven primarily by a much higher rate of accuracy on AC problems (45%) when the terms were negatively valenced images, relative to positive and control images, which showed very little difference (17% and 18% respectively). A univariate analysis of variance comparing content types within AC inferences showed a main effect of content type, positive-negative and negative-control differences reaching statistical significance ($p = .001$ and $p = .003$

respectively). The control-positive difference was not statistically significant. Accuracy rates were comparable between positive, negative, and control conditions across MP, MT, and DA inferences. One-way ANOVAs showed no main effect of content for any inference type separately; neither did any pairwise comparisons within these groups reach statistical significance. This content by inference type interaction is depicted in Figure 7.7, from which a number of similarities can be seen with Experiments 6 and 7. For example, the larger differences between content conditions on DA and AC inferences and the increased accuracy on AC inferences when the content is negative.

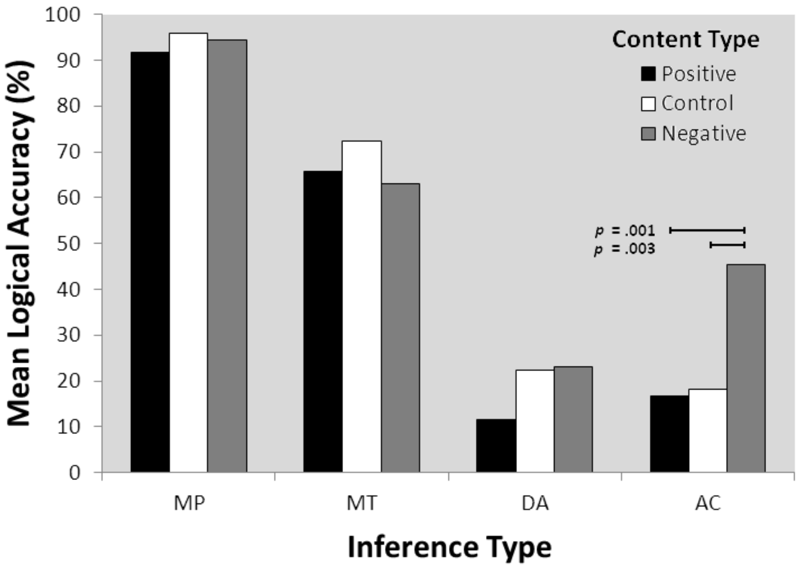


Figure 7.7 Problem Type by Content Type interactions with images, based on accuracy

The analysis also showed a marginal main effect of content type [$F(1,66) = 3.09$, $p = .05$, $\eta_p^2 = .09$]. This effect of content suggests that using negative images as terms leads to higher accuracy rates (56%) than control (52%) and positive images (46%). However, only the positive-negative comparison reached statistical significance ($p = .016$).

7.5 General Discussion

The current chapter aimed to investigate the effects of integral, emotive content on conditional reasoning in order to compare the effects of integral emotion with the effects of incidental emotion reported in Experiment 5. The experiments reported here also allow a comparison of the effects of integral emotion on conditional reasoning tasks with those found in syllogistic reasoning (Experiments 1, 2, 3, 4, and findings from the existing literature already discussed). Content was varied within- and then between-participants. This yielded results suggestive of the fact that positive content reduces logical accuracy relative to negative content, with control or neutral content resulting in accuracy rates somewhere between the two. However, the results also suggest that this is primarily the case for indeterminate inferences, DA and AC, with little effect of content being found on either MP or MT inferences. Negative content increasing logical accuracy on DA and AC inferences is in contrast to the findings of Blanchette and Richards (2004), who report higher numbers of logically inaccurate 'No' responses to DA inferences, and higher numbers of logically inaccurate 'Yes' responses to AC inference with any emotive content. Key features of the materials which may account for these inconsistencies, such as the believability of the conditionals, are controlled for in the current experiments, though no mention of them is made in the work of Blanchette and Richards. As the effects of emotion seem to vary across levels of belief in a number of the experiments reported here, this highlights the need for greater transparency and detail in published studies.

The results across all three studies show that negative content generally leads to higher accuracy than positive or control content on DA, and particularly AC inferences. One possible reason for this is that these are invalid inferences. Logical accuracy is typically lower for invalid inferences than valid ones, suggesting that they are more difficult. If this is the case, whether because additional rules need to be applied or the number of alternative causes to be considered is greater, then emotion would be expected to have a larger impact on these inferences. If emotion served as cognitive load, accuracy would be expected to be suppressed for both positive and negative content. This is not the case. However, if emotion is used as an additional source of information when reasoning about more difficult items, positive content might be expected to lead individuals to affirmative responses or to go with their initial answers, whereas negative content might be expected to make people more cautious, and reason more carefully.

That the effects are found primarily on DA and AC problems may be explained by the negative emotion cueing more motivated reasoning on these inferences. Alternatively, the increased demands of the indeterminate inferences may have led people to seek alternative cues about how to proceed. Finding this in the valence of the problem would then account for the differing levels of accuracy resulting from different amounts careful processing.

Another possible explanation for this effect is the converse probability of the conditionals, as this was not initially controlled for in Experiments 6 and 7. As the majority of content effects were found in DA and AC inferences, and it has been previously shown that these inferences are most affected by the existence of alternative explanations (of which the converse probability is a proxy), the control of $P(p|q)$ in Experiment 8 by pretesting for believability of the conditionals with images presented in both orders ($p \rightarrow q$, $q \rightarrow p$) may account for the reduced content effects, though overall they are consistent in their direction with the results of experiments 6 and 7. The effects of content in this case were reduced, suggesting that the effects of emotive content may be in some way linked to converse probabilities, and is a topic considered in more detail in the following chapter.

Following the two variations on the study of integral emotive content in Experiments 6 and 7, in a novel approach to conditional reasoning, emotive imagery from the IAPS was combined with the conditional reasoning paradigm in Experiment 8 in order to test the effect of replacing verbal terms in the conditionals with emotive images. The results showed that there was a small effect of emotive valence with visual content, such that people appeared to be more accurate when reasoning about negative imagery than about positive imagery. With the accuracy of the control imagery varying from Experiments 6 and 7 and within Experiment 8, it is difficult to say whether positive imagery decreases accuracy, negative imagery increases accuracy, or whether there is some interaction of the two, though the results are promising in terms of encouraging future work on reasoning with visual imagery. These findings are also interesting in that they provide a promising methodology for investigating aspects of emotion which are non-verbal, and thus open up an area of research into how integral as well as potentially incidental emotive imagery may affect decision making. On possible area in which this would be particularly relevant is warning signs which contain written as well as visual information. If the individual is required to draw inferences from the text, which is often presented in the form of conditional statements, then an understanding of how emotional imagery affects the inferences people draw is important.

As a general point across Experiments 6, 7, and 8, unlike the conditionals used by Handley, Newstead, and Trippas (2011), the conclusions were not empirically true or false. They were based on graded beliefs, where the belief ratings were taken from a previous study or pretesting. This was included to replicate the design of Experiment 5, although responses were restricted here to categorical *Yes*, *No*, and *Maybe* options. However, based on previous findings, believable conditionals were expected to lead to more logical responding than unbelievable ones, and this was found to be the case in Experiments 6 and 7. However, the effects of emotion were larger for high-believability as opposed to low-believability items. Although the increased logical accuracy on believable items may be explained by the increased cognitive effort required to process low-believability, counter-to-belief items, increased emotion effects on high-believability items appears closer to a fluency than a load effect. If an individual believes a statement, they may devote less effort to critically evaluating it, or the logical validity of the inference, and thus may rely on emotion as a cue to how to respond.

The finding that emotion effects are larger on DA and AC inferences might be explained in a similar way. The indeterminate nature of these inferences may require greater cognitive effort to process, thus leaving less available resources to employ fully or correctly any logical rules, leading the individual to rely on the content valence to direct their reasoning. Although this may, in the case of negative content, lead to an attempt at employing more careful yet more effortful strategies, that positive content is used to justify low effort strategies leads to an overall reduction in load when the groups are considered together. These possibilities are tentative, and cannot be fully explored with the data available here, though they present a number of interesting avenues for future research.

To summarise the findings, although integral emotion has relatively little main effect on conditional reasoning, it has a replicable and consistent effect on reasoning accuracy with DA and AC inferences. Although this is more pronounced for AC inferences, across Experiments 6, 7, and 8 it would appear that negative content increases logical accuracy on these indeterminate inferences relative to control and positive content. It is difficult to say whether negative content improves accuracy or positive content suppresses accurate responding given the accuracy on control content varies, being closer to negative content in Experiment 6 and closer to positive content in Experiment 7, but the difference between positive and negative content would appear consistent. This is especially notable given that the same pattern is found when verbal terms are replaced with visual markers in the novel methodology of Experiment 8, and all of the experiments reported in this chapter provide support for the mood as information explanation of how (integral) emotions affect reasoning. Furthermore, this support for information theories is similar to that found with syllogistic reasoning under the Necessity-Possibility paradigm in Experiment 1, and to some extent in Experiment 2. The support for information theories in the current chapter is also similar to that found with syllogistic reasoning under the Belief-Bias paradigm in Experiments 3 and 4. Experiment 5, investigating incidental emotion and conditional reasoning however found little support for either information or load theories. Taken together, the previous experiments provide relatively weak support in favour of the information theories, whereas the current experiments (6, 7, and 8) provide much more consistent findings in support of the idea that emotion is used as a source of information when deciding which reasoning strategies to employ.

In relation to previous work in the literature, these findings are inconsistent with the results of Blanchette and colleagues (Blanchette, 2006; Blanchette & Leese, 2011; Blanchette & Richards, 2004). For example, Blanchette and Richards, whose work the current studies are based on, found that people were more likely to draw invalid inferences when the conditionals were emotive – either positive or negative – than when they were neutral; outlined above. Although this is not what was found here, they do report more pronounced effects of emotion on DA and AC inferences. This is an interesting discrepancy, especially given that Blanchette and Richards were able to replicate their reduction in logical accuracy using neutral terms which had been conditioned to be emotional. One possible explanation, as outlined above, may be the believability of the conditionals; there is no mention of the believability being controlled, and if this varied systematically between emotive and neutral statements such that the neutral items were more believable than the emotive ones, they are likely to have been responded to more accurately in line with the consistently replicated belief effect. This was to some extent controlled in this chapter by manipulating the believability of the conditional statements, but alternative methods of controlling this will be considered in the following chapter.

Having now compared the effects of incidental and integral emotion across syllogistic reasoning in the Necessity-Possibility and Belief-Bias paradigms, and conditional reasoning with both verbal and visual markers, the following chapter seeks to further our understanding of emotion and conditional reasoning by replicating the design of Experiments 6 and 7 whilst controlling directly for converse probability (a proxy of believability and alternative causes) and investigating the effect of presentation format. As mentioned above, DA and AC inferences are more prone to the effects of enabling and disabling conditions, and this can be controlled by taking into account $P(p|q)$. Also discussed above is the presentation of the premises and the conclusions (e.g. Table 7.1). In Experiments 6, 7, and 8 the format used by Blanchette and Richards (2004) was adopted, yet this is not typical of the work in the reasoning literature. Whereas this chapter has aimed to develop the work on conditionals in the emotion literature, it is now important to consider how this programme of work relates to the designs found in the reasoning literature, and how the effects reported in Experiments 6, 7, and 8 relate to conditionals when the number of alternative causes, alluded to earlier, are controlled.

Chapter Eight

Conditional Reasoning, Emotion, and Alternative Antecedents

8.1 Introduction (Experiment 9)

The results from the previous chapter suggest that positive content in conditional reasoning leads to lower accuracy rates than negative or control content. However, these effects are found primarily on DA and AC inferences. This was found when content valence was varied within (Experiment 6) and when it was varied between participants (Experiment 7), as well as when the verbal content was replaced with visual content (Experiment 8).

One possible explanation for the effects being found only on DA and AC problems in Experiments 6 and 7 is that the number of alternative antecedents varied either across inference types or across content types. One way of assessing this is to take into account correlates of the number of alternative antecedents such as the converse probabilities of the conditionals. That is, the probability of *p* occurring given *q*, $P(p|q)$. This suggestion that the results presented in Experiment 6 and replicated in Experiment 7 may be due to differences in converse probability arises from research which has shown that the drawing of these inferences is more highly influenced by the availability of enabling and disabling factors, and the availability of alternatives than the drawing of MP and MT inferences (Cummins et al., 1991). The number of alternative causes and disabling factors is largely described by the converse probability of a conditional statement; if there is only one possible cause of *q*, and that is *p*, then the probability of *p* given *q* is high. If there are many possible causes of *q*, such as *m*, *n*, *o* and *p*, the probability of *p* having occurred given

q is lowered. Given the rule "*If p then q*", the drawing of inferences (particularly DA and AC, as will be discussed below) is dependent not only on the conditional probability, P($q|p$), but also on the converse probability, P($p|q$).

Although alternatives and disabling conditions have been described in published work (e.g. Cummins et al., 1991), Serpell (2011, unpublished thesis) provides perhaps the most clear illustration of the alternative causes. Taking the conditional statement "*If the butter is heated, then the butter will melt*", it can be seen that there are relatively few alternative causes. What else would make butter melt besides heating it? This can be thought of as the converse probability being high; P($p|q$)=High; If the butter has melted, it is highly probable that it was heated. Alternatively, given the conditional "*If the stone is kicked, then the stone will move*", it can be seen that there are many alternative causes. The stone may have been thrown, or moved by an animal, or shaken by natural events. In this case, the converse probability is low; P($p|q$)=Low. If the stone has moved, it is not very likely to be because it was kicked.

Few alternative causes; P($p|q$)=High

If the butter is heated (p), the butter will melt (q).

The butter was heated, the butter melted

Many alternative causes; P($p|q$)=Low

If the stone is kicked (p), the stone will move (q)

The stone was kicked, the stone moved

The stone was thrown, the stone moved

A dog picked up the stone, the stone moved

There was an earth tremor, the stone moved

In relation to the impact of P($p|q$) on endorsement rates of each inference type, Cummins and colleagues (1991) present data showing that the number of alternative causes affects the rate at which DA and AC inferences are accepted, but that alternative causes have little impact on the acceptance of MP and MT inferences. They show that when there are fewer alternative causes, DA and AC inferences are accepted at higher rates than if there are more alternative causes, and suggest this is possibly due to the limited number of alternatives leading the individuals to treat the rules as biconditional. That is, if *p* is the only cause of *q*, it would be extremely unlikely that *q* would occur if *p* hadn't, which makes "*if p, then q"* almost equivalent to "*if q, then p"* – P($p|q$) is high.

In relation to emotion as load and emotion as information theories, converse probability is important to control as the number of alternative causes affects the number of situations which need to be considered in order to evaluate each inference. This search for alternatives, which is synonymous with a search for alternative models discussed in earlier chapters on syllogistic reasoning, is affected by cognitive ability, or available cognitive resources, which load theories argue will be affected by emotive content. Similarly, the search for alternatives will be affected, according to information theories, by positive emotions cueing the acceptance of initial models, and negative emotions cueing an extended search. This latter possibility is, given the support for information theories found in the previous chapter, the one which the current experiment will control for. If the results replicate the findings in Chapter 7 after controlling for the number of alternatives, this will provide stronger support for the information theory of emotion effects in reasoning.

As in Experiments 6, 7, and 8 the aims of Experiment 9 are to investigate the impact of emotive content on conditional reasoning, and use any patterns revealed to further our understanding of how these effects occur by ruling out the possibility that they can be accounted for by differences in converse probabilities. Experiment 9 develops the previous work by controlling for converse probability, which, as outlined above, may account for some of the content effects found with DA and AC inferences if alternatives and content are assumed to have covaried, or if there was a possibility of this given that alternatives were not explicitly controlled.

In addition to investigating the effects of emotive content on logical accuracy and rates at which the inferences are drawn, the current experiment will also include a variant of the mood measure used in Experiment 5. This is in order to assess the impact of the emotive content on experienced mood, and provide data to shed light on the question raised in Section 7.1 as to whether emotive content alters the experienced mood of individuals, or operates without altering subjective emotional states.

In summary, the current chapter will replicate the design used in Experiment 7, but using a set of conditional statements in which converse probability is controlled. If the increased accuracy of negative content relative to positive content found earlier is due to the content valence, accuracy would be expected to be higher for negative content than positive content again. If the effects can possibly be attributed to the availability of alternatives, as measured by the converse probabilities, and the availability of both alternative causes and disabling conditions, no difference between content types would be expected.

8.1.1 Pre-Testing of Conditionals

In order to obtain a selection of conditional statements with emotive content which were also matched for converse probability, a range of items and their converse were presented to a small group of volunteers. The volunteers were asked to rate the conditional statements for their positivity and probabilities on 100-point scales. 0

indicated negative and 0% probability, 100 represented positive and 100% certainty. The full pool of items and list of those selected for use can be found in Appendix D.

Probability and positivity ratings were analysed in a 3 Content (Positive, Control, Negative) x 2 Believability (Believable, Unbelievable) x 2 Direction (Conditional, Converse) design; whereby Direction indicates whether P($q|p$) or P($p|q$) was being rated. For example, given the statement "If the butter is heated, the butter will melt", rating the conditional direction is rating the probability and positivity of the statement as presented above; whereas rating the converse direction is rating the probability and positivity of the statement "If the butter has melted, then the butter was heated". Means for each cell in this design for probability and positivity ratings are shown in Table 8.1.

Table 8.1 Possibility and Positivity ratings (%) for the conditional statements used in Experiments 9 and 10, by content type, believability, and direction

Probability Ratings (%)					
		Believable		**Unbelievable**	
Content		Conditional	Converse	Conditional	Converse
Positive	*M*	70	75	46	49
	SD	10	4	14	5
Control	*M*	85	71	44	43
	SD	11	8	1	37
Negative	*M*	87	71	28	54
	SD	8	18	16	30
Positivity Ratings (%)					
		Believable		**Unbelievable**	
Content		Conditional	Converse	Conditional	Converse
Positive	*M*	83	84	70	73
	SD	2	12	9	11
Control	*M*	48	46	48	51
	SD	12	10	1	2
Negative	*M*	6	9	7	5
	SD	8	6	2	2

As intended, probability ratings differed significantly as a function of believability [Believable; M = 76.54, SD = 3.46, Unbelievable M = 44.01, SD = 3.46, $F(1,12)$ = 22.40, p < .001, η_p^2 = .65], but not across content type or direction. Similarly, positivity ratings differed significantly as a function of content type [$F(2,12)$ = 176.56, p < .001, η_p^2 = .97]. All pairwise comparisons were statistically significant at p<.001; Positive (M = 77.43, SD = 7.54), Control (M = 48.40, SD = 7.55), Negative (M = 6.93, SD = 7.53). Positivity did not vary across levels of believability or direction. Content, Believability, and Direction showed no significant interactive effects on probability or positivity ratings. Controlling these properties rules out the possibility that any differences between content types found in this experiment are the result of confounded converse probabilities.

8.1.2 Method and Results

Participants, Design, and Procedure

The results reported here are based on a sample of 73 undergraduate Psychology students at Plymouth University who participated for course credit. Age and gender were not recorded.

The current experiment, as in Experiment 7, adopts a 2 Believability (High, Low) x 3 Content Type (Positive, Control, Negative) x 4 Inference Type (MP, MT, DA, AC) mixed-ANOVA, with content type being varied between-participants. The between-participants design was chosen for the development of the previous experiments, rather than the within-participants design of Experiment 6 to eliminate any potential reduction in content effects caused by switching between content types. The procedure for the current study followed exactly that of Experiment 7, with the only difference being the conditionals that were presented. Response times were also recorded in order to assess any impact of speed on accuracy, and a measure of mood was included to assess change in experienced mood before and after the reasoning task. For this part of the current experiment, participants were asked to rate, on a ten-point Likert scale anchored at '*Very Unhappy*' and '*Very Happy*', their mood before and after completing the reasoning task. This allows some investigation of whether integral mood operates by creating an experienced mood as in incidental mood manipulations, or without directly altering the individuals' mood (a question raised in Chapters 3, 4, and 7).

Mood Ratings

There was a main effect of time (pre-reasoning versus post-reasoning) on ratings of mood, which reached statistical significance, [$F(1,70) = 10.94$, $p = .001$, $\eta_p^2 = .14$]. Mood pre-reasoning was significantly higher ($M = 6.08$, $SD = 1.80$) than mood post-reasoning ($M = 5.74$, $SD = 1.71$).

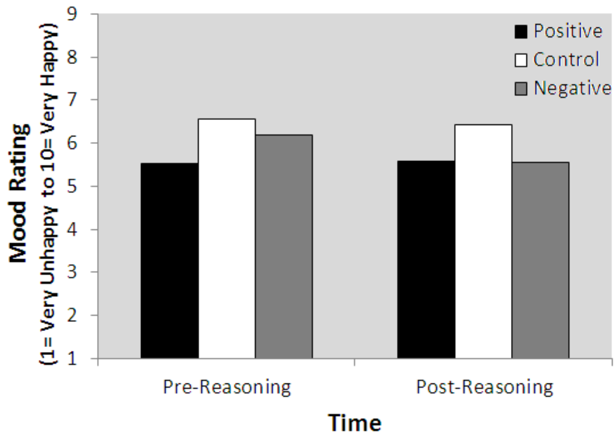


Figure 8.1 Pre- and Post-Reasoning mood ratings

Although Time did not interact with Content, individual paired-comparison *t*-tests for each content type showed that the main effect of Time is driven by a larger decrease pre- ($M = 6.20$, $SD = 1.71$) to post-reasoning ($M = 5.56$, $SD = 1.61$) for negative content, [$t(24) = 2.78$, $p = .01$, $d = 1.42$], than for control [Pre $M = 6.57$, $SD = 1.47$;

Post *M* = 6.44, *SD* = 1.41, *t*(22) = 1.00, *p* = .33], or positive content [Pre *M* = 5.52, *SD* = 2.06; Post *M* = 5.28, *SD* = 1.90, *t*(24) = 1.66, *p* = .11] ; see Figure 8.1.

Within each level of Time, although no main effect of content was found for pre-reasoning ratings [*F*(2,70) = 2.17, *p* = .12, η_p^2 = .06], post-hoc analyses showed that those in the positive condition reported significantly lower mood (*M* = 5.52, *SD* = 2.06) than those in the control condition (*M* = 6.57, *SD* = 1.47, *p* = .05, *d* = .58), but their ratings were not significantly lower than those in the negative condition (*M* = 6.20, *SD* = 1.80, *p*=.18). Individuals in the negative and control conditions did not show a significant difference in pre-reasoning mood ratings (*p*=.48). Post-reasoning, a main effect of content was found [*F*(2,70) = 3.12, *p* = .05, η_p^2 = .08], in which the average mood of the positive content condition (*M* = 5.28, *SD* = 1.90) did not differ from that of the negative condition (*M* = 5.6, *SD* = 1.61, *p* = .55), the mood of the negative condition did not differ from that of the control condition, (*M* = 6.44, *SD* = 1.41, *p* = .07), but the positive and control conditions differed significantly (*p* = .02, *d* = .70).

Comparing the pre- and post-reasoning ratings using the RCI allows the variability of the mood rating scale to be taken into account, and provides a clearer estimate of mood change caused by the content of the problems. With an estimate of test-retest reliability of α = 0.93 based on the change across ratings for the entire sample, the percentage of participants within each content condition who showed a decrease, no-change, or increase, in their mood ratings are shown in Table 8.2.

Table 8.2 Change in Pre- to Post-Mood Ratings based on RCI scores

	Direction of Reliable Change in Pre to Post Mood Ratings (% of Sample)		
Content	**Decreased**	**No Change***	**Increased**
Positive	15	85	0
Neutral	0	100	0
Negative	16	84	0

*No-change indicates either no difference between pre- and post-reasoning ratings, or an unreliable change; that is, a change which is within the bounds expected by the variability of the measure

These results, combined with those of the ANOVA on mood rating suggest that although the completion of the reasoning task appears to lower mood in a general sense, the specific valence of the content does not serve to generate positive or negative mood states in the participants. However, as the positivity ratings of each group of conditionals was shown to differ in the pre-test phase, we can rule out the possibility that any differences found in accuracy rates or rates of drawing the inference between content conditions is due to differences in experienced mood and is instead related to how the problem content is perceived and processed. The problem content is perceived as more or less positive depending on the content type, but this difference does not translate into differences in ratings of subjective mood.

Reasoning Accuracy

The mean accuracy rates, along with standard deviations, for each cell of a 2 Believability (High, Low) x 4 Inference Type (MP, MT, DA, AC) x 3 Content Type (Positive, Control, Negative) mixed-ANOVA are shown in Table 8.3. A main effect of Believability was found [$F(1,70) = 5.82$, $p = .02$, $\eta_p^2 = .08$], whereby high-believability problems ($M = 59.84$, $SD = 13.37$) are responded to more accurately than low-believability problems ($M=54.93$, $SD = 17.86$), replicating the effect of believability found in Chapter 7.

Table 8.3 Descriptive statistics for participants' mean reasoning accuracy (%) on conditionals with emotive content; P(q|p) controlled, content varied between-participants

			Inference Type			
Content	**Believability**		**MP**	**MT**	**DA**	**AC**
Positive	High	M	84	70	56	38
N=23		*SD*	31	41	44	39
	Low	M	78	42	42	34
		SD	38	40	40	37
Control	High	M	98	63	33	33
N=25		*SD*	10	38	36	42
	Low	M	91	57	54	37
		SD	25	43	47	48
Negative	High	M	82	68	48	46
N=23		*SD*	32	38	44	48
	Low	M	92	58	32	42
		SD	24	40	38	40

There was also a significant Believability by Content interaction [F(2,70) = 5.24, p = .008, η_p^2 = .13] (Figure 8.2). Accuracy rates drop between high-believability and low-believability when the content is negative and they drop more drastically when the content is positive; but accuracy increases between high-believability and low-believability for control content. The difference between high- and low-believability items is statistically significant for positive content [t(24) = 3.32, p = .003, d = .33], but not for control, [t(22) = -1.24, p = .23], or negative content [t(24) = 1.33, p = .20]. This suggests that believability only has an effect when the content is positive, though may also be due to the limited difference in reported emotional experience between the negative and control conditions.

The difference in accuracy rates for low-believability problems is significant between positive and neutral content (p = .04, d = .27), but not for positive-control and control-negative comparisons (p = .17 and p = .47 respectively). For high-believability content, none of the pair-wise comparisons across content types was significant.

This is different from the patterns found in Experiments 6, 7, and 8 whereby accuracy typically increased across positive to control to negative content. The current results suggests that content valence has little effect when the items are believable, but when the items are unbelievable positive content leads to a decrease in accuracy. This is not due to differences in rates of drawing each inference between positive-believable and positive-unbelievable problems as no difference was found in the number of inferences drawn between these problem types [$t(24) = -.30$, $p = .77$]. However, the time spent considering positive-unbelievable problems was significantly longer (M = 8421ms, SD = 2811ms) than the time spent considering positive-believable problems [M = 7084ms, SD = 2837ms, $t(24) = -3.54$, $p = .002$, d = .49]; this increase in thinking time seems to have led to lower accuracy yet comparable rates of drawing each inference type.

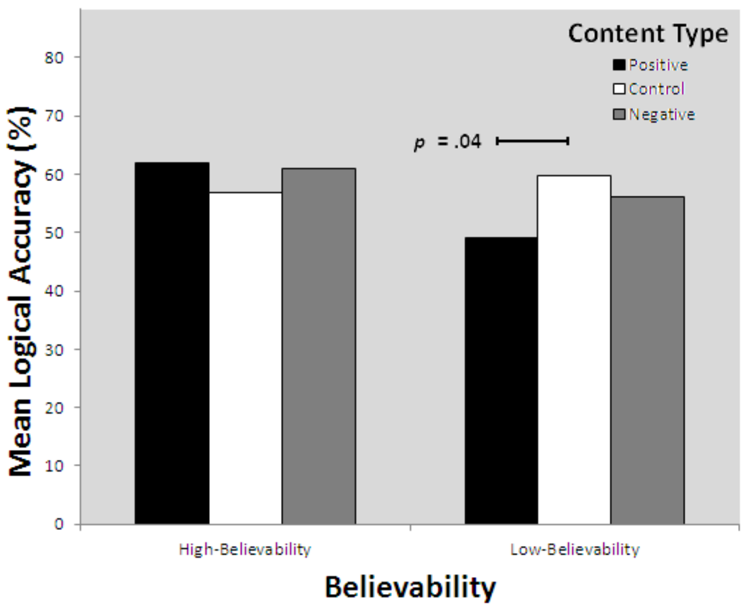


Figure 8.2 Beliebavility by Content-Type Interaction found in accuracy rates (Content varied between-participants, converse probability controlled)

A main effect of Inference type was also found [$F(3,210) = 31.25$, $p < .001$, $\eta_p^2 = .31$]; whereby MP inferences ($M = 87.33$, $SD = 26.06$) are responded to more accurately than MT ($M = 59.59$, $SD = 33.50$, $p < .001$, $d = .92$), MT more than DA ($M = 44.18$, $SD = 34.99$, $p = .03$, $d = .45$), and DA more than AC ($M = 38.36$, $SD = 36.34$, $p = .06$, $d = .16$). Although no main effect of Content ($p = .77$), no Believability by Inference interaction ($p = .12$), or any Content by Inference interactions ($p = .67$) were found, there was a marginal Believability by Inference by Content interaction [$F(6,210) = 2.06$, $p = .06$, $\eta_p^2 = .06$] (Figure 8.3).

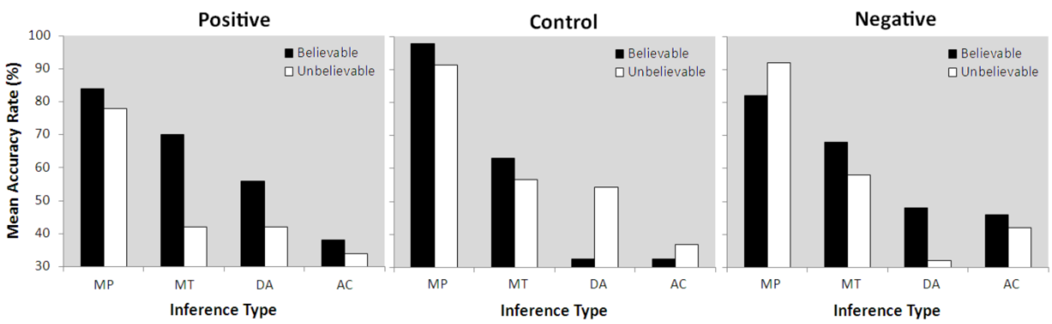


Figure 8.3 Marginal Inference by Believability by Content Interaction found within Accuracy Rates (Content varied between-participants, converse probability controlled)

The pattern shown by this three-way interaction suggests that high-believability items are generally responded to more accurately than low-believability items, though this difference is larger and more consistent with positive content. Under Control content, MP and MT show little effect of believability, but low-believability DA and AC inferences are responded to more accurately. With negative content, it is broadly the high-believability inferences that are responded to more accurately, as with positive content. Of interest in this (marginal) interaction is the difference of the control content condition. If the panels of Figure 8.3 are viewed as believability by validity interactions, they represent a similar finding to Chapter 5, showing a belief-bias-like effect – the interaction between logical validity and believability – that was reduced by emotive content. However, this should be treated with caution as the interaction here is only marginal, and will be returned to when rates of drawing the inference are analysed.

Rates of Drawing the Inference

In order to assess the potential reduction in belief-by-logic interaction caused by emotive content, which was hinted at in the analysis of accuracy rates, a 2 Believability (Believable, Unbelievable) x 2 Validity (Valid, Invalid) x 3 Content type (Positive, Control, Negative) mixed-ANOVA was conducted on rates of drawing the inference. The mean percentage of times MP and MT inferences were drawn were collapsed to create the Valid category, and DA and AC were collapsed to create the Invalid category. Descriptive statistics for each cell in this design are shown in

Table 8.4.

Table 8.4 Descriptive statistics for rates at which participants draw valid believable, valid unbelievable, invalid believable and invalid unbelievable conclusions, by emotive content; P(q|p) controlled, content varied between participants

		Valid		**Invalid**	
Content		**Believable**	**Unbelievable**	**Believable**	**Unbelievable**
Positive	M	77	60	50	51
N=25	*SD*	*31*	*35*	*41*	*29*
Control	M	80	74	66	53
N=23	*SD*	*18*	*28*	*36*	*44*
Negative	M	75	75	49	55
N=25	*SD*	*29*	*25*	*44*	*31*

A main effect of validity was found [$F(1,70) = 28.31$, $p < .001$, $\eta_p^2 = .29$], whereby valid inferences (M = 73.56, SD = 27.78) are drawn more frequently than invalid inferences (M = 54.09, SD = 37.62). This did not interact with content type or believability however. No main effect of believability was found, nor did believability interact with content type. There was also no main effect of content type, although validity, believability and content did show a significant three-way interaction [$F(2,70) = 3.10$, $p = .05$, $\eta_p^2 = .08$], depicted in Figure 8.4. The belief-bias effect, or conditional equivalent, only seems to be present to some extent in the positive and negative content conditions, and only insofar as the interaction represents differing effects of belief over levels of validity. The direction of the effect is almost reversed between positive and the negative conditions. Belief has a larger effect on valid problems when they contain positive content, but a larger effect on invalid problems when the content is negative. Though the overall increase in the validity by believability interaction for positive and negative content is the same as the effects found in Chapter 5 with syllogistic reasoning, that the directions differ suggesting that the finding is less robust than expected, and explanations for this will be considered in the summary of this experiment.

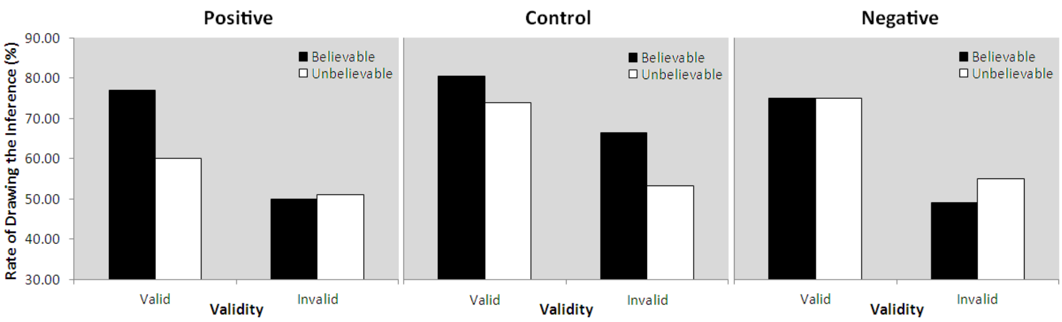


Figure 8.4 Validity by Believability by Content type interaction in rates of drawing the inference; content between-paticipants, converse probability controlled

8.1.3 Summary of Experiment 9

Experiment 9 replicates the findings of Experiments 6, 7, and 8 in that the accuracy rate for valid inferences is higher than the accuracy rate for invalid inferences, and that accuracy broadly decreases across MP to MT to DA to AC inference. The previous finding that inferences related to high-believability conditionals were responded to more accurately than those related to low-believability conditionals was also replicated. Although no main effect of content was found, content did interact significantly with inference type and believability, suggesting that the belief effects vary as a function of inference type, and that this relationship varies as a function of content type as described above. Of particular interest is the fact that believable DA and AC inferences are responded to much more accurately than unbelievable DA and AC inferences when the content is positive and negative, but unbelievable DA and AC inferences are responded to more accurately with control content. These results are similar to those found in Experiments 6, 7, and 8 in which content effects are most pronounced on DA and AC inferences. They are however smaller than the previous differences, suggesting that controlling for the number of alternative antecedents reduces content effects, which in turn suggests that content effects may be the results of content varying the use of or search for alternative causes.

When the rates at which each inference is drawn are considered, the main effect of validity is found again, though believability and content have little effect. However, of interest was the different effect of belief across levels of validity found for positive and negative content. The previous findings with syllogistic reasoning (Chapter 5) that belief-bias is reduced by emotive content does not seem to hold in conditional reasoning, although this may be due to the variability of believability within conditional statements and premises as they have been presented here. For example, although a conditional statement may have been rated as believable, such as “If it rains, then the roads will be wet”, the premises may have a different level of belief (“It rains”, “The roads are wet”, “It did not rain”, “The roads are not wet”), and it is unclear which ‘beliefs’ will be relied upon or ignored during the reasoning task.

However, controlling for converse probability (and alternative antecedents) goes some way to matching inference believability to conditional believability. Furthermore, the results still tell us about how inferences drawn from highly-believable and less believable statements are affected by emotion, and this is useful in comparing the different effects of emotion across syllogistic and conditional reasoning. That different effects of belief are found highlights the need to consider not only the source of the believability when interpreting results from research on reasoning and emotion, but also serves to highlight the need to consider differences across types of reasoning task.

8.2 Using a Standard Presentation Set (Experiment 10)

Up to this point, the premise-conclusion pairings used by Blanchette and colleagues have been adopted in order to replicate the original designs as closely as possible whilst controlling for confounds in the original materials. These issues have been discussed previously. However, within the reasoning literature the pairings such as those presented earlier in Table 7.1 (reproduced below in the top portion of Table 8.5) are not commonly used, and as such, Experiment 10 uses premise-conclusion pairings more typical of the reasoning, rather than emotion, literature. The conditionals were again controlled for converse probability, and content varied between participants.

The data reported here is derived using the same experimental procedure as in Experiment 9, with the same set of conditionals which control converse probability. However, it restricts the response options available to participants to *Yes* and *No*, as well as using more common pairings of premise-conclusion statements, rather than those used by Blanchette and Richards' (2004). This brings the current study's methodology in line with methods more typically used in the thinking and reasoning literature whereby individuals are required to indicate whether an inference in valid or not. This enables the current experiment to evaluate content effects in relation to previous work on conditionals outside of the emotion literature, which has thus far been the focus of the work in Chapters 6 and 7, as well as allowing a more direct comparison with the work on syllogisms in which typical response options are valid (Y) and invalid (N). These differences can be seen in Table 8.5.

Table 8.5 Non-standard Premise-Conclusion pairs taken from Blanchette and Richards (2004) compared with the more typical pairings used in the current study (Experiment 10)

Inference	Premise	Conclusion	Responses
Blanchette and Richards (2004)			
MP	P	q?	Y/N/Maybe
MT	¬q	p?	Y/N/Maybe
DA	¬p	q?	Y/N/Maybe
AC	q	p?	Y/N/Maybe
Experiment 10			
MP	p	q?	Y/N
MT	¬q	¬p?	Y/N
DA	¬p	¬q?	Y/N
AC	q	p?	Y/N

8.2.1 Method and Results

Participants, Design, and Procedure

Participants recruited for this study were 90 students (30 male) from Plymouth University who participated for course credit. Their mean age was 23 years (*SD* = 5.97). A 2 Believability (High, Low) x 3 Content Type (Positive, Control, Negative) x 4 Inference Type (MP, MT, DA, AC) mixed-ANOVA was conducted, as in the previous experiments, on both logical accuracy and on the rates at which each inference type is drawn. Content type was varied between participants.

Reasoning Accuracy

Means and standard deviations for each cell in the design, based on accuracy, are shown in Table 8.6.

Table 8.6 Descriptive Statistics for participants' accuracy rates on conditionals with emotive content, usign a standard presentation pairing (Content varied Between-participants)

			Inference Type			
Content	**Believability**		**MP**	**MT**	**DA**	**AC**
Positive	High	M	67	47	34	23
N=30		*SD*	48	41	32	37
	Low	M	83	39	24	38
		SD	27	40	35	41
Control	High	M	100	31	48	23
N=30		*SD*	0	36	45	39
	Low	M	98	48	39	22
		SD	9	43	38	36
Negative	High	M	94	31	36	28
N=30		*SD*	15	33	36	43
	Low	M	90	41	38	40
		SD	28	44	33	44

The analysis of accuracy data showed a significant main effect of inference type [$F(1,261) = 103.17$, $p < .001$, $\eta_p^2 = .54$], and a significant interaction between inference and content type [$F(6,261) = 3.15$, $p = .005$, $\eta_p^2 = .07$]. There was also a significant three-way interaction between inference type, believability, and content type [$F(6,261) = 3.02$, $p = .007$, $\eta_p^2 = .07$]. No other main or interaction effects reached statistical significance.

The effect of inference type appeared to be that responses to MP inferences were much more accurate than responses to MT, DA or AC inferences (all pairwise comparisons p<.001). Accuracy rates on AC inferences were significantly lower than on MT inferences ($p < .05$), but MT-DA and DA-AC pairwise comparisons did not reach statistical significance. The interaction between believability and inference type suggests that low-believability conditionals are responded to more accurately than high-believability conditionals when the inference is MP, MT or AC, but that for DA inferences high-believability conditionals are responded to more accurately than low-believability ones.

The interaction between inference type and content type is shown in Figure 8.5 which also highlights the only statistically significant pairwise comparisons. These patterns suggest that content only has a significant effect on accuracy rates for MP inferences, such that positive content leads to lower accuracy rates, whereas there is no difference between control and negative content.

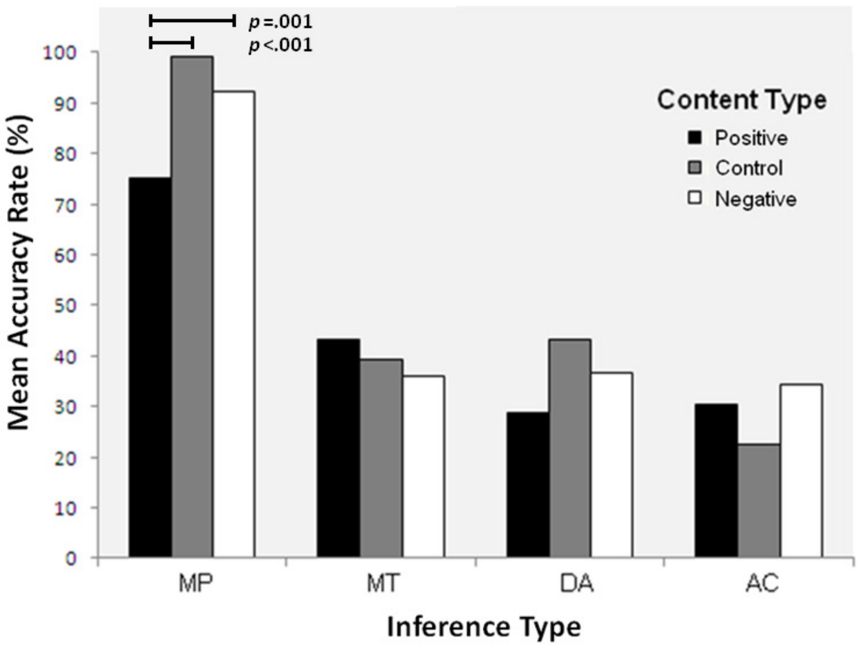


Figure 8.5 Inference by Content Type interaction, standard presentation, converse probability controlled, content varied between-participants

The three-way interaction between believability, inference type and content type shown in Figure 8.6 suggests that moving from high-believability to low-believability conditionals increases the rates at which MP and AC inferences are drawn, but decreases the rates at which MT and DA inferences are drawn - when the content is positive. Moving from high-believability to low-believability conditionals has little effect on MP and DA rates but increase the drawing of MT and AC inferences – when the content is negative. Finally, the move from high-believability to low-believability shows little effect on MP and AC drawing but increases in MT and decreases in DA rates - when the control content is used. Although these patterns do not appear to be particularly robust, as indicated by their variability across experiments (compare, for example, Figure 8.6 with Figure 8.3), that content alters the effect of believability differently across inference types is interesting in that it provides some suggestion that content has its effect on reasoning by altering the reliance on beliefs. This relates back to the belief-bias like effect found in Experiment 9, in which the effect varies across content types, and supports the use of paradigms which incorporate believability as a factor in exploring the interaction between emotion and reasoning.

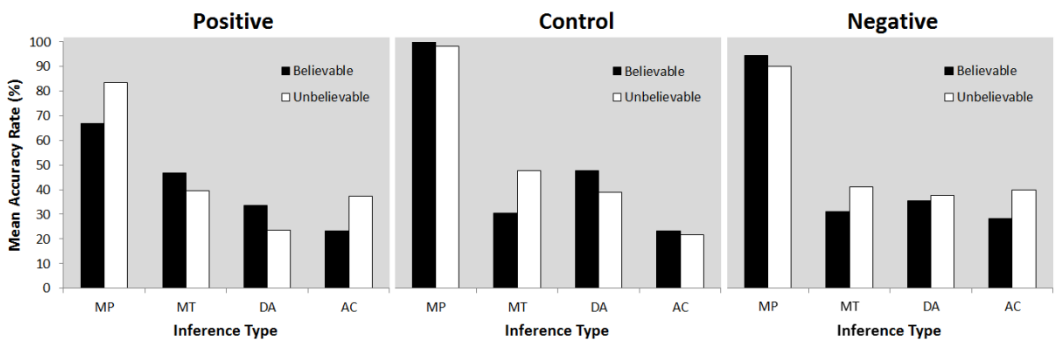


Figure 8.6 Inference by Content Type by Believability interaction in accuracy rates; standard presentation, converse probability controlled, content varied between-participants

Rates of Drawing the Inference

Means and standard deviations for each cell in a 2 Believability (High, Low) x 2 Inference Type (MP, MT, DA, AC) x 3 Content Type (Positive, Control, Negative) design, based on the inferences drawn can be found in Table 8.7,

Table 8.7 Descriptive Statistics for participants' rates of drawing the inference; 2 Believability (Believable, Unbelievable) x 3 Content Type (Positive, Neutral, Negative) x 4 Inference Type (MP, MT, DA, AC)

			Inference Type			
Content	**Believability**		**MP**	**MT**	**DA**	**AC**
Positive	High	M	98	47	66	77
N=30		*SD*	9	41	32	37
	Low	M	83	39	76	63
		SD	27	40	35	41
Control	High	M	100	31	52	77
N=30		*SD*	0	36	45	39
	Low	M	98	48	61	78
		SD	9	43	38	36
Negative	High	M	94	31	64	72
N=30		*SD*	15	33	36	43
	Low	M	90	41	62	60
		SD	28	44	33	44

The analysis of rates at which inferences are drawn showed a significant effect of Inference Type [$F(3,261) = 41.19$, $p < .001$, $\eta_p^2 = .32$], whereby MP inferences were drawn most frequently ($M = 94.07$, $SD = 13.76$), followed by AC ($M = 70.97$, $SD = 36.71$), DA ($M = 63.80$, $SD = 30.36$), and finally MT inferences ($M = 39.44$, $SD = 35.20$). All pairwise comparisons were significant at $p<.001$, except the difference between DA and AC, which was not statistically significant. This pattern of results matches those found in Chapter 7. Believability also interacted with content type [$F(2,87) = 6.26$, $p = .003$, $\eta_p^2 = .13$].

As can be seen from the depiction of this interaction in the upper panel of Figure 8.7, positive content leads to an overall higher rate of drawing the inferences than control or negative content. However, when the conditional is less believable, positive and negative content reduce the rates at which inferences are drawn relative to control content. This is a result which was not found in the inference rate data from Experiment 9, although for comparison, the non-significant content by believability interaction is shown in the lower panel of Figure 8.7. There was also a believability by inference type interaction [$F(3,261) = 4.55$, $p = .004$, $\eta_p^2 = .05$], such that people drew MP and AC inferences less when the conditional was low- than when it was high-believability, but people drew MT and DA inferences more frequently when the conditional was low- than when it was high-believability.

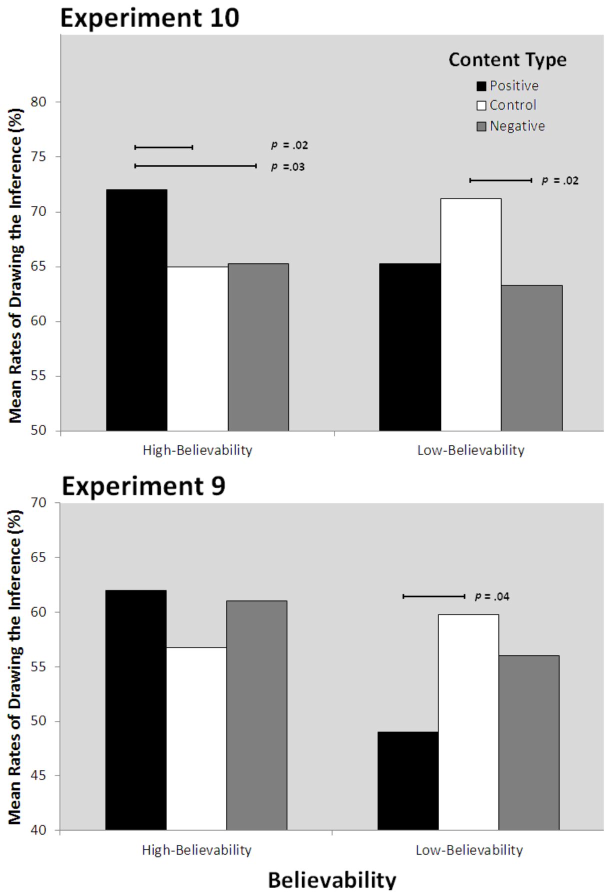


Figure 8.7 Rates at which each inference is drawn by Belieavbility and Content Type; standard presentation, converse probability controlled, content varied between-participants

For direct comparison with Experiment 9, a 2 Believability (Believable, Unbelievable) x 2 Validity (Valid, Invalid) x 3 Content Type (Positive, Control, Negative) analysis was ran whereby the validity levels were created by collapsing inference type as in Section 8.1.2. Means for each cell are shown in Table 8.8.

Table 8.8 Descriptive statistics for rates at which participants draw valid believable, valid unbelievable, invalid believable and invalid unbelievable conclusions, by emotive content; P(q|p) controlled, content varied betweenparticipants, standrad presentation.

		Valid		Invalid	
Content		**Believable**	**Unbelievable**	**Believable**	**Unbelievable**
Positive	M	73	61	72	69
	SD	22	19	27	32
Control	M	65	73	64	70
	SD	18	23	31	32
Negative	M	63	66	68	61
	SD	19	24	33	30

The analysis revealed no main effect of validity, believability or content type; only a believability by condition interaction which is captured by the analysis above.

8.3 Discussion of Experiments 9 and 10

The results from Chapter 7 showed that positive content in conditional reasoning tasks leads to lower rates of logical accuracy than negative or control content, but that this effect was found mostly on DA and AC inferences. The current chapter tested whether differences in the availability of alternative antecedents across the experimental conditions could account for these patterns of responding, and as a result, provides a replication of the experiments in Chapter 7 with materials for which converse probability is controlled as a correlate of alternative antecedents. Experiment 9 is a direct replication of the design of Experiment 7 using the new materials, and Experiment 10 is a replication of the design, with the new materials, but using response options more typical of the conditional reasoning literature.

Accuracy Rates and Drawing the Inference

In both experiments, an effect of inference type was found whereby accuracy rates decreased across MP to MT to DA to AC inferences. The main effect of believability which has been found previously in this thesis, namely, that unbelievable conditionals generally lead to lower accuracy rates then believable conditionals was only replicated in Experiment 9. The data from this experiment also showed believability to interact with content type, though in a different way to that found in earlier experiments. Rather than the increasing accuracy across positive to control to negative content found in Chapter 7, Experiment 9 shows only small effects suggestive of both positive and negative content increasing accuracy when the conditional is believable, but impairing logical accuracy when the conditional is less believable. No main effects of content were found on logical accuracy in either experiment reported in this chapter. There is however some suggestion that positive content leads to lower logical accuracy than control or negative content, though this is primarily found with MP inferences. Neither of these patterns is particularly strong, and neither is in line with current theories of how emotion might be expected to interact with reasoning.

Rates of drawing the inference show few similarities between Experiments 9 and 10. Experiment 9 found valid inferences to be drawn more than invalid ones, but this did not replicate in Experiment 10, although inference type did significantly affect rates of drawing the inference. In experiment 9, believability did not interact with content type as it did in Experiment 10, though these patterns of drawing the inference bear little relation to the way in which accuracy rates vary as a function of believability and content type in Chapter 7. Finally, the three-way interaction between believability, validity, and content found in experiment 9, showing increased believability by validity interactions with positive and negative, relative to control, content, was not found in Experiment 10.

It is interesting that controlling for $P(q|p)$ eliminates the differences in reasoning accuracy across content types, suggesting that they are a function of converse but not conditional probabilities. Either the differences in previous experiments between content types was due to the differences in the availability of alternatives, although, not having been controlled it might be assumed that they didn't vary systematically; or the emotional valence of content appears to act through the converse probability, at least to a small degree. Though this study did not set out to investigate this, it suggests a profitable avenue for future research in terms of which aspects of conditional statements are influenced by emotional valence. This has particular relevance when the number of alternatives is considered in terms of alternative models which need to be evaluated (Cummins, 1997; Cummins et al., 1991), and given that the effectiveness of such a search, or the inclination to begin such a search, may be determined by emotion.

An additional avenue of research would be to consider in more detail the effect of changing the presentation from *Yes-No-Maybe* to *Yes-No*; forcing individuals to respond with yes or no forces them to guess if they are unsure which may reduce any effects of content by increasing the variability in each condition. Drawing on ideas from eye-witness testimony (e.g. Weber & Perfect, 2011), replacing the 'Maybe' response with a 'Don't Know' response might serve to clarify the effect of emotive content by removing extraneous variability from the dataset. By allowing the exclusion of cases where individuals would otherwise be forced to guess *yes* or *no*, *valid* or *invalid*, *follows* or *does not*, 'noise' created by such guessing would be removed and make any effects of emotive content clearer.

In relation to the existing literature, the accuracy results from Experiments 9 and 10 largely replicate the effects of inference type found by Blanchette and Richards (2004), though the effects of content do not – Blanchette and Richards found happy and sad content to reduce logical accuracy, whereas Experiments 9 and 10 found no main effects. Experiment 10 found different results for accuracy; MP inferences were responded to much more accurately than MT, DA, and AC, all of which were responded to with comparable accuracy; in relation to Blanchette and Richards' results showing that accuracy decreased from MP to MT to AC to DA inferences. In terms of the interaction between content type and inference type found in Experiment 10, positive and negative content led to comparable accuracy rates on MT, DA and AC inference, but negative content leads to higher accuracy than positive content on MP inferences. This is contrary to Blanchette and Richards' finding that positive and negative content both suppressed logical accuracy on MP inference relative to control content, and to similar degrees.

Subjective Mood and Emotive Content

The inclusion of a pre- and post-reasoning mood measure in Experiment 9 allowed and investigation of the extent to which emotive content altered subjective mood ratings. This element was included to address the questions raised previously as to whether content creates a subjective mood state or not, and whether this might be one way in which emotive content alters reasoning. In combination with the pre-test data, it was found that although content may be perceived and rated as more or less positive or negative, this did not result in changes in subjective mood ratings across the content conditions. The implications of this are that the few effects found in Experiments 9 and 10 that relate to content effects (integral emotion) cannot be attributed to 'experienced' emotion; content does not have its effect, with the current materials at least, by altering an individuals' subjective emotional state.

In relation to information and load theories, if it is the generation and maintenance of an emotional state which is thought to be the source of cognitive load, this would explain the lack of support for load theories found in the current results. Similarly, it provides an explanation for the small amount of support found for the information theories; both integral and incidental emotion contain information, so that content does not alter subjective mood does not undermine the information explanation.

Summary

In summary, differences in reasoning performance found between positive, negative, and control emotion on DA and AC inferences are removed or reduced when the converse probability is controlled in verbal conditionals. The patterns found in Experiments 6, 7, and 8 of support for information theories do not replicate clearly, and the suppression of logical accuracy by positive content is small. However, these findings lay the groundwork for developing more refined experimental designs in future work, highlighting the need to carefully control the availability of alternatives. In this sense they contribute to our understanding of emotion effects in reasoning by providing much more controlled studies than currently exist in the literature.

Although controlling $P(p|q)$ appears to eliminate content differences in verbal conditionals, converse probabilities were controlled in Experiment 8, with visual conditionals, and negative imagery led to higher accuracy rates than positive imagery. That content effects are more robust in visual tasks is interesting, and provides yet another avenue for future investigation. It might be hypothesised that the difference between moods across verbal and visual content is a result of familiarity with the (verbal) problem format, and a form of discounting. The extent to which individuals, especially student populations, have been exposed to both syllogistic and conditional reasoning and the extent to which they may have developed certain expectancies or schemas may be related to the extent to which they attend to their emotions. If an individual enters an experiment they perceive as a reasoning task, they may be cued to ignore (discount) emotion as a source of information. The visual conditionals used in Experiment 8 provide one possible avenue for exploring emotion effects in a paradigm which is less familiar and thus likely to be less prone to this discounting effect than verbal conditional reasoning and syllogistic tasks. However, in the interest of exploring emotion effects across a broader range of paradigms, the following chapter will investigate the effect of incidental emotion on the Ratio-Bias task (e.g. Denes-Raj & Epstein, 1994). This task requires individuals to decide from which of two boxes of black and white ‘marbles’ they are more likely to select a black marble, and contrasts low-effort frequency-based responding with higher-effort probability-based responding. As such, the use of the ratio-bias task develops the idea of comparing low- and high-effort processing of reasoning and decision making tasks in a way which is similar to the Belief-Bias paradigm but which is less reliant on formal logical rules.

Chapter Nine

Ratio-Bias and Incidental Emotion

9.1 Introduction

In changing from the Necessity-Possibility paradigm to the Belief-Bias paradigm in Chapter 5, the fact that reasoning tasks may not necessarily measure the relative use of Type One versus Type Two processes, but rather the amount of Type Two processing was discussed (Section 2.2.4). Whereas the Necessity-Possibility paradigm seems likely to do the latter, the Belief-Bias paradigm, by putting logic and belief in conflict, provides a way of contrasting the relative use of the two systems. In the Necessity-Possibility paradigm differences in accuracy between emotion conditions may be seen as the result of differing levels of Type Two engagement, reflected in the number of models evaluated for each problem, rather than the difference between Type One and Type Two based responding (Chapter 4). In contrast, the Belief-Bias paradigm allows a measure of both the reliance on analytic processes and on prior beliefs, and it is this contrasting of the systems which is returned to in the current chapter.

The studies reported so far have focused on typical reasoning problems in the form of syllogistic and conditional reasoning tasks, and they have investigated incidental and integral emotion, and, as outlined above, the effects of emotion have been considered in relation to increases in Type Two processing or relative use of Type One and Type Two processing. The findings from these studies have been mixed, though there is some consistent support for Information Theories (e.g. Chapter 7); those which posit positive mood will impair logical performance, but negative mood will increase logical performance. The focus of the current chapter is an alternative paradigm to these tasks which provides another way of assessing the relative reliance on Type One and Type Two processing; The Ratio-Bias task. This complements the work on the Belief-Bias paradigm by comparing two different types of Type One and Type Two process other than belief and logic, using instead frequency-based and probability-based judgements. Such a paradigm allows the generalisability of the results from Chapter 5 to be investigated, whilst also allowing incidental emotion to be examined in a different type of task.

In the typical ratio-bias task, a scenario is outlined whereby the individual is presented with two boxes, each containing a given number of black marbles and white marbles. These numbers, for each box, are given to the participant. They are then told that their task is to select the box from which they are most likely to draw a black marble should they reach in blindfolded and take one out at random.

The properties of this task can be manipulated to contrast low versus high effort response strategies; for example the number of marbles of each colour in the boxes can be manipulated such that the frequency of black marbles and the probability of drawing a black marble are either congruent or incongruent. That is, the choice of a box based on the absolute number of black marbles (Frequency) can be made to coincide with the relative number of black marbles (Probability). For example, if Box A contains 5 black marbles, and 5 white marbles, and Box B contains 2 black marbles and 8 white marbles, choosing based on Frequency and Probability yield the same selection: Box A. To extend this explanation; based on Frequency, there are more black marbles in Box A than in Box B. Thus Box A will be selected. Similarly, based on Probability, there is a 50% chance of selecting a black marble from Box A versus only a 20% chance of selecting a black marble from Box B. Consequently, Box A should be selected as the most likely to yield a black marble. In this case, Frequency and Probability are said to be 'congruent'.

However, Frequency and Probability can also be made incongruent, such that each strategy leads to a different selection. For example, if Box A contains 5 black marbles and 5 white marbles, but Box B contains 10 black marbles and 30 white marbles. In this case, the frequency of black marbles is higher in Box B, whereas the probability of selecting a black marble is higher in Box A (Box A = 50%, Box B = 25%).

If these two strategies, selecting based on frequency versus selecting based on probability are considered low-effort versus high-effort processing, then the ratio-bias task presents a useful analogue to the syllogistic and conditional reasoning tasks in which believability and validity are manipulated. Furthermore, given recent work which has suggested that belief-based responding may not in fact be a Type One response (Handley et al., 2011), the Ratio-Bias task avoids this assumption by comparing frequency and probability based judgements rather than belief and logic based judgements. Although manipulation of integral emotion is somewhat problematic in this task, incidental emotion can be manipulated, and thus allows an investigation of the impact of incidental emotion on the use of frequency and probability based strategies. This is discussed below when considering the inclusion of emotion in the Ratio-Bias paradigm (Section 9.2).

In summary, taking into account this evaluation of both Type One and Type Two processes the current chapter turns away from traditional reasoning tasks, and presents studies which utilise a ratio-bias task (Pacini & Epstein, 1999). This task makes use of discrepancies between the probability of an outcome and the perceived frequency of an outcome in order to assess the relative use of frequency- and probability-based strategies in decision making. Given that probability based judgements are more effortful and require more cognitive processing than frequency based judgements, the ratio-bias task can be seen as a way of distinguishing between high- and low-effort strategies. This dichotomy, although potentially over-simplifying the range of processes that may be involved in the task, provides a link to dual-process theories of reasoning, and the different reasoning strategies which may be utilised. Thus the ratio-bias task provides a paradigm which fits well within the theoretical framework adopted for the investigation of syllogistic and conditional reasoning, but extending the investigation from logic and belief to frequency and probability.

9.2 Experiment 11

Previous research has shown that individuals tend to favour the higher frequency options (Pacini, Muir, & Epstein, 1998), even when the probability of the target outcome is worse (Denes-Raj & Epstein, 1994). It has also been found that the degree of difference in the probability of drawing a black marble between the 'correct' and 'incorrect' options is related to the number of optimal responses (Denes-Raj & Epstein, 1994). If there is a larger difference between the options in the absolute probability of selecting the desired coloured marble, people find it easier to make the correct selection.

In the current study the incidental emotion (mood) of individuals will be varied between positive, control, and negative. Incidental as opposed to integral emotion was chosen for these studies in order to simplify the design of the study and aid interpretation of the results. If integral emotion had been varied, the items in each box would have been necessarily different to generate different emotions. This in turn is likely to have required less than perfect matching of size, shape, colour, and properties such as their ability to capture attention. Given that individuals have been shown to attend more to negative elements in verbal and visual arrays (Forgas, 2007; Pratto & John, 1991; Schimmack, 2005), it was deemed preferable to focus on incidental emotion, and thus control for stimulus variables such as those listed above by using the same visual items (marbles) across conditions.

The degree of difference in absolute probability of selecting the desired target from each box (Difficulty) will also be manipulated. It is expected that as in previous research, when the difference in probabilities is low (High Difficulty; Hard), people will make more incorrect, sub-optimal box choices than when the difference is large (Low Difficulty; Easy). Congruency will also be manipulated, and would be expected to impair performance. That is when the frequencies and probabilities lead to different box selections (Incongruent trials), higher numbers of incorrect choices would be expected than when both strategies lead to the same choice of box (Congruent trials), based on the assumption that individuals may be more reliant on frequency cues than probability cues as these require less effort to process; frequency computations do not require the relative frequencies of black and white marbles to be compared within and between boxes.

Previous work in this thesis has used the conflict of logic and belief in the belief-bias paradigm to provide a test of the effects of emotion on Type One and Type Two processing. In the ratio-bias task, this idea of conflicting responses from each type of processing is achieved by varying the congruency of the responses from frequency and probability based processing. In the current design, it is incongruent trials which put frequency-based and probability-based responses in conflict alongside the manipulation of mood. When both frequency and probability lead to the same choice of box, both systems lead to the same response, and few effects of mood would be expected regardless of how emotion affects reasoning. Similarly, the effects described above and found in the previous work on the ratio-bias task would be expected in the control condition (Denes-Raj & Epstein, 1994; Pacini et al., 1998), namely a larger number of errors when frequency and probability indicate different boxes, and a higher reliance on frequency when problems are more difficult; that is, when the difference in absolute frequency of selecting a black marble from each box is smaller as opposed to larger.

However, in the positive and negative conditions, the effect of congruency and difficulty would be expected to differ from the control condition if emotion served as load or information. If mood serves as a source of cognitive load, the effects of difficulty and congruency would be expected to be more pronounced, with more individuals basing their decisions on frequency-based cues due to limited processing capacity. If the incidental emotion served as information, then negative mood would be expected to suppress the effects of congruency and difficulty, directing the individual to invest more effort in the calculation of probabilities than relying on frequency-based information. Positive mood on the other hand would be expected to increase the congruency and difficulty effects, directing individuals to accept the more easily accessible frequency-based responses. Details of how these factors will be varied are described in the methods sections, followed by the findings.

9.2.1 Method and Materials

Participants

The participants in this study were 70 (9 male) undergraduate psychology students (Age; M = 24 years, SD = 8 years) at Plymouth University who participated for course credit. Participants were randomly allocated to one of the three mood conditions, positive (N = 26), control (N = 22), and negative (N = 22).

Mood Manipulation Task

In order to manipulate participants' moods, the writing task described in Chapter 3 was used (Brand et al., 2007) in which participants were required to type about a positive, control, or negative life event for ten minutes. This task was completed after participants had been briefed and signed consent forms. The instructions for this task were identical to those used for the manipulation of incidental emotion in Experiments 1 and 5.

After completing this task but before beginning the ratio-bias task participants were asked to rate their current mood using a sliding scale ranging from 0 (Very Sad) to 100 (Very Happy). They were also asked to complete this mood rating procedure after they had finished the ratio-bias task. After this final mood rating, prior to debriefing, participants were asked to read and rate a selection of jokes as in previous studies to neutralise any negative effects of the mood manipulation.

Ratio-Bias Task

The ratio-bias tasks consisted of a series of 56 pairs of boxes presented on screen to participants. Each box contained a selection of black and white marbles. Participants were instructed to indicate from which box they would be most likely to draw a black marble. The full text of the brief, instructions, and debrief can be found in Appendix E. Decisions were indicated by clicking a button which was displayed below each box, and which were labelled Box One and Box Two for the left and right boxes respectively. An example trial screen is shown in Figure 9.1.

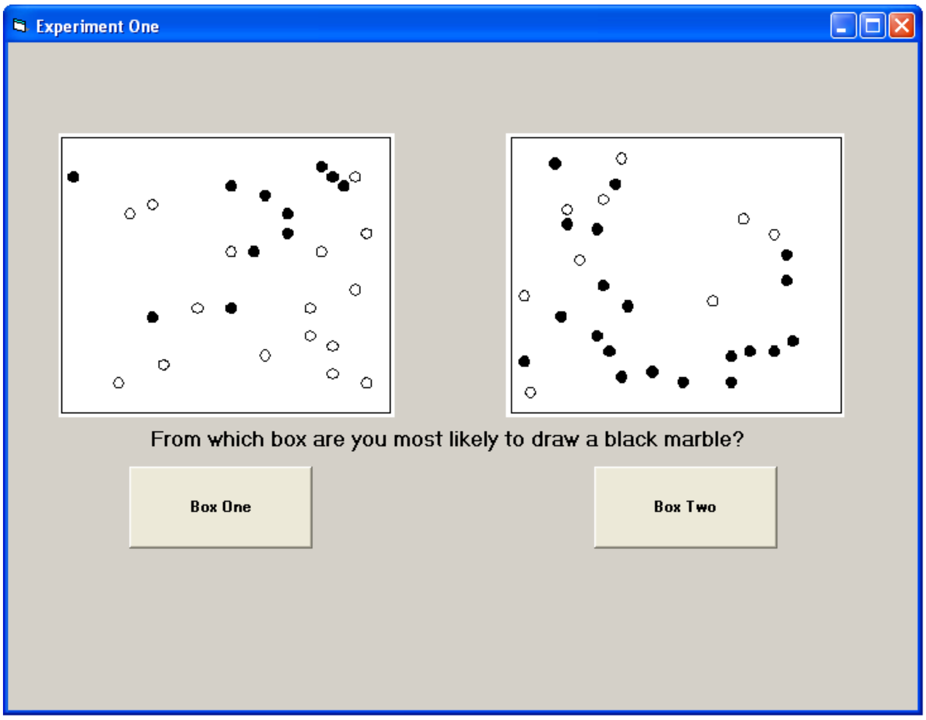


Figure 9.1 An example Ratio-Bias task trial

Congruency and difficulty were crossed across the trials. Items could either be Congruent, whereby black marble frequency and probability were highest for the same box, or Incongruent, whereby black marble frequency and probability are highest in different boxes. Difficulty was varied by the discrepancy in the probability of drawing a black marble across the boxes. In high (Hard) difficulty trials, the difference in probabilities was between 5% and 20%. For example, if Box A has a 35% probability of drawing a marble, and Box B has a 40% chance of drawing a marble, the difference in probabilities in 5%, and the trial is classified as 'hard'. In low difficulty (Easy) trials, the difference was between 25% and 40%.

Trial items were created using *R* (Venables & Smith, 2010) in conjunction with a script designed by D. Trippas (personal communication, 2010) to plot black and white points at random. After specifying the total number of marbles to be included in each 'box', and specifying the number of black marbles to be included, the script generated two boxes with black and white marbles randomly distributed across the 'boxes', which are treated as graphical planes by the program. A variant of this script was used in Experiment 12 and is available from the author. This method of specifying the properties of the images and then plotting them was used to create all test trials in both experiments.

The resulting design of this study was a 2 Difficulty (Easy, Hard) x 2 Congruency (Congruent, Incongruent) x 3 Mood (Positive, Control, Negative) mixed factorial ANOVA conducted on the number of optimal box choices (Accuracy); those for which the *probability* of drawing black marble is highest.

Procedure

The experimental procedure for this study broadly followed the previous studies. Participants were seated at computer terminals in a laboratory, and were presented with a brief and instructions on screen. Progression through the program was controlled by mouse-click responses. Following the brief and consent screens, participants completed the mood manipulation task, followed by a mood rating scale. This was followed by the ratio-bias trials, which were followed in turn by another mood rating scale. To conclude, a joke rating section was presented followed by the debrief.

9.2.2 Results

The mood ratings showed a significant main effect of condition [$F(2,67) = 5.964$, $p = .004$, $\eta_p^2 = .15$], with mood ratings decreasing across positive ($M = 68.08$, $SD = 13.83$) to control ($M = 62.68$, $SD = 14.56$) to negative ($M = 49.59$, $SD = 26.22$). Pairwise comparisons revealed the difference between negative and control, and negative and positive to be the statistically significant ($p = .024$, $d = .62$ and $p = .001$, $d = .92$

respectively), with the positive-control difference not reaching statistical significance despite being medium in size and in the intended direction (p = .33, d = .38).

The mean accuracy rates for each cell of the design are shown in Table 9.1. Accuracy is defined as the percentage of trials on which the participant selected the box with the highest probability of selecting a black marble. The results showed a significant main effect of congruency [F(1,67) = 49.55, p < .001, η_p^2 = .43], and difficulty [F(1,67) = 338.81, p < .001, η_p^2 = .84], suggesting that congruent items (88%) are responded to more accurately than incongruent items (82%), and easy items (92%) are responded to more accurately than hard items (78%). These results replicate those of previous work (Denes-Raj & Epstein, 1994; Pacini et al., 1998).

Table 9.1 Mean accuracy rates (%) and SD's for the ratio-bias task, for each mood condition, by congruency and difficulty condition (Experiment 11)

Congruency		**Congruent**			
Difficulty		**Easy**		**Hard**	
		M	*SD*	*M*	*SD*
Mood	Positive	93.13	1.40	82.97	9.71
	Control	91.88	3.34	85.06	11.00
	Negative	93.51	2.10	84.09	6.59
	Total	92.86	2.43	83.98	9.22
Congruency		**Incongruent**			
Difficulty		**Easy**		**Hard**	
		M	*SD*	*M*	*SD*
Mood	Positive	92.58	1.40	73.35	8.70
	Control	90.91	9.14	75.97	15.04
	Negative	92.86	9.68	68.83	9.99
	Total	92.14	5.18	72.76	11.62

Congruency and difficulty also showed a significant interaction [F(1,67) = 33.09, p < .001, η_p^2 = .34]. This suggests that congruency has a much larger impact when the items are more difficult; such that both congruent and incongruent easy items were responded to equally accurately (*M* = 93% and *M* = 92% respectively), whereas difficult incongruent items were responded to much less accurately than difficult congruent items (*M* = 73% and *M* = 84% respectively).

No main effect was found for mood condition [$F(2,67) = 0.288$, $p = .75$, $\eta_p^2 < .01$], and mood did not interact with congruency, but showed a similar pattern to the significant interaction found between mood and difficulty [$F(2,67) = 4.77$, $p = .012$, $\eta_p^2 = .13$]. This interaction (Figure 9.2) suggests that the effects of mood are larger for more difficult items. The difficulty by mood interaction is driven by the change in the relative accuracy of each mood condition between easy and hard items. On easy items there is little effect of mood, yet on hard items positive and negative emotion leads to lower accuracy than the control condition; however, univariate ANOVAs revealed the mood effects within hard items to be non-significant.

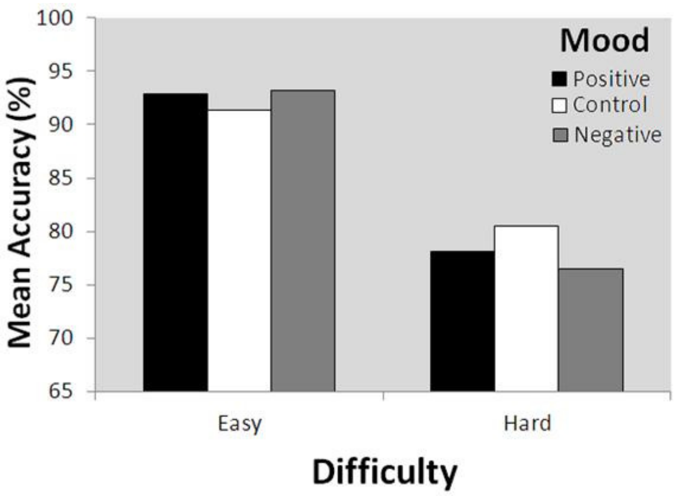


Figure 9.2 Difficulty by Mood Interaction (Experiment 11)

These findings, and the lack of a significant congruency by condition interaction suggests that mood does not necessarily inhibit Type Two high-effort processing, but rather reduces the effectiveness with which it is employed. If mood had an impact on the amount of Type Two processing, the congruency factor is the one which would be expected to show effects as the incongruent items put the responses from frequency- and probability-based processing in conflict. That mood only interacts with difficulty suggests that the effect is due to difficulty rather than conflict.

Summary of Experiment 11

The results of Experiment 11 replicate the findings of previous work (Denes-Raj & Epstein, 1994; Pacini et al., 1998) in that accuracy is higher for congruent than incongruent items, and higher for easy than hard items. The interaction between difficulty and mood seems to suggest, similarly to the results of Chapter 7, that emotion effects are found primarily when the tasks are more difficult. However, whereas Experiments 6, 7, and 8 provided support for Information theories, with accuracy increasing across positive to control to negative emotions, the results of Experiment 11 show some suggestion of emotion operating in line with Load theories; positive and negative emotions reduced participants' accuracy when the problems were hard. These results however did not reach statistical significance, even on the items (incongruent, hard) which showed the greatest mood effects. Harder problems increase the effect of mood relative to easier problems, and this interaction was found to be significant, although the main effect of mood within the harder conditions did not itself reach statistical significance.

9.3 Experiment 12

Given the findings above with respect to congruency and difficulty effects, which are consistent with previous research, the differences between the difficulty categories were increased. Whereas Easy problems in Experiment 11 had boxes whose probabilities of drawing the target marble differed by between 25% and 40%, and the hard problems had boxes whose probabilities varied between 5% and 20%, in Experiment 12, Easy items had boxes whose probabilities differed by between 40% and 60%, whereas difficult items had boxes whose probabilities differed by between only 1% and 10%. This has the effect of making the easy problems easier, and the hard problems harder, and was done in order to attempt to increase the mood effects which were present in the incongruent and difficult problem conditions. The reasoning behind this adapted approach is that given the mood effects are small, and that they only result in slight differences between specific conditions, namely difficult problems; then by increasing the difference between high and low difficulty, for example, the impact of mood may have a more pronounced effect if it is replicated. In this regard, Experiment 12 aims to test the same hypotheses as Experiment 11.

9.3.1 Method

Participants

The participants in this study were 68 (26 male, 42 female) undergraduate psychology students (Age; *M* = 21 years, *SD* = 3 years) at Plymouth University who participated for course credit. Participants were recruited through the university's points manager system and emails to internal mailing lists. Participants were randomly allocated to one of the three mood conditions, positive (*N*=25), control (*N*=18), and negative (*N*=25).

Materials, Design, and Procedure

The mood manipulation procedure used in Experiment 12 was identical to that used in Experiment 11. No changes were made to the task instructions or presentation. The ratio-bias task was identical to that described in Section 9.2.1, except that the difficulty categories were altered to maximise the differences between conditions. As outlined above, Hard and Easy difficulty trials were defined as the difference in the absolute probability of drawing a black marble between the two boxes being between 1% and 10% (Hard) or between 40% and 60% (Easy). The design and procedure were identical to that used in Experiment 11.

9.3.2 Results

As with Experiment 11, the mood ratings showed a significant main effect of condition [$F(2,651) = 9.11$, $p < .001$, $\eta_p^2 = .22$], with mood ratings decreasing across positive ($M = 62.80$, $SD = 10.94$) to control ($M = 59.83$, $SD = 11.27$) to negative ($M = 45.28$, $SD = 20.65$). Pairwise comparisons revealed the difference between negative and control, and negative and positive to be the statistically significant ($p < .001$, $d = 1.11$ and $p = .003$, $d = .91$ respectively), with the positive-control difference not reaching statistical significance despite being medium in size and in the intended direction ($p = .53$, $d = .23$). To assess mood effects on the ratio-bias task, a 2 Difficulty (Easy, Hard) x 2 Congruency (Congruent, Incongruent) x 3 Mood (Positive, Control, Negative) mixed ANOVA was conducted on response accuracy, the cell means and standard deviations for which are shown in Table 9.2.

Similarly to Experiment 11, the analysis showed main effects of Congruency [$F(1,50) = 22.44$, $p < .001$, $\eta_p^2 = .31$] and Difficulty [$F(1,50) = 83.35$, $p < .001$, $\eta_p^2 = .63$], such that congruent problems (97%) were responded to more accurately than incongruent ones (90%), and easy (99%) more accurately than hard (89%). There was no main effect of mood, and mood did not show any significant interaction with congruency.

An interaction between congruency and difficulty [$F(1,65) = 15.47$, $p < .001$, $\eta_p^2 = .192$] was also found, and, as in Experiment 11, suggests that the difference between hard-congruent and hard-incongruent trials is larger than the difference between easy-congruent and easy-incongruent trials. This is depicted in Figure 9.3.

Table 9.2 Mean accuracy rates (%) and SD's for the ratio-bias task, for each mood condition, by congruency and difficulty condition (Experiment 12)

Congruency		**Congruent**			
Difficulty		**Easy**		**Hard**	
		M	*SD*	*M*	*SD*
Mood	Positive	98.86	3.95	92.85	7.33
	Control	99.21	2.31	92.85	7.72
	Negative	99.64	1.60	96.07	5.42
	Total	99.87	0.98	94.07	6.83
Congruency		**Incongruent**			
Difficulty		**Easy**		**Hard**	
		M	*SD*	*M*	*SD*
Mood	Positive	95.00	11.84	82.14	16.14
	Control	98.90	2.69	78.57	15.70
	Negative	97.86	4.08	89.64	8.18
	Total	97.03	7.85	84.10	14.05

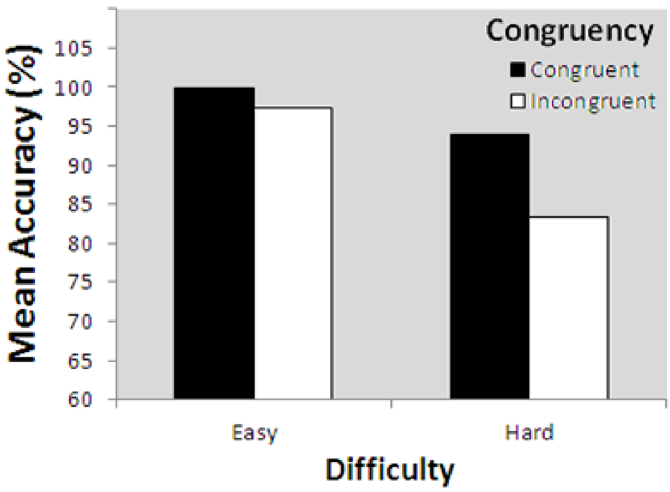


Figure 9.3 Congruency by Difficulty interaction (Experiment 12)

Also as in Experiment 11, the results of Experiment 12 reveal a significant interaction effect between Difficulty and Mood [$F(2,50) = 4.18$, $p = .02$, $\eta_p^2 = .14$], which suggests that the effect of mood is larger for hard items than it is for easy items. This interaction is depicted in Figure 9.4. Furthermore, a Univariate ANOVA revealed no significant effect of mood for easy items, but a significant main effect of mood for hard items [$F(2,50) = 3.71$, $p = .03$, $\eta_p^2 = .13$]. Pairwise comparisons show that negative mood (92%) lead to higher accuracy than both the positive (87%, $p = .04$) and control conditions (86%, $p = .02$), but that the positive and control conditions did not differ significantly in their mean accuracies.

Figure 9.4 Difficulty by Mood Interaction (Experiment 12)

Summary of Experiment 12

The results of Experiment 12 replicate the main effects found in Experiment 11. Congruent items are responded to more accurately than incongruent ones, and easy more accurately than hard ones. Similarly, the interactions suggest that in most cases the difficulty and congruency effects act as multipliers of each other; such that, for example, hard problems are responded to less accurately than easy ones when they are congruent, but hard problems are responded to *even less* accurately than easy ones when they are incongruent. It was also found that when the problems were hard, negative mood lead to higher rates of accuracy than the positive or control conditions. This increased accuracy with negative emotion is in line with the experiments reported previously in Chapter 7, though is in contrast to the findings of lower accuracy for positive and negative mood conditions in Experiment 11.

9.4 Discussion

Both studies reported here replicate the effects of congruency and difficulty found in previous research such as that by Denes-Raj and Epstein (1994); incongruency and increased difficulty led to higher reliance on frequency-based judgements. The current experiments move beyond these existing findings by including incidental emotion as a factor in the design. Although there were no main effects of mood, mood did interact with congruency and difficulty in both experiments. Though this suggests that the effects of mood are larger for incongruent and difficult items, the effects of mood varied across experiments. In Experiment 11, positive and negative moods reduced accuracy relative to the control condition on harder problems, whereas in Experiment 12 negative mood resulted in higher accuracy, relative to control, on more difficult problems. Positive emotion also resulted in an increase in accuracy on hard items in Experiment 12 relative to control, though this did not reach statistical significance. One possible explanation of this smaller effect is the strength of the mood manipulation, in which positive and control conditions were not found to differ in their reported moods; yet this is interesting in itself in that mood ratings were similar across conditions in both studies despite the effects of emotion condition differing within the difficult items across studies.

In Experiment 11 accuracy varied as a function of mood on difficult problems such that control mood led to the highest accuracy rates, followed by positive mood, with negative mood leading to the lowest accuracy rates. In terms of processing, this suggests that incidental emotion, particularly negative emotion, increases reliance on frequency-based judgements relative to the control condition when problems are more difficult. In Experiment 12, effects of mood were also found on the more difficult 'hard' items, but such that negative emotion resulted in higher accuracy than the positive or control conditions.

Finding mood effects on the harder problem items is consistent with the results of Experiments 6, 7, and 8 where effects of integral emotion were found on the more difficult, indeterminate, DA and AC inferences but not on easier or determinate problems such as MP and MT inferences. However, that the pattern of emotion effects is different across Experiments 11 and 12 needs consideration. In Experiment 11, emotion appears to suppress the use of high-effort probability-based judgements in a manner more consistent with Load theories than Information theories. This is in contrast to Experiment 12 and the results from the conditional reasoning studies (Chapter 7) in which positive emotion suppresses logical accuracy whereas negative emotion improves it; results consistent with Information theories. These differences may be indicative of a variation in how emotion is integrated across different levels of difficulty, and may suggest that at moderate levels of difficulty, as in Experiment 11, emotion serves as load, whereas at higher levels of difficulty, as in Experiment 12 (and on more difficult conditional reasoning problems such as DA and AC inferences in Chapter 7), emotion is used as a source of information. It might be argued that if emotion serves as load in one situation then it should act as cognitive load in all situations based on the premise that emotional experience requires cognitive resources to generate and maintain (Chapter 2). However, although emotional experience may require some cognitive resources to generate initially, it may be the case that (as in Experiment 11) further resources are then allocated to its maintenance, thus leading to patterns supportive of emotion-as-load theories; or it may be the case that after this initial generation of an emotional state, if the task is acknowledged as difficult (as is suggested may occur in Experiment 12), then no further resources are allocated to the maintenance of the emotional state, but the valence of the state is used to guide further processing of the problem, thus leading to results supportive of emotion-as-information.

Another point which needs consideration in the results across Experiment 11 and Experiment 12 in which the easy problems are made easier and the harder problems made harder, is that the overall accuracy was higher in this second experiment. Whilst the finding that accuracy is higher on the easier-easy problems seems self-explanatory, that accuracy was higher for the harder of the hard problems is counter intuitive. This pattern does however lend support to the above proposition that an overall increase in difficulty potentially increases the extent to which individuals apply themselves to the problem; if a person is aware that a task is difficult, they may perform better because they are more prepared and motivated to do so than if the task is only of moderate or low difficulty. Although this account appears relatively parsimonious, its accuracy cannot, unfortunately, be tested within the current studies, which did not record motivation or perceived difficulty in any way.

An alternative explanation for the increased accuracy in Experiment 12 would be differences between the samples tested. This seems unlikely given the identical recruitment methods, identical populations from which the samples were drawn, and both studies being conducted within the same month.

To develop this discussion of the effects found in Experiments 11 - of positive and negative emotion reducing accuracy on hard problems, though not to a statistically significant degree - incidental mood requires cognitive resources to process and maintain; this has been argued earlier as one possible mechanism of interaction between emotion and reasoning (Chapter 2). In Experiment 11, this additional load from problem difficulty and emotion would make it difficult for individuals to effectively base their decisions on probability calculations, and thus lead to lower accuracy when individuals are in the positive and negative conditions relative to the control condition. This would also explain the mood by difficulty interaction. When problems are easy, the difference in absolute probabilities for each box is larger and more easily perceptible than when the problem is difficult; so the comparison can be made whilst maintaining an emotion. When the problem is difficult, the difference between the probabilities is smaller, and the calculation of these may need to proceed further before one becomes apparent as the correct choice. This limits cognitive resources more than the easy condition, so will be hindered by the maintenance of a mood state. Such a process might also be thought of as individuals faced with a moderately difficult problem, because of the difficulty condition and additional load from the emotion relying on simple strategies because they either lack the resources or the motivation to engage fully with the task; the use of frequency as a basis for their judgement.

The increase in accuracy for negative mood (on difficult problems) found in Experiment 12, however, suggests that when the problems are made even more difficult, individuals use their mood as a source of information rather than being hindered by it as a source of cognitive load, as discussed above. However, although seemingly intuitive, the existence and nature of a turning point at which an individual's approach changes from simple heuristics due to a lack of resources to engaging effortful processing when they realise the problem is difficult is, with the current data, speculative; though it does present an interesting challenge for future research. One possible approach to investigating these contrasting results would be to run a series of studies using the Ratio-Bias paradigm with differing levels of load generated by concurrent tasks and attempting to observe the hypothesised shift from Load- to Information-theory consistent results.

With respect to the implications of these findings for dual-process theories and emotion and reasoning interaction, the results suggest that emotion has a larger impact on Type Two processing. In both experiments, there was a main effect of congruency and some suggestion of interactive effects with emotion – though none of these reached statistical significance. On congruent trials, low effort frequency based responses and higher effort probability based responses will lead to the same response. However, on incongruent trials, the application of a probability based response is necessary to reach the correct response. As accuracy was lower for incongruent trials relative to congruent ones in both experiments, this might be indicative of less effective use of Type Two, high effort, probability-based processing. Whether this is due to less attempted use of Type Two processing, or less effective use of Type Two processing when it is attempted is unclear from the current data, but would provide one interesting extension of the current work. The inclusion of protocol analysis into the design would provide a better understanding of what people are attempting to do when they make a decision on the ratio-bias task whereas the current methodology only records the accuracy of their responses.

Although the use of the ratio-bias task is based on existing work in the literature, its combination with incidental emotion is novel, and adds to our understanding of how emotion interacts with Type One and Type Two processing. It also highlights a number of avenues for further work, the first of which should be an attempt at replicating the findings of Experiments 11 and 12, and a closer inspection of the conditions which lead to, or mask, the effects of difficulty, congruency, and emotion. It would be useful to establish the conditions under which mood effects are found in order to aid future development of the paradigm as a means of investigating mood effects in reasoning. By narrowing down the range of problems on which effects are found, we can learn something about when emotion has an impact on Type One and Type Two processing, which may be informative for evaluating the 'turning point' explanation of the results presented in this chapter.

It would also be interesting to extend the current studies in a similar way to the extension of conditional reasoning tasks in the previous chapter by including integral emotion, or emotional images. Though difficult, investigation of whether and to what extent integral mood, and making decisions about boxes of snakes versus boxes of kittens for example, has on reasoning could develop our understanding of how attentional systems are involved and at what stage emotion has an effect on decision making. Up to this point, how cognitive resources are allocated to either generating and maintaining emotions, or for inclusion as information in reasoning has not been considered, yet attentional control systems might be involved in these processes, and are thus worth further investigation. This might be achieved by speeding the presentation of the boxes to better understand the time-course of emotion effects, or by using eye-tracking paradigms to explore how people's engagement in the task varies as a function of emotion.

In summary, mood effects in the ratio-bias task are most pronounced when the trials are more difficult. Although some evidence is found to suggest that incidental positive and negative emotion reduce accuracy on difficult problems (Experiment 11), evidence was also found which suggests that when the problems are made more difficult, incidental emotion may serve as a source of information (Experiment 12), and negative emotion improves the accuracy of participants' responding relative to those in the positive emotion and control conditions.

Chapter Ten

General Discussion

The overall aim of the work presented in this thesis was to further our understanding of whether and how emotional experiences impact on reasoning processes. This chapter will consider the theories and data presented in the preceding chapters in relation to this aim, and provide discussion of the work in relation to the existing Load and Information theories of how emotion affects reasoning, and in relation to what it can tell us about dual process theories of reasoning with respect to emotion. The chapter concludes with a consideration of wider theoretical implications, and the methodological implications of the results for programmes of work investigating emotion and reasoning.

Understanding the impact of emotion on reasoning was first approached here by exploring theories of emotion, and reviewing the work which tries to define emotion; from ancient Greek philosophers such as Aristotle through to contemporary psychologists such as LeDoux (1998) and Forgas (2001). This review, which constitutes the body of Chapter 1 also gave rise to a focus on the cognitive elements of emotion, and how these could be conceptualised in terms of 'dimensions of emotion', be they positive and negative affect (Watson et al., 1988), or pleasantness and activation (Feldman-Barrett & Russell, 1999).

Chapter 2 then reviewed the reasoning literature, introducing a range of theories of reasoning alongside types of reasoning before outlining how the work on emotion and reasoning could be integrated. It is here that Load and Information theories were first combined with models of reasoning, and the aim of this thesis is outlined in terms of testable hypotheses. If emotion serves as information, negative emotion should lead to higher rates of logical accuracy than positive emotion as the former serves to cue a careful and analytical approach, whereas the latter serves to cue reliance on low-effort, initial, heuristic responses. If, however, emotion serves as load, with both positive and negative emotions requiring cognitive resources to be generated and maintained through activation of associated memories and appraisals of situations or redirection of attention to the properties of emotive stimuli, logical performance should be decreased by both. How these hypotheses were expected to manifest in each paradigm, from necessity and possibility within syllogistic reasoning through to frequency versus probability in the ratio-bias task was dealt with in detail within each chapter and for each experiment.

The twelve experiments in this thesis can be grouped both by the problem types used or by whether it was the emotive valence of the content that was manipulated (integral emotion), or whether emotion was manipulated by using a task separate from the reasoning component (incidental emotion). This distinction between incidental and integral emotion was introduced in Experiments 1 and 2, adopting terminology used by Blanchette and Richards (2010). In Experiment 1, emotion was manipulated by having participants write about an emotive life event prior to completing the reasoning task; Experiment 2 varied integral emotion; the manipulation of emotion by varying the content of the reasoning tasks themselves, and in subsequent experiments, both integral and incidental emotion were investigated in syllogistic and conditional reasoning. The findings from the experiments which manipulate incidental emotion will be considered first, followed by those which manipulated integral emotion. Each of these sections will consider the degree to which the findings support Load and Information theories, as well as addressing the question of whether incidental and integral emotion have different effects on reasoning performance.

The findings will also be considered in relation to Dual Process Theory (DPT; Chapter 2). The conceptualisation of the reasoning system as being able to deploy two types of processing, either relatively low-effort heuristic or high-effort analytic reasoning, provides a framework for interpreting previous work on emotion and reasoning, as discussed in Chapter 2. As such, the results from the twelve studies will be considered in relation to dual-process theories and how they can help us to understand the impact of emotion on reasoning. This is followed by a discussion of the wider theoretical implications, and how the results relate to models of emotion and cognition considered in Chapter 2. Finally, consideration is given to the methodological implications of the findings in relation to improving mood manipulation and measurement when they are combined with reasoning tasks.

In summary, this chapter will evaluate the evidence for Load and Information explanations of how emotion may impact reasoning, in relation to both incidental and integral emotion. The results will be discussed in relation to dual process theories, and the theoretical and methodological implications considered in light of potential future work.

10.1 Incidental Emotion

As outlined in Chapter 1, the work of theorists such as Barlow (1991) and Alloy (1991) can be interpreted as emotion acting as cognitive load. This may occur through the inappropriate activation of emotional systems and memories (Barlow, 1991), or stimuli priming associations or appraisals which load working memory (Blanchette, 2006); ideas which have been supported by the work of researchers such as Richards et al (2000) and Oaksford et al (1996) who have shown reduced speed and logical accuracy as a result of anxiety and negative emotion. If emotion serves as cognitive load, then individuals would be expected to show poorer performance on reasoning tasks under both positive and negative emotion conditions.

This expected reduction in performance was tested by varying incidental emotion in Experiments 1, 5, 11, and 12. Experiment 1 investigated emotion effects in syllogistic reasoning using the necessity-possibility paradigm. This paradigm was utilised as it allows a measure of the extent to which individuals search for alternative models of the premises. This is important for investigating the impact of emotion on reasoning as increased load would be expected to reduce the number of models considered. The necessity-possibility paradigm investigates this by exploiting the distinction between possible-strong (PS) and possible-weak (PW) syllogisms (Evans et al., 2001; Evans et al., 1999). Individuals typically generate initial models that support the presented conclusion for PS syllogisms, but subsequent models will falsify this initial conclusion. PW syllogisms are the opposite, with initial models having invalid conclusions, but one or more subsequent models having valid conclusions. When asked to assess the necessity of conclusions, it is PS syllogisms which are of interest, as additional models are necessary to overrule the incorrect 'necessary' response that would result from reliance on a single model, whereas when asked to assess the possibility of conclusions, it is PW syllogisms which are of interest; these require additional models to be formulated (with valid conclusions) in order to overrule the initial 'not-possible' response that would result from consideration of only the first model generated. (See Chapter 3 for a detailed rationale).

Although the written mood manipulation was effective, no statistically significant main effect of mood was found, nor was there a significant effect of mood on possible-strong syllogisms under necessity instructions. Under possibility instructions, a small effect of mood was found on possible-weak syllogisms, in which people in the control condition performed less accurately than those in the negative condition, with the positive condition falling somewhere in between. These findings therefore lend little support to Load theories.

Information theories on the other hand, suggest that emotions may serve as an additional source of information when making judgements. For example, when making judgements about life satisfaction, positive or negative moods induced by the weather at the time of questioning may affect self-reported life satisfaction, or positive and negative moods may alter the extent to which individuals rely on familiarity as a cue to judge the fame or otherwise of company names (Kitamura, 2005). Chapters 1 and 2 make the case that emotions may also be used as information when reasoning, such that positive moods may be expected to cue less effortful processing and a reliance on heuristics, whereas negative emotion may serve to cue more careful, effortful processing.

Considering Experiment 1 in light of information theories, the results were consistent with such an interpretation; yet the control condition showed performance below that of the positive group. The only difference reaching statistical significance here was where people in the negative condition responded more accurately than those in the control condition. This finding is consistent with work such as that by Chang and Wilson (2004), discussed earlier, which found increased logical performance on a cheater-detection variant of the Wason selection task relative to a positive condition. However, Chang and Wilson were using the selection task, and did not include a control condition. No work has investigated positive, negative, *and control* conditions using the necessity-possibility paradigm, and as such, the results from other paradigms may not necessarily generalise to necessity-possibility studies, although the findings are relatively consistent across the experiments and paradigms reported in this thesis.

In order to investigate whether mood effects are found with other types of reasoning task besides syllogisms, Experiment 5 investigated the effect of incidental mood on conditional reasoning. In Experiment 5, the mood manipulation was less effective than in Experiment 1; although mood ratings were in the directions expected, they did not reach statistical significance. Despite these smaller effects of the mood manipulation, analysis of endorsement rates for each type of inference that can be drawn from a conditional statement revealed a marginal main effect of mood, which post-hoc comparisons found to reflect negative mood leading to lower endorsements when averaged across all inference types than the control group. The work of Evans, Handley, and Bacon (2009) has found that using a speeded task leads to an overall reduction in endorsements of conditional inferences, which might suggest that negative moods lead individuals to spend more time considering the inferences, and thus make them less likely to endorse them. This also lends support to Information theories, in that more careful processing as would be expected with negative emotion should also take more time. In further support of this increase in careful reasoning is the higher confidence people reported in their decisions under negative mood in Experiment 1; a variable which might be considered in future work, along with a more careful consideration of response times and the responses which are made.

Within each inference type, the only effect to reach statistical significance showed that negative mood, relative to control, reduced endorsement (increased logical accuracy) of highly-believable AC inferences. The accuracy level in the positive mood for highly believable AC inferences was comparable to the control condition. This contradicts load theories, and lends further support to information theories which would suggest negative emotion should lead to higher logical accuracy than positive emotion; but the difference was found in such a specific cases, and after a mood manipulation of limited effectiveness, that the findings should be treated with caution.

Experiment 5 is much closer in nature to the Wason selection task, using conditional reasoning to investigate the impact of incidental emotion on reasoning. As outlined above, very few results within this study reached statistical significance. However, the finding outlined above, that negative mood resulted in higher logical accuracy on highly-believable AC inferences, relative to positive and control conditions which were comparable, provides some support for information theories, and in that one specific condition supports Chang and Wilson's findings, providing increased support for information theories across varied reasoning paradigms.

Finally, Experiments 11 and 12 investigated the effect of incidental emotion on the ratio-bias task. This task presents individuals with two boxes, each containing a selection of black and white 'marbles', and their task is to select the box from which they would be most likely to draw a black marble if they drew a marble at random. By varying the numbers of black and white marbles in each box, the relative frequency of black marbles can be altered, as can the probability of drawing a black marble from each box. This allows trials to be devised whereby the box with the highest number of black marbles also has the highest probability of drawing a black marble; frequency and probability are congruent, or alternatively, the box with the highest number of black marbles may have the lowest probability of drawing a black marble; frequency and probability are incongruent. Furthermore, the difference in the absolute probability of drawing a black marble from each box may be large (Easy trials), or small (Hard trials).

In both of these studies, the mood manipulation was partially effective, such that mood ratings were significantly lower for the negative condition than the control or positive conditions, though the difference between positive and control did not reach statistical significance. The results of the ratio-bias task, which are designed to highlight the relative use of frequency-based (Type One) and probability-based (Type Two) processes in decision making showed mixed results. Experiment 11 found that both positive and negative mood suppressed selection of the box of marbles with the highest probability of selecting the desired target for difficult problems, which would appear to support load theories except that the differences did not reach statistical significance. In contrast to this pattern of findings, Experiment 12 found that negative mood increased selection of the box of marbles with the highest probability of selecting the desired target. The positive and control conditions showed lower rates of selection of the 'correct' box, but rates that were comparable. Furthermore, these mood effects were only found on the more difficult items. As no previous work has investigated the interactive effects of problem difficulty and emotion, a speculative discussion of the causes of this interaction was presented at the end of Chapter 9. The main ideas outlined in that chapter were that when the task is more difficult, such as a smaller difference in absolute probabilities between the options, processing of probabilities must proceed further, and thus requires more cognitive effort, which is already being consumed by the maintenance of emotion, whether that be through activation of ideas and memories associated with the episode chosen for the written manipulation task or through attention being directed towards these memories rather than the demands of the task (Chapter 1). This was suggested to alter as the problems were made even more difficult in Experiment 12; when the problems are extremely difficult, individuals may be forced to use emotion as information because they cannot effectively complete the probability comparison when the task is more difficult. This serves to highlight the need to develop the work presented here to consider a range of tasks, and a range of difficulties; issues discussed shortly.

In summary, Experiment 11 suggested marginal but not statistically significant suppression of accurate box choices by both positive and negative mood, in line with Load theories, whereas Experiment 12 found negative mood to increase the rate of correct choices relative to the positive and control conditions, in line with Information theories. Though these are findings from the ratio-bias task, Experiment 12 shows patterns of negative mood improving analytical processing and attention to detail similar to those found in other work which has investigated the effects of emotion. For example, the work discussed in Chapter 2 by Schnall and colleagues (2008) showing negative mood to improve performance on the embedded figures task, or the work of Storbeck and Clore (2005) showing that induced negative mood reduces false-memory effects, as well as findings by Blanchette and Campbell (2005, 2012) showing increased logical accuracy on syllogistic reasoning tasks when the content was related to relevant negative events.

As outlined above, the results of Experiments 1, 5, 11, and 12 found relatively little support for load theories of the impact of emotion on reasoning. However, this does not mean that they supported information theories either. Although there is stronger support for information theories as explanations of how incidental emotion impacts reasoning, the effects found across the studies discussed above have been small, and often only found under very specific conditions. For example, emotion effects which follow the expected Information pattern are typically found on indeterminate inferences in conditional reasoning, and on the more difficult trials in the ratio-bias task. There is also general support from these patterns for more considered reasoning with negative emotion; as indicated by increased logical accuracy and higher confidence ratings, discussed above.

In relation to the question raised above as to whether incidental and integral emotions have the same effect, the results from Experiment 12, and their similarity to work such as that by Blanchette and Campbell (2005, 2012) which varies integral emotion, seems to suggest that the effects are indeed similar across emotion types. However, Estrada and colleagues (1997) found that physicians in a negative mood, rather than integrating information more effectively or accurately than those in a positive mood – as might be expected given the work showing the ‘benefits’ of negative emotions - actually performed worse than those in a positive mood. It was physicians in a positive mood that made more effective use of relevant information. This will be considered in more detail in the following section, after reviewing the experiments in the current work which manipulated integral emotion.

From the results considered above, the manipulation of incidental emotion can be seen to have a range of effects on reasoning across the different paradigms studied here. This highlights potential issues such as the choice of scale or type of mood manipulation which impact both the strength and effectiveness of incidental emotion manipulations, and the measurement of reasoning in such studies. These are discussed below when reviewing the methodological implications of the work in this thesis, and cover consideration of the methods used in measuring emotional experience, and the need to carefully assess which reasoning processes are being measured by the task under investigation.

10.2 Integral Emotion

The following section considers the impact of manipulating integral emotion on reasoning in relation to Load and Information theories. By varying emotion within as well as external to the reasoning tasks, the similarities and differences between the effects of incidental and integral emotion on reasoning could also be assessed.

Whereas Experiment 1 investigated incidental emotion in the necessity-possibility paradigm, Experiment 2 made use of the same paradigm but varied integral emotion. Under necessity instructions, no evidence was found to suggest that emotional content impacts upon performance. In light of the limited findings across incidental (Experiment 1) and integral emotion (Experiment 2) within the necessity-possibility paradigm, no clear conclusions can be drawn in relation to Load or Information theories.

Although the necessity-possibility paradigm provides a good way of investigating the extent to which individuals search for alternative models this might be considered a measurement of the amount of Type Two processing engaged in. Given the interest of DPT in both Type One and Type Two processes, a paradigm which can more directly compare the relative use of each type of processing is useful for investigating the impact of emotion on Type One and Type Two processing. To this end, Experiments 3 and 4 adopted the Belief-Bias paradigm. This allowed a measure of both reliance on prior beliefs when reasoning and reliance on logical structure.

These experiments presented individuals with syllogisms whose conclusions varied believability and logical validity orthogonally, and used the rates at which participants endorsed each problem type (valid-believable, valid-unbelievable, invalid-believable, and invalid-unbelievable) to calculate an index of belief-based (Type One) and logic-based (Type Two) processing. These were presented in an online study (Experiment 3), and replicated in a laboratory setting (Experiment 4). The results, taken together, suggest that reliance on both beliefs *and* logical structure increases across positive to control to negative content.

Considering only the increasing reliance on logic supports Information theories, and previous work in related fields showing increased attention to detail, structure, and source monitoring with negative emotion (Kitamura, 2005; Schnall et al., 2008). All of these processes which involve higher cognitive effort are increased with negative emotion. However, Goel and Vartanian (2011) found that negative content resulted in decreased reliance on beliefs relative to positive content; the pattern which might have been predicted by Information Theories, but the opposite of what was found in Experiments 3 and 4. The current findings also contradict those of Blanchette, Richards, Melnyk, and Lavda (2007) who found decreased logical accuracy for both positive and negative emotive content in syllogistic reasoning. Blanchette and her team, interestingly, found that when the content was negative and was of particular relevance to the individuals, logical accuracy improved and reliance on beliefs decreased. This is similar to the arguments made by Johnson-Laird and colleagues (2006), who found content specific to an individual's condition was reasoned about more accurately by individuals diagnosed with psychological illnesses, and serves to highlight the need to consider personal relevance in designing materials for such studies (see also the discussion of subjectivity in Chapter 1). This may provide one explanation for why the current findings generally differ to those of Blanchette and Johnson-Laird and colleagues; the current results reflect the impact of emotive content rather than personally relevant emotive content, which may be processed differently. Future work might explore this area by grouping participants on some dimension of relevance and relating positive, control, and negatively valenced content to this dimension.

In addition, the strength of emotions experienced in relation to specific content, such as the terror-related content used by Blanchette et al. (2007), needs to be taken into consideration. Experiments 11 and 12, varying incidental emotion, suggest that increasing the difficulty of the task alters how emotion is integrated in the reasoning process at different levels of difficulty. Increasing the intensity of the emotional content might have a similar effect on reasoning performance and the integration of emotion. It might be expected that moderately intense emotion still leaves enough cognitive resources available to attempt some level of effortful processing, and thus Load-effects would be found, whereas extremely intense emotional content may limit the availability of cognitive resources so severely that individuals resort to using emotion as a source of information. Up to this level of intensity (and cognitive load), an individual may continue to try and engage effortful processing. After this point, the individual may realise that their resources are too limited to process all problems with equally high effort strategies, at which point emotion is used to inform their choices about which problems to process in a more careful, effortful way or inform their choice of response. How this might be studied empirically was discussed in Chapter 9.

At the far end of this emotional intensity dimension however, it may be the case that the only processes that an individual is left capable of engaging are low effort ones, and paradigms which can assess differing levels of Type One processes will be required to assess the impact of emotion on reasoning. It would be interesting to develop the ideas alluded to in the current work with respect to content of both varying emotional intensity and varying personal relevance in order to explore the relationship between emotional intensity and Load versus Information theories further: to develop our understanding of when emotions serve as load and when they serve as information, and if this is a function of intensity as well as task difficulty.

The alignment between belief and logic and Type One versus Type Two processing has typically been accepted within the reasoning literature, but recent work suggests belief-based responding may not be characteristic of Type One processing as claimed by dual-process theorists. Handley, Newstead, and Trippas (2011) provide evidence that belief-based responding may actually take longer than logic-based responding in certain circumstances. This suggests that belief-based responding in this paradigm may be more akin to Type Two processing, which undermines the aim of comparing the relative use of Type One and Type Two processes. However, if both are taken to be measures of effortful processing, this may account for the findings in Experiments 3 and 4 that both logic- and belief-based responding increase across the content conditions and provides clearer support for Information theories.

Whereas Experiment 5 considered incidental emotion in conditional reasoning, Experiments 6 and 7 investigated the effects of integral emotion. By replacing the *p* and *q* terms in conditional statements of the form "if *p* then *q*" with emotively valenced words, the impact of integral emotion on participants' judgements of whether MP, MT, DA, and AC inferences 'follow' or not could be evaluated. Valence was varied within and between participants respectively for Experiments 6 and 7 in order to investigate differences between the two methodologies, and to control for order effects, discounting, and thus the possibility that interspersing content types would reduce the effect of any given content type.

Experiment 6 found clearer support for Information theories, with logical accuracy increasing across positive to control to negative content types, for AC and DA inferences. These differences were statistically significant between positive-negative and control-negative content for DA inferences, and between positive-negative content for AC inferences. Experiment 7 found the same pattern of results, with more pronounced differences between positive and negative content types. This increase in effect size for the between-participants version of the design supports the suggestion that within-participant presentation may reduce the impact of emotion content manipulations, potentially through participants discounting the stimuli valence, and both experiments support Information theories of how emotions impact reasoning.

It is interesting though that the content effects are found primarily on DA and AC inferences. As discussed in the summary of Chapter 7 and the introduction to Chapter 8, this may be due to the willingness to endorse DA and AC inferences being more related to the availability of alternative causes than MP and MT inferences (Cummins et al., 1991). How emotion may affect the extent to which individuals search for these alternatives is considered in Chapter 7 in relation to the difficulty of indeterminate problems leading people to rely on emotion as information, in which case negative emotion leads to a more careful consideration of the inferences. This explanation briefly considered the possibility that more alternative antecedents would need to be considered, which in turn formed the rationale for controlling the converse probability (and thereby the alternative antecedents) in Chapter 8, and the designs of Experiments 9 and 10.

The availability of alternatives may have been confounded with emotion content as the number of alternatives was not assessed. If there were fewer alternative causes for *q* in any of the emotion conditions, then people may be more likely to draw AC and DA inferences. Given 'If *p* then *q*', if there are very few causes of *q*, then given *q*, it is more likely that *p* occurred than if there were many causes of *q*, and similarly, given ¬*p*, *q* appears less likely as there are few other causes of *q* besides *p*. Experiments 9 and 10 addressed this by controlling for $P(p|q)$, a proxy for the number of alternative causes, in addition to varying the response options between those used by Blanchette and colleagues (Yes, No, Maybe; Experiment 9), and the Yes-No response options used more commonly in the reasoning literature (Experiment 10). The results of both experiments show that after controlling for alternative causes the effects found in experiments 6 and 7 were eliminated. There were very few effects of content type on the rates at which each inference was drawn, with the exception that overall, positive content tended to lead to lower logical accuracy than negative or control content, but again primarily on DA and AC inferences. Other differences which reached statistical significance were not in line with either Load or Information theories, and only occurred in specific conditions not directly relevant to the testing of the experimental hypotheses. This suggests that the effects found previously in Experiments 6 and 7 may be dependent on the number of alternatives. However, the evidence for this comes from a lack of emotion effects being found when alternative causes are controlled for, suggesting that there may be an interaction between emotion and the number of possible alternatives; a potential area for future investigation. These results might imply that it may be the elaborated search for alternative causes which is most affected by integral emotion, which is supportive of the conclusions drawn from Experiments 6 and 7 that emotion appears to impact performance on harder problems; potentially suggesting that Type Two processes are more susceptible to any impact of emotion than Type One processes. It also lends support to the conclusions from Experiments 11 and 12; although these experiments used incidental emotion, the largest effects of emotion were found on the hardest problems: those which require effortful processing to respond to accurately.

The results found with syllogistic reasoning in Experiments 1, 2, 3, and 4, and conditional reasoning in Experiments 5, 6, 7, 9, and 10 all came from verbal reasoning tasks. In order to investigate the impact of emotive imagery on reasoning, Experiment 8 introduced a novel variation on the traditional conditional reasoning paradigm: replacing the *p* and *q* terms not with emotive words, but with emotive images. The results of people's reasoning about these 'visual conditionals' showed a strong resemblance to the findings of Experiments 6 and 7 with verbal conditionals. No effect of content type was found on MP and MT inferences, nor were any found on AC inferences; yet for DA inferences, negative images resulted in significantly higher rates of logical accuracy than either positive or control images (which did not differ in the rates of accuracy they resulted in).

These findings, taken together with the findings from the incidental emotion experiments discussed above, contrast with the earlier work of Blanchette and colleagues (Blanchette, 2006; Blanchette & Leese, 2011; Blanchette & Richards, 2004). For example, whereas the work of Blanchette and Leese found that individuals in more negative moods made more logical errors when reasoning about negative, relative to neutral content, the current work seems to show that negative emotion (in any form) increases rates of logical accuracy. These disparities and possible explanations for them are considered below.

A key strength of these experimental findings is the comparison of positive, control, and negative emotions within each paradigm. Previous work, as discussed in earlier chapters, has often neglected the neutral, control condition which makes it difficult to distinguish between the strengths of Load and Information theories due to the lack of a mid-point or baseline against which to compare the reasoning accuracy of positive and negative conditions. Including a control condition allows the effects of positive and negative emotion to be considered as increases or decreases relative to 'normal'. This programme of work has found little support for the idea that emotion serves as cognitive load, at least in so far as how its effects manifest across the reasoning tasks used here, but has found more support for the argument that emotion serves as a source of information, guiding people's use of different types of reasoning process.

Furthermore, it is apparent across the majority of the experiments reported here that emotion has a larger impact when the task is more difficult. Although this may initially appear to support the Load theories, whereby more demanding tasks reduce already finite cognitive resources, which are then less able to absorb the additional demands of emotion, it highlights the necessity of including both positive and negative, as well as control conditions. It is not that performance is impaired more and equally by positive and negative emotion relative to control conditions when the task is more difficult, but that the disparity in performance between positive and negative emotion increases on more difficult problems. A summary of the findings in each experiment is shown in Table 10.1.

From this summary, and the preceding discussion, it can be seen that syllogistic reasoning provides some of the most mixed results, whereas the results from conditional reasoning are more consistent. This highlights the need to consider task properties such as the difficulty of the items when investigating whether emotion operates as Load or Information. Though provided these caveats are kept in mind, the overall body of work presented here provides stronger support for Information theories than Load theories. This comes from the increased logical accuracy found with negative emotion relative to positive emotion. Although there is little evidence that positive emotion decreases logical performance to levels significantly below the control group, which might be expected if positive emotion served as a cue to greater reliance on biased Type One processes, this might be explained by the control and positive emotion conditions being more similar than the control and negative groups. People are generally in relatively positive moods, and positive content may have a less drastic effect than negative content. These issues have been discussed in preceding chapters, but are also considered again below in relation to whether positive and negative emotion effects improve or suppress reasoning performance relative to 'normal'.

Table 10.1 Summary Table of Experimental Findings (Emotion conditions are denoted by N, C and P for Negative, Control, and Positive respectively)

Reasoning	Paradigm	Incidental	Integral
Syllogistic	Necessity-Possibility	Exp1; Some support for information theories, logical responding N>P on PW-Possibility items	Exp2; No effect of emotion on the problem types relevant to the hypotheses
	Belief-Bias		Exp3 (Online); Logical accuracy N>P, but both >C Exp4 (Lab); Logical accuracy N>P, but both >C. Both studies showed reliance on logic N>C>P, but also reliance on belief N>C>P, providing no clear support for either load or information theories.
Conditional	Verbal	Exp5; Limited effectiveness of the mood manipulation. Few effects of emotion. Reliance on logic N>C>P, but also reliance on beliefs (N=C)>P	Exp6 (Within); Logical accuracy N>(P=C), on DA and N>P on AC inferences. Exp7 (Between); Logical responding (N=C)>P on AC and DA inferences, Support for information theories.
	Visual		Exp8; Logical accuracy N>(C=P) on AC inferences, some support for information theories.
	Controlled Antecedents		Exp9 and Exp10; few consistent effects of emotion. No support for either load or information theories
Ratio-Bias		Exp11, (P=N)<C, but only on difficult problems. Exp12; Some indication that logical accuracy N>(C=P), but only on the more difficult problems; differences did not reach statistical significance.	

10.3 The findings in relation to Dual Process Theory

The findings from this thesis have been discussed in light of load and information theories in detail above, but they can also be considered in relation to Dual Process Theory, and what they can tell us about the effects of emotion on Type One and Type Two processing. As described throughout, the paradigms employed have allowed an assessment of the extent to which Type Two processes are engaged through examining logical accuracy on the reasoning tasks or selection of the appropriate box on the ratio-bias task. The Belief-Bias paradigm has allowed an assessment of the relative use of Type One and Type Two processing by contrasting people's reliance on beliefs with their reliance on logical structure in syllogistic reasoning. If, however, the status of belief-based reasoning is in doubt with respect to which type of process it constitutes, the Ratio-Bias paradigm provides an alternative comparison in the form of frequency and probability based judgments.

Perhaps the easiest way of considering emotion effects in relation to DPTs is to consider where the effects are found. The effects of emotion are most pronounced in the experiments using conditional reasoning, and on the harder ratio-bias problems (Experiments 11 and 12). Focusing on the ratio-bias experiments, these results suggest that emotion is primarily impacting Type Two processing of probabilities, as it is on the incongruent items and problems where there is little difference between frequency and probability that careful, analytical processing has the largest impact on accuracy. There is also evidence that can be interpreted in support of this from the conditional reasoning experiments in which emotion has a larger effect on AC and DA inferences (Experiments 6, 7, and 8). These are those inferences to which responses are most affected by alternative causes (Experiments 9 and 10), and assessment of these requires more effortful processing than the MP inferences in particular (Newstead, Handley, Harley, Wright, & Farrelly, 2004).

An issue introduced briefly here, and in more detail in previous chapters, is the unusual finding from the belief-bias studies. Initially conducted to compare and contrast the relative reliance on beliefs and logical structure in reasoning, the results show that negative content increases reliance on both logic and belief relative to positive content. Taking the increase in the use of logic alone, these results provide support for Information theories. However, the increase in reliance on prior beliefs does not fit with this explanation. In Chapter 5, this was considered in terms of individual differences in how emotion is incorporated into the reasoning process, and was supported by the reduced interaction between belief and logic indices with either type of emotive content; some people may use emotion as information, others may find it an additional drain on cognitive resources. However, if belief-based responding is in fact not a Type One process (Handley et al., 2011), and it is instead considered a Type Two process, the results from Experiments 3 and 4 provide consistent evidence in support of Information theories. It should however be considered that although belief-based responding may not be a Type One process, treating it as a cognitively demanding Type Two process in the same sense as Type Two processes are conceived in the other experiments may be a step too far without further work which directly considers this possibility. Recent work has started to directly investigate this idea (Handley et al., 2011; Morsanyi & Handley, 2011), but future work on the relationship of belief-based processing to more widely accepted Type Two processes in syllogistic reasoning and emotion might help to clarify this point further and distinguish between the two explanations.

In summary, the work presented in this thesis suggests that emotions primarily impact Type Two processes, as evidenced by larger emotion effects on harder problems. The results also suggest that belief-based responding may not be a Type One process, in line with previous work already discussed; thus the processes thought to belong to Type One and Type Two processing may need rethinking. Furthermore, the interaction of Type One and Type Two processes also needs refining in relation to emotion research at least. The reduced interaction index under both positive and negative emotion in Experiments 3 and 4, and the varying impact of emotion across difficulty types in later studies does not fit easily within DPT frameworks. However, the conceptualisation of reasoning processes as belonging to Type One or Type Two still provides a useful starting point for work investigating the impact of emotion on reasoning.

10.4 Wider Theoretical Implications

Whereas the previous sections have considered the results across Incidental and Integral manipulations of emotion in light of Load and Information theories, this section considers a number of more general implications for theories which try to explain how emotion and reasoning might interact.

One of the key ideas presented in this thesis is that emotion has a greater effect on more difficult problems. There is some support for this in the larger emotion effects found on the harder problems in the ratio-bias task, and the increased emotion effects on AC and DA problems. However, although the ratio-bias task is a relatively straightforward case, and difficulty, as defined in that paradigm, was built into the design, the difficulty of AC and DA inferences relative to MP and MT inferences is more open to debate. It may not be the case that AC and DA inferences are 'more difficult' in terms of cognitive demands, but that they require a greater search for alternative antecedents than MP and MT inferences in order to respond correctly.

This effect of problem difficulty and potential confounding of number-of-alternatives with emotion or inference type which may have explained the results of

Experiments 6 and 7 was controlled for in Experiments 9 and 10. These experiments found that by controlling a proxy of alternative antecedents, the increased emotion effects on AC and DA inferences were eliminated. This may be because the availability of alternatives was indeed confounded across content types; or it may be that in controlling for the number of antecedents in the pre-test, the factor which creates the effect of negative mood, namely, its encouraging people to think of alternative possibilities, was 'controlled out'. This latter explanation seems the most likely as similar patterns were found across Experiment 6, 7, and 8. It is unlikely that the number of antecedents would have been confounded across all three of these studies, especially given the change from verbal to visual conditionals.

The work presented across the conditional reasoning studies, and to a lesser extent the syllogistic reasoning studies provides some evidence that negative emotions lead to better logical performance, but methodologically, the 'correct' response may not need to be 'logical' or 'Type Two'. Though this distinction fits well within the dual process framework, and provides one way of distinguishing between Load and Information theories (the rationale for which is covered in Chapters 1 and 2), it may be that negative mood affects reasoning by increasing the search for alternatives; not necessarily increasing the use of logical rules or other systematic Type Two processing. This relates to the work of Evans, Handley, and Bacon (2009) noted above, which might be taken to suggest that negative emotion leads to more time spent considering inferences and conclusions; considering alternative 'states of the world' may not necessarily be a Type Two process, and situations may conceivably arise where this extended search or broader view is in contrast to, or at least, not dependent on, 'logical' performance.

It should also be noted that previous work has made the case that searching for alternatives *is* a Type Two process, although a low-effort, heuristic, Type One search for alternatives might be plausible and would not necessarily contradict the work of Newstead et al (2004) given work suggestive of the fact that 'logical' and 'Type Two' processing are not necessarily the same thing (e.g. Handley et al., 2011). In order to clarify these explanations of how and when reasoning tasks measure Type One and Type Two processes, we need to know more about what types of processing fall under each category.

This might be one explanation for differences in reasoning between integral and incidental emotion. Emotion effects appear to be larger when integral rather than incidental emotion is manipulated, which may therefore suggest that integral emotive content makes people engage to a greater extent in a search for alternatives, whereas incidental emotion does not. As discussed above, given that the necessity-possibility paradigm might be considered one in which the amount of high-effort processing varies, and the belief-bias paradigm considering relative use of high and low-effort processing, there may be cases where emotion leads to different levels of low-effort processing, without any (or at least very little) high-effort processing. The current findings suggest that integral emotion has a larger effect on reasoning, and would appear to operate as information. It may be that incidental emotion affects lower-effort strategies more, and potentially leads to load effects, but the paradigms used in this thesis, which address high-effort or high- versus low-effort processing fail to capture these effects. This seems likely to provide a fruitful avenue of further research: the differences between incidental and integral emotion. By furthering our understanding of these differences, possibly by developing the use of conditional reasoning paradigms to use more closely controlled statements (in terms of alternative antecedents), we may be able to distinguish between greater Type Two processing, and a more intuitive extended search for alternative situations.

Differences in the extent to which individuals search for counter examples as a result of different integral or incidental emotions might be considered in terms of effects on motivation or thinking dispositions. The current work found very few effects when considering attention to emotion (Experiment 2), approach-avoidance, and actively open minded thinking (Experiment 5). However, the current work does not consider any direct measures of motivation, instead considering the search for or use of alternatives and additional models as evidence of motivated reasoning. Including a measure of, or manipulating, an individual's motivation to reason logically would provide an interesting addition to the work reported here. For example, if individuals were rewarded for logical accuracy, this might overcome the impact of emotion, cueing individuals to search for alternatives, encouraging more engagement with the logical structure of the task.

In addition to the possibility that integral emotion leads to greater engagement than incidental emotion, which needs further investigation, there is the question of contrasting results within the literature. This point has been highlighted earlier, in the work of Blanchette and her work with a range of collaborators over the years. Although there are a range of results which seem to show a coherent picture (albeit inconsistent with the findings reported here), such as that both positive and negative emotions reduce logical accuracy (Blanchette & Richards, 2004; Blanchette et al., 2007), there is other work which suggests that negative content, particularly when relevant to the individual, can increase logical accuracy (Blanchette & Campbell, 2012; Johnson-Laird et al., 2006). These studies specifically focused on problem content; that is, integral emotion, so the variation cannot be attributed to a difference between incidental and integral effects. One factor to consider is the extent to which these studies have controlled for the availability and number of alternative antecedents when conditional statements are used, and controlling for factors such as believability when syllogistic reasoning is used. Believability and the availability of alternatives have been shown to affect reasoning, and as such, if these are not controlled, or controlled for in different ways within the previous research, they may account for differences between the existing findings in the literature and those reported in this thesis. An additional factor to consider, introduced above, is the intensity of the emotion. Blanchette and Richards (2004) conditioned neutral words to be positively or negatively valenced, Johnson-Laird et al. (2006) had individuals high and low in obsessive compulsive tendencies reason about guilt-related or neutral materials, whereas Blanchette et al. (2007) had individuals who had experienced terrorist attacks reason about terror-related material. No direct comparisons of these different intensities of emotion have been conducted, but the finding in the current experiment that task difficulty alters how emotions impact reasoning lends some support to the idea that the intensity of the integral or incidental emotion may also alter how problems are processed, an outline of which was presented in Section 10.2.

The current work finds, in general, support for the idea that emotion – both integral and incidental – serves as information, even after controlling for believability and problem structure. However, a number of differences across the studies have been highlighted, along with potential explanations and ways of improving the study designs; discussed here and elsewhere in the thesis. In relation to the models considered in Chapters 1 and 2, activation models such as Barlow's (1991) might be useful in guiding future research on attention and emotion (discussed above), but are limited in their ability to explain emotion effects which differ across studies. Similarly, though Dual Process Theory is valuable as a tool in designing studies to compare and contrast Type One and Type Two processing, also discussed above, it is heavily focused on reasoning processes. As such, it needs to be combined, as was attempted in the earlier chapters, with models of emotion and cognition interaction, such as Load and Information theories in order to provide a framework which allows competing explanations of emotion effects in reasoning to be tested. The Affect Infusion Model, introduced in Chapter 2 combines DPT and the predictions of Load and Information theories and captures a range of salient factors identified in the preceding discussion such as an individual's motivation to reason carefully, and task properties. These are broadly identified in the model as motivation or a specific goal, and the novelty of the task, though might reasonably be developed to consider different types of goals and task properties such as familiarity or believability. However, one limitation is its inability to help researchers characterise tasks in order to progress through the decision points (Figure 2.3). After the motivation to reason or make a judgment, and adequate cognitive capacity points have been passed in the model, affective state is considered (though this is largely left undefined), and is expected to direct an individual towards 'Substantive' (related to Type Two) or 'Heuristic' (Type One) processing.

Further investigation of these elements will allow us to more clearly determine when the patterns found in this thesis – mostly supporting Information theories – will be present, and when they will be less clear or lead to other types of reasoning described in the AIM, such as Direct-Access and Motivated Strategies (Chapter 2). It would be useful to develop research designs which evaluate the impact of emotion at each decision point in the AIM model, for example, first contrasting high and low familiarity materials across emotional content to distinguish between 'Direct Access' (e.g. recall from memory) and 'Motivated' (guided, selective search) strategies; then secondly investigating the effects of cognitive capacity and the importance of accuracy across emotional content types to distinguish between the effects of emotion on 'Heuristic' and 'Substantive' processing (which broadly map on to the Type One and Type Two distinctions used throughout this thesis). Evaluation of the decision point concerning the 'affective state' of the individual is addressed by the studies of incidental emotion reported in this thesis.

10.5 Methodological Implications

In endeavouring to fully investigate the impact of emotion on reasoning, a number of things have been learnt about effectively investigating the relationship between emotion and reasoning. This section brings together the most pertinent of these points, and considers the findings in relation to manipulation of incidental and integral emotion, and measuring reasoning and emotion.

10.5.1 Incidental and Integral Emotion Manipulation

In the studies reported here on incidental emotion, a written manipulation task was used, though to varying degrees of success. Writing about a positive, negative, or neutral life event (Brand et al., 2007) was found to be effective in inducing moods in Experiment 1, and partially effective in Experiments 11 and 12, though had little effect in Experiment 5, despite the task being administered in the same way each time. One possible explanation for the difference in apparent effectiveness may be how mood was recorded in order to check the effectiveness of the manipulation.

In Experiment 1, both the PANAS and five-point Likert scale ratings of 'happy' and 'sad' were used and showed similar patterns for the effectiveness of the manipulation. Experiments 11 and 12 used a sliding scale ranging from 0 (Very Sad) to 100 (Very Happy), and appeared to show that in both cases the negative induction was more effective at altering participants' subjective mood ratings than the positive or control manipulations. It is odd, then, that Experiment 5 in which the manipulation check used a similar response scale for the same manipulation showed no effects of the writing task on people's reported moods. Experiment 5 required participants to mark an X on a line labelled 'Very Sad' and 'Very Happy', the position of which was then standardised to a 0-to-100 point scale.

If the similarity of scales between Experiments 5, 11, and 12 are taken to rule out the possibility of the scale used affecting the results in the manipulation checks, then other differences must be considered. A major difference between Experiment 5 and all others is the placement of the manipulation check. Whereas the other experiments measured subjective mood ratings after the manipulation but prior to the reasoning task, the manipulation check in Experiment 5 was administered *after* the reasoning task. Thus the apparent lack of effectiveness may be a result of an ineffective mood manipulation, the dissipation of the induced emotional experiences, or a normalising effect of the reasoning task. Evidence in support of this latter hypothesis can be found in the work of Van Dillen and colleagues, which has shown that cognitively demanding tasks can reduce negative mood (Van Dillen, Heslenfeld, & Koole, 2009; Van Dillen & Koole, 2007). Future work should therefore ensure manipulation checks are administered prior to the tasks of interest, and aim to develop our understanding of the duration of induced emotion. In relation to the interpretation of the findings reported here, this dissipation of mood may suggest that alternative manipulations and manipulation checks may need to be considered. One possibility for manipulating mood which has been shown to provide lasting emotional states is the continuous music technique briefly described in Chapter 1 (Eich & Macaulay, 2001). This involves having participants listen to a particular piece of music and chart their emotional experience on a grid labelled with axes of valence and arousal. This could overcome dissipation of mood issues if it was administered periodically throughout a study, and the reasoning tasks paused if the emotion fell below a certain threshold.

In relation to the work of Van Dillen and colleagues on reasoning tasks being used to reduce emotional experience, the current work suggests a bidrectionality to this relationship. That some effects of emotion have been found on reasoning tasks suggests that although reasoning tasks may have an effect on emotional experience, emotional experience can also have an effect on reasoning tasks. This does raise the question of how best to separate out these effects, or investigate one direction of effect only. If both effects occur simultaneously, then the instances of mood effects on reasoning reported in this thesis might be considered underestimates of the true effect; if completing a reasoning task reduces the experienced mood, and thus reduces the 'amount' of emotion left to serve as information (or load) in completing the reasoning tasks. It would be interesting to develop this idea by measuring both mood and reasoning over an extended period in order to learn more about the relationship between the two.

Related to these manipulation checks is the finding that emotion effects typically appear to be smaller when incidental emotion is manipulated. This may indicate that the emotions generated by the written manipulation are not 'strong' enough, or do not endure for long enough (if Experiment 5 is taken to suggest emotions reducing over time) to impact on the reasoning tasks, or, on occasion (Experiments 11 and 12), the measures of mood. Alternatively, it may indicate that integral and incidental emotion affect reasoning in different ways. One possible explanation for the larger effects with integral emotion is the salience of the emotional element. Integral emotion does not draw attention to the content valence in the same way as asking individuals to write about a happy or sad life event, and thus may be less prone to discounting effects, whether conscious or otherwise. Some evidence for this can be found in Experiments 6 and 7, in which varying integral emotion between participants led to larger effects than when the content was varied between participants. Chapter 7 discusses the justification for exploring these two designs in relation to the salience of the content types being reduced when content varies between participants, and considers the reduced potential for discounting effects as an explanation of the larger effect sizes.

It is curious that differences in mood ratings between the conditions can be accompanied by only minor effects in the reasoning task; partial differences in the mood ratings can be accompanied by consistent differences in the reasoning task; and simultaneously no effects be found in either as a result of the emotion manipulation. Future work, as well as investigating the intensity of emotional experiences over time more thoroughly might also investigate the effects of different 'strengths' of emotion manipulation in relation to the impact of emotion on reasoning tasks. As discussed at the start of this thesis, few studies which use emotion manipulations report effect sizes in their manipulation checks. In addition, whereas the current body of work has investigated general positive as opposed to negative emotion relative to control conditions, 'degrees' of positive and negative emotion might be assessed in future work. This could be achieved by developing the use of imagery in conditional reasoning studies, making use of existing data on the valence and arousal of images in the IAPS picture set (Lang et al., 2005) to create conditions of increasing valence whilst controlling for arousal, or indeed, investigating the relative effect of valence in relation to the effect of arousal. Such a series of studies might help to further distinguish between Load and Information explanations, or whether emotion serves as information when it is 'mild', but load when it is 'severe', or vice versa. The differences in logical accuracy between positive and negative conditions as the 'severity' of the emotion increases may also be informative. It might be hypothesised for example that extremely graphic images would lead emotion to be used as information, whereas milder imagery may lead to results congruent with Load theories where there is enough available capacity to attempt effortful processing, based on the findings of other experiments (e.g. Experiments 11 and 12) which show some suggestion of a Load-Information distinction between difficult and extremely difficult problem types.

The question was raised earlier as to whether integral emotion manipulations affect subjective mood ratings in the same way as incidental emotion manipulations. This was tested by including a single-item measure of mood in Experiment 9. A main effect of content type was found for post-reasoning (but not pre-reasoning) ratings of mood. This effect was such that participants in both the positive and negative content conditions reported more negative moods than the control condition, although it was only the positive-control content comparison which reached statistical significance. This is unlike the measures of mood in studies varying incidental emotion (e.g. Experiments 11 and 12) in which mood ratings typically follow the expected patterns, of positive higher than control higher than negative, even if they do not consistently reach levels that are statistically significantly different.

Even if integral emotion doesn't necessarily alter an individual's subjective experience of mood (though whether this might be expected or not was a question raised in Chapter 8), the difference in the overall valence for the content used (as indicated by pre-testing of the materials) does still appear to have an impact on reasoning performance in the tasks used here. Furthermore, emotive content would seem to impact reasoning, though specifically on more difficult tasks, in a manner most often consistent with Information theories. This would suggest that the manipulation of integral emotion was effective, even though it does not necessarily register on measures of subjective emotional experience. There is also the possibility, mentioned above and earlier in the thesis, that integral and incidental emotion do not both generate 'emotional experiences', and may thus affect reasoning in different ways.

Furthermore, though integral emotion does not alter subjective ratings of experience in the same way as incidental emotion, they both show an impact on reasoning. In relation to Load and Information theories, the work presented here suggests that emotion more often serves as information which leads to a consideration of how both incidental and integral emotion could be informative. Considering significant differences in mood ratings are found between conditions when incidental emotion is manipulated, the emotional experience may be considered more salient. As this experience is self-reported, individuals might reasonably be considered aware of their emotions, and thus may try to integrate them into their reasoning processes. The case for integral emotion is less clear, as little or no 'experienced' emotion seems to be generated by emotive content. This could be due to a lack of extremely distressing (or extremely pleasant) content being used in the studies, and much more graphic content may have resulted in stronger emotional states which could be captured by the mood ratings. Alternatively, emotive content may serve as information but in a more local sense. Emotional responses to each individual reasoning item, which may not necessarily combine to an overall emotional experience, could nonetheless serve as information.

Understanding more fully the relationship between incidental and integral emotion would be an important next step in research investigating the impact of emotion on reasoning and vice versa. This might be achieved by including both self-report and physiological measures throughout the reasoning phases of the experiments. If integral and incidental emotions generate emotional experiences, some correlation might be expected between the measures. If integral emotion only operates through generating emotional responses to each individual item, then continual monitoring of physiological responses and periodic self-report measures would be more likely to detect this than a single self-report measure. If, however, the effects of integral emotion are not caused by an emotional state, but some other mechanism, there might be less correlation between physiological measures (particularly of attention or other potential mechanisms through which integral emotion may have its effect) and self-reported measures of emotional experience. Thus although future research which varies integral emotion may proceed under the assumption that emotion is being varied if independent pre-testing of content valence shows significant differences between conditions, it would be worthwhile investigating the relationships between integral and incidental emotion further. Some ways of doing this and some initial steps, such as measuring emotional experience after reasoning about emotive content, have been taken in this thesis, but to do the comparison justice would entail its own programme of research which builds on the initial ideas discussed here.

10.5.2 Measuring Emotion and Reasoning

Related to the differences in incidental and integral emotion is the need to measure emotional experience. In this thesis, the PANAS, single item 'happy' and 'sad' ratings, and a single dichotomous happy-sad mood measure have been used. The theoretical basis for adopting these has been dealt with elsewhere (e.g. Chapter 1), but in practical terms, the results reported in Chapter 3 indicated that the PANAS and single item happy and sad measures showed the same results. It is thus recommended that unless positive and negative affect are of particular theoretical relevance to the work, future studies may benefit from the faster administration time, and limited distraction, of using a 'happy' and a 'sad' item. The five item Likert-scale response, covering 'not at all', 'a little', 'moderately', 'quite a bit', and 'extremely' for these happy and sad items would seem to be sufficiently sensitive to changes in mood generated by the written manipulation task as to be comparable to the longer PANAS. Later experiments adopted analogue scales anchored at *very happy* and *very sad* requiring participants to indicate their mood with a cross (Experiment 5), or use a sliding scale (Experiments 11 and 12), which then converted these into scores ranging from 0 to 100, as described above. Although these scales were not directly compared to the PANAS, they appear to track changes in self-reported mood states well, and may also provide useful alternatives to longer scales.

In relation to the theoretical work on the structure of emotion, the similarity of responses from scales measuring single or multiple dimensions might be taken to show that the manipulations used affect ratings universally; both the positive and negative dimensions are affected by the manipulations. This would explain the similarity in Happy and Positive-Affect ratings, and the Sad and Negative-Affect ratings reported in Experiment 1. Unfortunately, this means that the current findings can say little about the structure of emotion, but the manipulations and manipulation checks can be used to make the case that ‘happy’ and ‘sad’ items can be used in research to map the positive and negative affective dimensions which frequently occur across different models of emotion. The methodological implications of this have been considered above; namely that they can be used to improve efficiency and reduce distraction in the collection of experimental data.

In relation to the need to measure reasoning in order to assess the impact of emotion, what has become clear throughout this thesis is the need to consider which reasoning processes are being measured. As outlined above, both the use of Type Two processing (using the search for additional models in the necessity-possibility paradigm) and the relative use of Type One and Type Two processing (using measures of reliance on belief, logic, frequency, and probability) have been the key measures of the paradigms used in this thesis. This is important to consider in reasoning work which aims to compare Load and Information theories as the distinction between high and low effort processing is what allows the predictions of each class of theory to be evaluated. The findings reported here suggest that it is in the more effortful processing, on the more difficult tasks, where emotion has the greatest impact. Although relatively few effects of emotion have been found on 'easy' tasks requiring only low-effort responses, it would be interesting to combine the above outline for a study on *degrees* of emotion and the impact of these emotions on Type One processing. It is possible that few effects were found on Type One processing in this thesis because of the comparison between general positive and general negative emotion.

Extreme emotions might have more of an impact even on lower-effort reasoning tasks, and would serve to supplement the work in this thesis by extending the range and degree of emotions investigated. In addition, it has been shown that perceptual and processing fluency lead to small increases in positive affect (Topolinski & Strack, 2009). If easy tasks are processed with more ease, and this generates positive affect, it is possible that easy tasks reduce the distinctions between the emotion conditions, thus eliminating any effects of the emotion manipulation. The effects on low-effort, Type One processes is thus another potential area of research and could be combined with the above mentioned work required to investigate the direction of effects in emotion and reasoning research; if emotions can impact on reasoning (this thesis) and reasoning can be used to reduce experienced emotion (e.g. Van Dillen et al., 2009), how and when each of these effects occur and how they interact are interesting questions to consider.

10.6 Closing Summary

This thesis set out to investigate whether and how emotion affected reasoning, across a range of reasoning paradigms: syllogistic reasoning, conditional reasoning, and the ratio-bias-task, and for two different emotion manipulations: incidental and integral. These experiments were couched in terms of comparing Load theories; those which posit any emotion will serve as cognitive load, and Information theories; those which suggest positive and negative emotion serve as sources of information, the former cueing reliance on low-effort strategies, and the latter cueing reliance on higher effort strategies.

The findings across the twelve studies reported in this thesis, including an experiment using novel visual conditionals, are more supportive, overall, of Information theories. However, the findings are not entirely consistent, and there have been a number of null findings which have led to the discussion of a range of theoretical and methodological implications. In addition, the impact of emotion has been found to be more pronounced on 'difficult' reasoning tasks: those which require Type Two processing to respond to in a logically accurate manner. Information based effects of mood are also found more consistently in conditional reasoning tasks than in syllogistic reasoning tasks, though even in these cases the availability of alternative antecedents moderates the effects of emotion.

Overall, it would seem that emotion effects are highly dependent on a range of task specific properties, many of which have been investigated here. For example, the believability of conclusions, whether initial or subsequent models in syllogistic reasoning yield necessary conclusions, the number of alternative causes, and whether emotion is varied within or between participants. This complexity is reflected in the few main effects of emotion that are present in the studies reported here, and the relatively numerous interactive effects that have been discussed. It is hoped that future work can build on these findings, and refine the methodologies used, either following the suggestions outlined in this final chapter, developing the use of imagery in reasoning tasks, or following new avenues of interest in the field.

In summary, there is some consistency in the effects of incidental and integral emotion across experiments and paradigms which can be most frequently explained by considering emotion a source of information. However, this is only a starting point, and the results presented here also raise a number of questions; namely, under what circumstances and in which reasoning tasks do emotions serve as information, and how might different emotions interact with the properties of the tasks involved.

References

Alloy, L. B. (1991). Depression and anxiety: disorders of emotion or cognition? *Psychological Inquiry, 2*(1), 72-96.

Allwood, C. M., Granhag, P. A., & Jonsson, A. (2002). Does mood influence the realism of confidence judgements. *Scandinavian Journal of Psychology, 43*, 253-260.

Ameel, E., Verschueren, N., & Schaeken, W. (2007). The relevance of selecting what's relevant: a dual process approach to transitive reasoning with spatial relation. *Thinking and Reasoning, 13*(2), 164-187.

Andrewes, D. (2004). *Neuropsychology: from theory to practice*. Hove: Psychology Press.

Ansburg, P. I., & Hill, K. (2003). Creative and analytic thinkers difer in their use of attentioanl resources. *Personality and Individual Differences, 34*, 1141-1152.

APA. (1994). *Diagnostic and statistical manual of mental disorders - text revision (DSM-IV-TR)* (4th ed.). Arlington, VA: American Psychiatric Publishing Inc.

Arnsten, A. F. T., & Dudley, A. G. (2005). Methylphenidate improves prefrontal cortical cognitive function through α2 adrenoceptor and dopamine D1 receptor actions: relevance to therapeutic effects in attention deficit hyperactivity disorder. *Behavioural and Brain Sciences, 1*(2), [Online: http://tinyurl.com/94xcakm].

Atkinson, R. C., & Shiffrin, R. M. (1968). Human memory: a proposed system and its control processes. In K. W. Spence & J. T. Spence (Eds.), *The psychology of learning and motivation* (pp. 89-195). New York: Academic Press.

Averill, J. R. (1969). Autonomic response patterns during sadness and mirth. *Psychophysiology, 5*(399-414).

Averill, J. R. (1998). What are emotions, really? *Cognition and Emotion, 12*(6), 849-855.

Bacon, A. M., Handley, S. J., & Newstead, S. E. (2003). Individual difference in strategies for syllogistic reasoning. *Thinking and Reasoning, 9*(2), 133-168.

Badcock, P. B. T., & Allen, N. B. (2003). Adaptive social reasoning in depressed mood and depressive vulnerability. *Cognition and Emotion, 17*(4), 647-670.

Baddeley, A. (1996). Exploring the central executive. *The Quarterly Journal of Experimental Psychology, 49A*(1), 5-28.

Baddeley, A. (2000). The episodic buffer: a new component of working memory? *Trends in Cognitive Sciences, 4*(11), 417-423.

Baddeley, A., & Hitch, G. J. (1974). Working memory. In G. A. Bower (Ed.), *Recent advances in learning motivation* (Vol. 8, pp. 47-90). New York: Academic Press.

Ball, L. J., Phillips, P., Wade, C. N., & Quayle, J. D. (2006). Effects of belief and logic on syllogistic reasoning: eye movement evidence for selective processing models. *Experimental Psychology, 53*(1), 77-86. doi: 10.1027/1618-3169.53.1.77

Bar-Haim, Y., Lamy, D., Pergamin, L., Bakermans-Kranenburg, M. J., & van Ijzendoorn, M. H. (2007). Threat-related attentional bias in anxious and non-anxious individuals: a meta-analytic study. *Psychological Bulletin, 133*(1), 1-24.

Barkley, R. A. (Ed.). (2005). *Attention-deficit hyperactivity disorder: a handbook for diagnosis and treatment* (3rd ed.). New York: The Guilford Press.

Barlow, D. H. (1991). Disorders of Emotion. *Psychological Inquiry, 2*(1), 58-71.

Barnett, R., Maruff, P., Vance, A., Luk, E. S. L., Costin, J., Wood, C., & Pantelis, C. (2001). Abnormal executive function in attenion deficit hyperactivity disorder: the effect of stimulant medication and age on spatial working memory. *Psychological Medicine, 31*, 1107-1115.

Baron, J. (1991). Beliefs about thinking. In J. Baron, J. F. Voss, D. N. Perkins & J. W. Segal (Eds.), *Informal reasoning and education*. Hillsdale, NJ.: Erlbaum Associates.

Baron, R. S., & Kerr, N. L. (2003). *Group process, group decision, group action* (2nd ed.). Buckingham: Open University Press.

Barrouillet, P., Gauffroy, C., & Lecas, J. (2008). Mental models and the suppositional account f conditionals. *Psychological Review, 115*(3), 760-772.

Barrouillet, P., & Lecas, J. (1999). Mental models in conditional reasoning and working memory. *Thinking and Reasoning, 5*(4), 289-302.

Beer, J. S., Knight, R. T., & D'Esposito, M. (2006). Controlling the integration of cognition and emotion. *Psychological Science, 17*(5), 448-453.

Beller, S., & Spada, H. (2003). The logic of content effects in propositional reasoning: the case of conditional reasoning with a point of view. *Thinking and Reasoning, 9*(4), 335-378.

Bentall, R. P. (2004). *Madness explained: psychosis and human nature*. London: Penguin Books.

Berridge, C. W., Devilbiss, D. M., Andrzejewski, M. E., Arnsten, A. F. T., Kelley, A. E., Schmeichel, B., . . . Spencer, R. C. (2006). Methylphenidate preferentially increases catecholamine neurotransmission within the prefrontal cortex at low doses that enhance cognitive function. *Biological Psychiatry, 60*, 1111-1120.

Berridge, K. C. (2003). Pleasures of the brain. *Brain and Cognition, 52*, 106-128.

Blair, J., Mitchell, D., & Blair, K. (2005). *The psychopath: emotion and the brain*. Oxford: Blackwell Publishing.

Blanchette, I. (2006). The effect of emotion on interpretation and logic in a conditional reasoning task. *Memory and Cognition, 34*(5), 1112-1125.

Blanchette, I., & Campbell, M. (2005). *The effect of emotion on syllogistic reasoning in a group of war veterans*. Paper presented at the XXVII Annual Conference of the Cognitive Science Society Stresa, Italy.

Blanchette, I., & Campbell, M. (2012). Reasoning about highly emotional topics: Syllogistic reasoning in a group of war veterans. *Journal of Cognitive Psychology, 24*(2), 157-164.

Blanchette, I., & Leese, J. (2011). The effect of negative emotion on deductive reasoning: examining the contribution of physiological arousal. *Experimental Psychology, 58*(3), 235-246.

Blanchette, I., & Richards, A. (2004). Reasoning about emotional and neutral materials. *Psychological Science, 15*(11), 745-752.
Blanchette, I., & Richards, A. (2010). The influence of affect on higher level cognition: A review of research on interpretation, judgement, decision making, and reasoning. *Cognition and Emotion, 24*(4), 561-595.
Blanchette, I., Richards, A., Melnyk, L., & Lavda, A. (2007). Reasoning about emotional contents following shocking terrorist attacks: a tale of three cities. *Journal of Experimental Psychology: Applied, 13*(1), 47-56.
Bodkin, J. A., Allgulander, C., Llorea, P. M., Spann, M. E., Walker, D. J., Russell, J. M., & Ball, S. G. (2011). Predictors of relapse in a study of duloxetine treatment for patients with generalised anxiety disorder. *Human Psychopharmacology, 26*, 258-266. doi: 10.1002/hup.1211
Bower, G. H. (1981). Mood and Memory. *American Psychologist, 36*(2), 129-148.
Braine, M. D. S. (1978). On the relation between the natural logic of reasoning and standard logic. *Psychological Review, 85*(1), 21.
Braine, M. D. S., & O'Brien, D. P. (1998). *Mental Logic*. Mahwah, NJ: Erlbaum.
Brand, S., Reimer, T., & Opwis, K. (2007). How do we learn in a negative mood? Effects of negative mood on transfer and learning. *Learning and Instruction, 17*, 1-16.
Brewer, M. B. (2005). *Intergroup relations* (2nd ed.). Maidenhead: Open University Press.
British Psychological Society. (2009). *Code of ethics and conduct*. Leicester: BPS [Online: http://tinyurl.com/7544zgk].
Bucciarelli, M. (2000). Reasoning strategies in syllogisms: evidence for performance errors along with computational limitations. *Behavioural and Brain Sciences, 23*(5), 669-670.
Bucciarelli, M., & Johnson-Laird, P. N. (1999). Strategies in syllogistic reasoning. *Cognitive Science, 23*(3), 247-303.
Bushman, B. J. (2002). Does venting anger feed or extinguish the flame? Catharsis, rumination, distraction, anger, and agressive responding. *Personality and Social Psychology Bulletin, 28*(6), 724-731.
Butchart, S., Forster, D., Gold, I., Bigelow, J., Korb, K., Oppy, G., & Serrenti, A. (2009). Improving critical thinking using web based argument mapping exercises with automated feedback. *Australian Journal of Educational Technology, 25*(2), 268-291.
Cabanac, M. (2002). What is emotion? *Behavioural Processes, 60*, 69-83.
Cannon, W. (1927). The James-Lange theory of emotion: a critical examination of an alternative theory. *American Journal of Psychology, 39*, 106-124.
Carver, C. S., & White, T. L. (1994). Behavioural inhibition, behavioural activation, and affective responses to impending reward and punishment: The BIS/BAS scales *Journal of Personality and Social Psychology, 67*(2), 319-333.
Chang, A., & Wilson, M. (2004). Recalling emotional experiences affects performance on reasoning problems. *Evolution and Human Behaviour, 25*, 267-276.
Chater, N., & Oaksford, M. (1999). The probability heuristic model of syllogistic reasoning. *Cognitive Psychology, 38*, 191-258.

Ciompi, L. (1997). The concept of affect logic: an integrative psycho-socio-biological approach to understanding and treatment of schizophrenia. *Psychiatry, 60*, 158-170.
Clore, G. L., & Huntsinger, J. R. (2007). How emotions inform judgement and regulate thought. *Trends in Cognitive Sciences, 11*(9), 393-399.
Craig, A., Tran, Y., Wijesuriya, N., & Boord, P. (2006). A controlled investigation into the psychological determinants of fatigue. *Biological Psychology, 72*(1), 78-87.
Craig, E. (2002). *Philosophy: a very short introduction*. Oxford: Oxford University Press.
Cummins, D. D. (1997). Reply to Fairley and Manktelow's comment of 'Naive theories and causal deduction'. *Memory and Cognition, 25*(3), 415-416.
Cummins, D. D., Lubart, T., Alksnis, O., & Rist, R. (1991). Conditional reasoning and causation. *Memory and Cognition, 19*(3), 274-282.
Dallos, R., & Denford, S. (2008). A qualitative exploration of relationship and attachment themes in families with an eating disorder. *Clinical Child Psychology and Psychiatry, 13*, 305-322. doi: 10.1177/1359104507088349
Damasio, A. R. (1994). *Descartes' error: emotion, reason, and the human brain*. New York: Putnam.
Darwin, C. (1998). *The Origin of Species*. Hertfordshire: Wordsworth Editions Ltd.
de Beauvoir, S. (1997). *The Second Sex*. London: Vintage Classics.
Denes-Raj, V., & Epstein, S. (1994). Conflict between intuitive and rational processing: When people behave against their better judgement. *Journal of Personality and Social Psychology, 66*(5), 819-829.
DeNeys, W. (2006a). Automatic-heuristic and executive-analytic processing during reasoning: chronometric and dual-task considerations. *The Quarterly Journal of Experimental Psychology, 59*(6), 1070-1100.
DeNeys, W. (2006b). Dual processing in reasoning: two systems but one reasoner. *Psychological Science, 17*(5), 428-433.
Derakshan, N., & Eysenck, M. W. (1998). Working memory capacity in high trait-anxious and repressor groups *Cognition and Emotion, 12*(5), 697-713.
Derryberry, D., & Reed, M. A. (1998). Anxiety and attentional focusing: trait, state and hemispheric influences. *Persoanlity and Indivdual Differences, 25*, 745-761.
Dube, C., Rotello, C. M., & Heit, E. (2010). Assessing the belief bias effect with ROCs: It's a response bias effect. *Psychological Review, 117*(3), 831-863.
Duncan, S., & Feldman-Barrett, L. (2007). Affect is a form of cognition: a neurobiological analysis. *Cognition and Emotion, 21*(6), 1184-1211.
Dutke, S., & Stöber, J. (2001). Test anxiety, working memory, and cognitive performance: supportive effects of sequential demands. *Cognition and Emotion, 15*(3), 381-389.
Eich, E., & Macaulay, D. (2001). Fundamental factors in mood-dependent memory. In J. P. Forgas (Ed.), *Feeling and thinking: the role of affect in social cognition* (pp. 109-130). Cambridge: Cambridge University Press.
Eich, E., Macaulay, D., & Ryan, L. (1994). Mood dependent memory for events of the personal past. *Journal of Experimental Psychology: General, 123*(2), 201-215.

Ellis, H. C., & Ashbrook, P. W. (1988). Resource allocation model of the effects of depressed mood states on memory In K. Fiedler & J. P. Forgas (Eds.), *Affect, Cognition, and Social Behaviour* (pp. 25-43). Göttingen: Hogrefe.

Engel, G. L. (1977). The need for a new medical model: a challenge for biomedicine. *Science, 196*(4286), 129-136.

Estrada, C. A., Isen, A. M., & Young, M. J. (1997). Positive affect facilitates integration of information and decreases anchoring in reasoning among physicians. *Organizational Behaviour and Human Decision Processes, 72*(1), 117-135.

Evans, C. S. (2002a). *Pocket dictionary of apologetics and philosophy of religion*. Leicester: InterVarsity Press.

Evans, D. (2002b). The search hypothesis of emotion. *The British Journal for the Philosophy of Science, 53*, 497-509.

Evans, J. S. B. T. (1991). Theories of human reasoning: the fragmented state of the art. *Theory and Psychology, 1*(1), 83-105.

Evans, J. S. B. T. (2003). In two minds: dual-process accounts of reasoning. *Trends in Cognitive Sciences, 7*(10), 454-459.

Evans, J. S. B. T. (2007a). *Hypothetical thinking with conditional statements: full research report*. Swindon: ESRC End of Award Report (RES-000-23-0722).

Evans, J. S. B. T. (2007b). On the resolution of conflict in dual process theories of reasoning. *Thinking and Reasoning, 13*(4), 321-339.

Evans, J. S. B. T. (2008). Dual-processing accounts of reasoning, judgement, and social cognition. *Annual Review of Psychology, 59*, 255-278.

Evans, J. S. B. T. (2010). *Thinking twice: Two minds in one brain*. Oxford: Oxford University Press (in press).

Evans, J. S. B. T., Barston, J. L., & Pollard, P. (1983). On the conflict between logic and belief in syllogistic reasoning. *Thinking and Reasoning, 13*(4), 321-339.

Evans, J. S. B. T., & Curtis-Holmes, J. (2005). Rapid responding increases belief-bias: evidence for the dual-process theory of reasoning. *Thinking and Reasoning, 11*(4), 382-389.

Evans, J. S. B. T., Handley, S. J., & Bacon, A. M. (2009). Reasoning under time pressure: a study of causal conditional inference. *Experimental Psychology, 56*(2), 77-83.

Evans, J. S. B. T., Handley, S. J., Hadjichristidis, C., Thompson, V. A., Over, D. E., & Bennett, S. (2007). On the basis of belief in causal and diagnostic conditionals *The Quarterly Journal of Experimental Psychology, 60*(5), 635-643.

Evans, J. S. B. T., Handley, S. J., & Harper, C. N. J. (2001). Necessity, possibility and belief: a study of syllogistic reasoning. *The Quarterly Journal of Experimental Psychology, 54A*(3), 935-958.

Evans, J. S. B. T., Handley, S. J., Harper, C. N. J., & Johnson-Laird, P. N. (1999). Reasoning about necessity ad possibility: a test of the mental model theory of deduction. *Journal of Experimental Psychology: Learning, Memory, and Cognition, 25*(6), 1495-1513.

Evans, J. S. B. T., Handley, S. J., Neilens, H., & Over, D. (2009). The influence of cognitive ability and instructional set on causal conditional inference. *The Quarterly Journal of Experimental Psychology, iFirst: http://tinyurl.com/9k76fg4*, 1-18.

Evans, J. S. B. T., Newstead, S. E., & Byrne, R. M. J. (1993). *Human reasoning: the psychology of deduction*. Hove: Lawrence Erlbaum Associates.
Evans, J. S. B. T., & Over, D. (2004). *If*. Oxford: Oxford University Press.
Evans, J. S. B. T., Over, D. E., & Handley, S. J. (2005). Suppositions, extensionality, and conditionals: a critique of the mental model theory of Johnson-Laird and Byrne (2002) *Psychological Review, 112*(4), 1040-1052.
Extremera, N., Durán, A., & Rey, L. (2007). Perceived emotional intelligence and dispositional optimism-pessimism: Analyzing their role in predicting psychological adjustment among adolescents. *Personality and Individual Differences, 42*(6), 1069-1079. doi: 10.1016/j.paid.2006.09.014
Eysenck, M. W., & Calvo, M. G. (1992). Anxiety and performance: the processing efficiency theory. *Cognition and Emotion, 6*, 409-434.
Eysenck, M. W., Derakshan, N., Santos, R., & Calvo, M. G. (2007). Anxiety and cognitive performance: attentional control theory. *Emotion, 7*(2), 336-353.
Eysenck, M. W., MacLeod, C., & Mathews, A. (1987). Cognitive functioning and anxiety. *Psychological Research, 49*, 189-195.
Eysenck, M. W., Payne, S., & Derakshan, N. (2005). Trait anxiety, visuospatial processing and working memory. *Cognition and Emotion, 19*(8), 1214-1228.
Feldman-Barrett, L., & Russell, J. A. (1999). The structure of current affect: controversies and emerging consensus. *Current Directions in Psychological Science, 8*(1), 10-14.
Ferreira, M. B., Garcia-Marques, L., Sherman, S. J., & Sherman, J. W. (2006). Automatic and controlled components of judgement and decision making. *Journal of Personality and Social Psychology, 91*(5), 797-813.
Fitness, J., & Curtis, M. (2005). Emotional intelligence and the trait meta-mood scale: relationships with empathy, attribution complexity, self-control, and responses to interpersonal conflict. *E-journal of Applied Psychology: Social Section, 1*(1), 50-62.
Ford, M. (1994). Two modes of mental representation and problem solution in syllogistic reasoning. *Cognition, 54*, 1-71.
Forgas, J. P. (1995). Mood and judgement: the affect infusion model (AIM). *Psychological Bulletin, 117*(1), 39-66.
Forgas, J. P. (2007). When sad is better than happy: negative affect can improve the quality and effectiveness of persuasive messages and social influence strategies. *Journal of Experimental Social Psychology, 43*, 513-528.
Forgas, J. P. (Ed.). (2001). *Feeling and thinking: the role of affect in social cognition*. Cambridge: Cambridge University Press.
Forgas, J. P., Bower, G. H., & Moylan, S. J. (1990). Praise or blame? Affective influences on attributions for achievement. *Journal of Personality and Social Psychology, 59*(4), 809-819.
Forgas, J. P., & Ciarrochi, J. V. (2002). On managing moods: evidence for the role of homeostatic cognitive strategies in affect regulation. *Personality and Social Psychology Bulletin, 28*, 336-345.
Freud, S. (1997). *The interpretation of dreams*. Hertfordshire: Wordsworth (Original work published in 1932).

García-Madruga, J. A., Gutiérrez, F., Carriedo, N., Luzón, J. M., & Vila, J. O. (2007). Mental models in propositional reasoning and working memory's central executive. *Thinking and Reasoning, 13*(4), 370-393.

Garcia-Marques, T., Mackie, D. M., Claypool, H. M., & Garcia-Marques, L. (2004). Positivity can cue familiarity. *Personality and Social Psychology Bulletin, 30*(585-592).

Garlick, D., & Sejnowski, T. J. (2006). There is more to fluid intelligence than working memory capacity and executive function. *Behavioural and Brain Sciences, 29*, 134-135.

Garnham, A., & Oakhill, J. (1994). *Thinking and reasoning*. Oxford: Blackwell.

Gazzaniga, M. S., Ivry, R. B., & Mangun, G. R. (2002). *Cognitive neuroscience: the biology of the mind* (2nd ed.). London: W.M. Norton and Company.

Gevins, A., & Smith, M. E. (2000). Neurophysiological measures of working memory and individual differences in cognitive ability and cognitive style. *Cerebral Cortex, 10*(9), 829-839.

Geyer, M. A., & Markou, A. (2000). Animal models of psychiatric disorders. *Psychopharmacology – 4th Generation of Progress*, [Online: http://tinyurl.com/9ka29rw].

Gigerenzer, G., & Goldstein, D. G. (1996). Reasoning the fast and frugal way: models of bounded rationality. *Psychological Review, 103*(4), 650-669.

Gilhooly, K. J., Logie, R. H., & Wynn, V. E. (1999). Syllogistic reasoning tasks, working memory, and skill. *European Journal of Cognitive Psychology, 11*(4), 473-498.

Gilhooly, K. J., Logie, R. H., & Wynn, V. E. (2002). Syllogistic reasoning tasks and working memory: evidence from sequential presentation of premises. *Current Psychology: Developmental, 21*(2), 111-120.

Gilovich, T., Griffin, D., & Kahneman, D. (Eds.). (2002). *Heuristics and biases: the psychology of intuitive judgement*. Cambridge: Cambridge University Press.

Goel, V. (2007). Anatomy of deductive reasoning. *Trends in Cognitive Sciences, 11*(10), 435-441.

Goel, V., & Vartanian, O. (2011). Negative emotions can atenuate the influence of beliefs on logical reasoning *Cognition and Emotion, 25*(1), 121-131.

Goleman, D. (2004a). *Destructive emotions and how we can overcome them: a dialogue with the Dalai Lama*. London: Bloomsbury.

Goleman, D. (2004b). *Emotional intelligence & working with emotional intelligence omnibus*. London: Bloomsbury.

Gorden, R. L. (1953). The effect of attitude toward Russia on logical reasoning. *The Journal of Social Psychology, 37*, 103-111.

Gross, J. J. (1999). Emotion regulation: past, present, future. *Cognition and Emotion, 13*(5), 551-573.

Hamer, M., Tanaka, G., Okamura, H., Tsuda, A., & Steptoe, A. (2007). The effects of depressive symptoms on cardiovascular and catecholamine responses to the induction of depressive mood. *Biological Psychology, 74*(1), 20-25.

Hand, G. A., Phillips, K. D., & Dudgeon, W. D. (2006). Perceived stress in HIV infected individuals: physiological and psychological correlates. *AIDS Care, 18*(8), 1011-1017.

Handley, S. J., Capon, A., Copp, C., & Harper, C. (2002). Conditional reasoning and the Tower of Hanoi: the role of spatial and verbal working memory. *British Journal of Psychology, 93*, 501-518.

Handley, S. J., Evans, J. S. B. T., & Thompson, V. A. (2006). The negated conditional: a litmus test for the suppositional conditional? *Journal of Experimental Psychology: Learning, Memory, and Cognition, 32*(3), 559-569.

Handley, S. J., Newstead, S. E., & Trippas, D. (2011). Logic, Belief, and Instruction: A test of the default interventionist account of belief bias. *Journal of Experimental Psychology: Learning, Memory, and Cognition, 37*(1), 28-43.

Hanoch, Y. (2002a). The effects of emotions on bounded rationality: a comment on Kaufman. *Journal of Economic Behaviour and Organisation, 49*, 131-135.

Hanoch, Y. (2002b). 'Neither an angel nor an ant': emotion as an aid to bounded rationality. *Journal of Economic Psychology, 23*, 1-25.

Harris, M., Chandran, S., Chakraborty, N., & Healy, D. (2003). Mood stabilizers: the archaeology of the concept. *Bipolar Disorders, 5*, 446-452.

Heller, W., & Nitschke, J. B. (1998). The puzzle of regional brain activity in depression and anxiety: the importance of subtypes and comorbidity. *Cognition and Emotion, 12*(3), 421-447.

Henle, M., & Michael, M. (1956). The influence of attitudes on syllogistic reasoning. *The Journal of Social Psychology, 44*, 115-127.

Ikegami, T. (2002). The role of state self-esteem in positive mood effects on person impression: when does a positive mood lead to a favourable view of others? *Japanese Psychological Research, 44*(1), 20-33.

Jacobson, N. S., & Truax, P. (1991). Clinical significance: a statistical approach to defining meaningful change in psychotherapy research. *Journal of Consulting and Clinical Psychology, 59*(1), 12-19.

James, W. (1884). What is an emotion? *Mind, 9*(34), 188-205.

Janis, I. L., & Frick, F. (1943). The relationship between attitudes toward conclusions and errors in judging logical validity of syllogisms. *Journal of Experimental Psychology, 33*, 73-77.

Johnson-Laird, P. N. (1983). *Mental-models: towards a cognitive science of language, inference, and consciousness*. Cambridge: Cambridge University Press.

Johnson-Laird, P. N., & Byrne, R. M. J. (1992). *Deduction*. Hove: Lawrence Erlbaum Associates.

Johnson-Laird, P. N., & Byrne, R. M. J. (2002). Conditionals: A theory of meaning, pragmatics, and inference. *Psychological Review, 109*(4), 646-678.

Johnson-Laird, P. N., Mancini, F., & Gangemi, A. (2006). A hyper-emotion theory of psychological illness. *Psychological Review, 113*(4), 822-841.

Kane, M. J., & Engle, R. W. (2002). The role of prefrontal cortex in working memory capacity, executive attention, and general fluid intelligence: an individual differences perspective. *Psychonomic Bulletin and Review, 9*(4), 637-671.

Kempton, S., Vance, A., Maruff, P., Luk, E., Costin, J., & Pantelis, C. (1999). Executive function and attention deficit hyperactivity disorder: stimulant medication and better executive performance in children. *Psychological Medicine, 29*, 527-538.

Kitamura, H. (2005). Effects of mood states on information processing strategies: two studies of automatic and controlled processing using misattribution paradigms. *Asian Journal of Social Psychology, 8*, 139-154.
Klauer, K. C., Musch, J., & Naumer, B. (2000). On belief in syllogistc reasoning. *Psychological Review, 107*(4), 852-884. doi: 10.1037//0033-295X.107.4.852
Krikorian, R., Zimmerman, M. E., & Fleck, D. E. (2004). Inhibitory control in obsessive-compulsive disorder. *Brain and Cognition, 54*, 257-259.
Kroenke, K., Spitzer, R. L., & Williams, J. B. (2001). The PHQ-9: validity of a brief depression severity measure. *Journal of General Internal Medicine, 16*(9), 606-613.
Kunda, Z. (1994). *Social cognition: making sense of people*. Cambridge, MA: The Massachusetts Institute of Technology Press.
Kyllonen, P. C., & Christal, R. E. (1990). Reasoning ability is (little more than) working memory capacity. *Intelligence, 14*, 389-433.
Lang, P. J., Bradley, M. M., & Cuthbert, B. N. (2005). *International affective picture system (IAPS): Instruction manual and affective ratings*: Technical Report A-6, The Centre for Research in Psychophysiology, University of Florida.
Langens, T. A., & Stucke, T. S. (2005). Stress and mood: the moderating role of activity inhibition. *Journal of Personality, 73*(1), 47-78.
Lavric, A., Rippon, G., & Gray, J. R. (2003). Threat-evoked anxiety disrupts spatial working memory performance: an attentional account *Cognitive Therapy and Research, 27*(5), 489-504.
Lazarus, R. S. (1982). Thoughts on the relations between emotion and cognition. *American Psychologist, 37*(9), 1019-1024.
Lazarus, R. S. (1984). On the primacy of cognition. *American Psychologist, 39*(2), 124-129.
LeDoux, J. E. (1995). In search of an emotional system in the brain: leaping from fear to emotion and consciousness In M. S. Gazzaniga (Ed.), *The cognitive neurosciences* (pp. 1047-1061). Cambridge, MA: The Massachusetts Institute of Technology Press.
LeDoux, J. E. (1998). Fear and the brain: where have we been, and where are we going? *Biological Psychiatry, 44*, 1229-1238.
LeDoux, J. E. (2000). Emotion circuits in the brain. *Annual Review of Neuroscience, 23*, 155-184.
LeDoux, J. E. (2006). The emotional brain, fear, and the amygdala. *Cellular and Molecular Neurobiology, 23*(4/5), 727-738.
Lefford, A. (1946). The influence of emotional subject matter on logical reasoning. *The Journal of General Psychology, 34*, 127-151.
Lehrer, J. (2009). Decision time. *BBC news magazine*, [Online: http://tinyurl.com/b83x24].
Levens, S. M., & Phelps, E. A. (2008). Emotion processing effects on interference resolution in working memory. *Emotion, 8*(2), 267-280.
Lewis, P. A., Critchley, H. D., Smith, A. P., & Dolan, R. J. (2005). Brain mechanisms for mood congruent memory facilitation. *NeuroImage, 25*, 1214-1223.

Macpherson, R., & Stanovich, K. E. (2007). Cognitive ability, thinking dispositions, and instructional set as predictors of critical thinking. *Learning and Individual Differences, 17*(2), 115-127.

Manktelow, K. (2000). *Reasoning and thinking*. Hove: Psychology Press.

Marewski, J. N., Gaissmaier, W., & Gigerenzer, G. (2010). Good judgements do not require complex cognition. *Cognitive Processing, 11*(2), 103-121. doi: 10.1007/s10339-009-0337-0

Marks, I. M., & Nesse, R. M. (1994). Fear and fitness: an evolutionary analysis of anxiety disorders. *Ethology and Sociobiology, 15*, 247-261.

Marrero, H., Gámez, E., & Díaz, J. M. (2008). BIS/BAS individual differences and the verification of conditional hypotheses. *Personality and Individual Differences, 45*, 296-301.

Masicampo, E. J., & Baumeister, R. F. (2008). Toward a physiology of dual-process reasoning and judgement: lemonade, willpower, and expensive rule-based analysis. *Psychological Science, 19*(3), 255-260.

Mather, M., Canli, T., English, T., Whitfield, S., Wais, P., Ochsner, K., . . . Carstensen, L. L. (2004). Amygdala responses to emotionally valenced stimuli in older and younger adults. *Psychological Science, 15*(4), 259-263.

Matlin, M. W. (2003). *Cognition* (5th ed.). Hoboken, NJ: John Wiley & Sons Inc.

Mayer, J. D. (2008). Brief mood introspection scale (BMIS). [Online: http://tinyurl.com/6voy9bk].

Mayer, J. D., Allen, J. P., & Beauregard, K. (1995). Mood induction for four specific moods: a procedure employing guided imagery vignettes with music. *Journal of Mental Imagery, 19*(1&2), 133-150.

Mayer, J. D., & Gaschke, Y. N. (1988). The experience and meta-experience of mood. *Journal of Personality and Social Psychology, 55*(1), 101-111.

Mayer, J. D., Salovey, P., & Caruso, D. R. (2008). Emotional intelligence: New ability or eclectic trait? *American Psychologist, 63*(6), 503-517. doi: 10.1037/0003-066X.63.6.503

McNally, R. J. (1998). Information processing abnormalities in anxiety disorders: implications for cognitive neuroscience. *Cognition and Emotion, 12*(3), 479-495.

Mill, J. S. (2006). *On Liberty and The Subjection of Women*. London: Penguin Books (Original works published 1869 and 1870 respectively).

Miu, A. C., Heilman, R. M., & Houser, D. (2008). Anxiety impairs decision-making: Psychophysiological evidence from an Iowa gambling task. *Biological Psychology, 77*, 353-358.

Miyake, A., & Shah, P. (Eds.). (1999). *Models of working memory: mechanisms of active maintenance and executive control* Cambridge: Cambridge University Press.

Monin, B. (2003). The warm glow heuristic: when liking leads to familiarity. *Journal of Personality and Social Psychology, 85*(6), 1035-1048.

Morgan, J. J. B., & Morton, J. T. (1944). The distortion of syllogistic reasoning produced by personal convictions. *The Journal of Social Psychology, 20*, 39-59.

Morsanyi, K., & Handley, S. J. (2011). Logic feels so good - I like it! Evidence for intuitive detection of logicality in syllogistic reasoning. *Journal of Experimental Psychology: Learning, Memory, and Cognition*, November 7th; Advanced Online Publication. doi: 10.1037/a0026099

Moutier, S., Plagne-Cayeux, S., Melot, A., & Houdé, O. (2006). Syllogistic reasoning and belief-bias inhibition in school children: evidence from a negative priming paradigm. *Developmental Science, 9*(2), 166-172.

Newstead, S. E., Handley, S. J., Harley, C., Wright, H., & Farrelly, D. (2004). Individual differences in deductive reasoning. *The Quarterly Journal of Experimental Psychology, 57A*(1), 33-60.

Newstead, S. E., Thompson, V. A., & Handley, S. J. (2002). Generating alternatives: a key component in human reasoning? *Memory and Cognition, 30*(1), 129-137.

Niedenthal, P. M. (2007). Embodying emotion. *Science, 316*(1002-1005).

Oaksford, M., & Chater, N. (2001). The probabilistic approach to human reasoning. *Trends in Cognitive Sciences, 5*, 349-357.

Oaksford, M., & Chater, N. (2009). Précis of Bayesian rationality: The probabilistic approach to human reasoning. *Behavioral and Brain Sciences, 32*, 69-120. doi: 10.1017/S0140525X09000284

Oaksford, M., Morris, F., Grainger, B., & Williams, J. M. G. (1996). Mood, reasoning, and central executive processes. *Journal of Experimental Psychology: Learning, Memory, and Cognition, 22*(2), 476-492.

Oberaurer, K. (2006). Reasoning with conditionals: a test of formal models of four theories. *Cognitive Psychology, 53*, 238-283.

Öhman, A., Flykt, A., & Esteves, F. (2001). Emotion drives attention: detecting the snake in the grass. *Journal of Experimental Psychology: General, 130*(3), 466-478.

Öhman, A., & Mineka, S. (2001). Fears, phobias and preparedness: toward an evolved module of fear and learning. *Psychological Review, 108*(3), 483-522.

Osman, M. (2004). An evaluation of dual-process theories of reasoning. *Psychonomic Bulletin and Review, 11*(6), 988-1010.

Over, D. E., & Evans, J. S. B. T. (2003). The probability of conditionals. *Mind and Language, 18*(4), 340-358.

Over, D. E., Hadjichristidis, C., Evans, J. S. B. T., Handley, S. J., & Sloman, S. A. (2007). The probability of causal conditionals. *Cognitive Psychology, 54*, 62-97.

Pacini, R., & Epstein, S. (1999). The relation on rational and experiential information processing styles to personality, basic beliefs, and the ratio-bias phenomenon. *Journal of Personality and Social Psychology, 76*(6), 972-987.

Pacini, R., Muir, F., & Epstein, S. (1998). Depressive realism from the perspective of cognitive-experiential self-theory. *Journal of Personality and Social Psychology, 74*(4), 1056-1068.

Palmer, B., Gignac, G., Bates, T., & Stough, C. (2003). Examining the structure of the trait meta-mood scale. *Australian Journal of Psychology, 55*, 154-158. doi: 10.1080/0004953042000298612

Parkinson, B. (1995). *Ideas and realities of emotion*. London: Routledge.

Parzuchowski, M., & Szymkow-Sudziarska, A. (2008). Well, slap my thigh: expression of surprise facilitates memory of surprising material. *Emotion, 8*(3), 430-434.

Perham, N., & Oaksford, M. (2005). Deontic reasoning with emotional content: evolutionary psychology or decision theory? *Cognitive Science, 29*(5), 681-718.
Phillips, L. H., Channon, S., Tunstall, M., Hedenstrom, A., & Lyons, K. (2008). The role of working memory in decoding emotions. *Emotion, 8*(2), 154-191.
Plutchik, R. (1980). A general psychoevolutionary theory of emotion. In R. Plutchik & H. Kellerman (Eds.), *Emotion: theory, research, and experience* (Vol. 1: Theories of emotion, pp. 3-33). New York: Academic.
Poliakoff, E., Miles, E., Li, X., & Blanchette, I. (2007). The effect of visual threat on spatial attention to touch. *Cognition, 102*, 405-414.
Pratto, F., & John, O. P. (1991). Automatic vigilance: The attenion-grabbing power of negative social information. *Journal of Personality and Social Psychology, 61*(3), 380-391. doi: 10.1037/0022-3514.61.3.380
Priest, G. (2000). *Logic: a very short introduction*. Oxford: Oxford University Press.
Quayle, J. D., & Ball, L. J. (2000). Working memory, metacognitive uncertainty, and belief-bias in syllogistic reasoning. *The Quarterly Journal of Experimental Psychology, 53A*(4), 1202-1223.
Raine, A., Buchsbaum, M., & LaCasse, L. (1997). Brain abnormalities in murderers indicated by positron emission tomography. *Biological Psychiatry, 42*, 495-508.
Reidy, D. E., Zeichner, A., Hunnicutt-Ferguson, K., & Lilienfeld, S. O. (2008). Psychopathy traits and the processing of emotion words: results of a lexical decision task. *Cognition and Emotion, 22*(6), 1174-1186.
Repovš, G., & Baddeley, A. (2006). The multi-component model of working memory: explorations in experimental cognitive psychology. *Neuroscience, 139*, 5-21.
Richards, A., French, C. C., Keogh, E., & Carter, C. (2000). Test-anxiety, inferential reasoning, and working memory. *Anxiety, Stress, and Coping, 13*(1), 87-109.
Rijmen, F., & De Boeck, P. (2001). Propositional reasoning: the differential contribution of 'rules' to the difficulty of complex reasoning problems. *Memory and Cognition, 29*(1), 165-175.
Rips, L. J. (1994). *The psychology of proof: deductive reasoning in human thinking*. London: MIT Press.
Rips, L. J. (2001). Two kinds of reasoning. *Psychological Science, 12*(2), 129-134.
Rossano, M. J. (2002). *Evolutionary psychology: the science of human behaviour and evolution*. Oxford: John Wiley & Sons Inc.
Ruff, C. C., Knauff, M., Fangmeier, T., & Spreer, J. (2003). Reasoning and working memory: common and distinct neuronal processes. *Neuropsychologia, 41*, 1241-1253.
Russell, J. A. (1980). A circumplex model of affect. *Journal of Personality and Social Psychology, 39*(6), 1161-1178.
Rusting, C. L. (1998). Personality, mood, and cognitive processing of emotional information: three conceptual frameworks. *Psychological Bulletin, 124*(2), 165-196.
Sackett, A. M., Meyvis, T., Nelson, L. D., Converse, B. A., & Sackett, A. L. (2008). You're having fun when time flies: the hedonic consequences of subjective time progression. [Online: http://tinyurl.com/n8lwzr].

Sacks, O. (2007). *The man who mistook his wife for a hat*. London: Picador.

Sakaki, M. (2004). Effects of self-complexity on mood incongruent recall. *Japanese Psychological Research, 46*(2), 127-134.

Salovey, P. (1992). Mood-induced self-focused attention. *Journal of Personality and Social Psychology, 62*(4), 699-707.

Salovey, P., & Birnbaum, D. (1989). Influence of mood on health-relevant cognitions. *Journal of Personality and Social Psychology, 57*(3), 539-551.

Salovey, P., Mayer, J. D., Goldman, S. L., Turvey, C., & Palfai, T. P. (1995). Emotional attention, clarity, and repair: exploring emotional intelligence using the trait meta-mood scale. In J. W. Pennebaker (Ed.), *Emotion, Disclosure, and Health* (pp. 125-154). Washington, DC: American Psychological Association.

Sartre, J. P. (2008). *A sketch for a theory of the emotions*. London: Routledge (Origianl work published in 1939).

Schaefer, A., Pottage, C. L., & Rickart, A. J. (2011). Electrophysiological correlates of remembering emotional pictures. *NeuroImage, 54*, 714-724.

Schimmack, U. (2005). Attentional interference effects of emotional pictures: Threat, negativity, or arousal? *Emotion, 5*(1), 55-66. doi: 10.1037/1528-3542.5.1.55

Schnall, S., Jaswal, V. K., & Rowe, C. (2008). A hidden cost of happiness in children. *Developmental Science, 11*(5), F25-F30.

Schultz, D. P., & Schultz, S. E. (2000). *A history of modern psychology* (7th ed.). Belmont, CA: Wadsworth.

Schwarz, N., & Clore, G. L. (1983). Mood, misattribution, and judgments of well being: informative and directive functions of affective states. *Journal of Personality and Social Psychology, 45*(3), 513-523.

Schwarz, N., & Clore, G. L. (2003). Mood as information: 20 years later. *Psychological Inquiry, 14*(3&4), 296-303.

Sechrist, G. B., Swim, J. K., & Melvin, M. M. (2003). Mood as information in making attributions to discrimination. *Personality and Social Psychology Bulletin, 29*, 524-531.

Serpell, S. (2011, unpublished thesis). *Necessity, Possibility and the Search for Counterexamples in Human Reasoning.* (Doctor of Philosophy), University of Plymouth, Plymouth.

Shackman, A. J., Sarinopoulos, I., Maxwell, J. S., Pizzagalli, D. A., Lavric, A., & Davidson, R. J. (2006). Anxiety selectively disrupts visuospatial working memory. *Emotion, 6*(1), 40-61.

Shynkaruk, J. M., & Thompson, V. A. (2006). Confidence and accuracy in deductive reasoning. *Memory and Cognition, 34*(3), 619-632.

Sigall, H., & Johnson, M. (2006). The relationship between facial contact with a pillow and mood. *Journal of Applied Social Psychology, 36*(2), 505-526.

Silvestrini, N., & Gendolla, G. H. E. (2007). Mood effects on autonomic activity in mood regulation. *Psychophysiology, 44*, 650-659.

Simeon, D., Stanley, B., Frances, A., Mann, J. J., Winchel, R., & Stanley, M. (1992). Self mutilation in personality disorders: psychological and biological correlates. *American Journal of Psychiatry, 149*, 221-226.

Smith, S. M., & Petty, R. E. (1995). Personality moderators of mood congruency effects in cognition: the role of self-esteem and negative mood regulation. *Journal of Personality and Social Psychology, 68*(6), 1092-1107.

Song, L. J., Huang, G., Peng, K. Z., Law, K. S., Wong, C., & Chen, Z. (2010). The differenital effects of general mental ability and emotional intelligence on academic performance and social interactions. *Intelligence, 38*, 137-143.

Stanovich, K. E. (1999). *Who is rational? Studies of individual differences in reasoning*. London: Lawrence Erlbaum Associates.

Stanovich, K. E. (2000). Composite actively open-minded thinking scale. [Online: http://tinyurl.com/8nacqzc]. Retrieved from

Stanovich, K. E., & West, R. F. (2000). Inividual differences in rasoning: Implicatons for the rationality debate? *Behavioural and Brain Sciences, 23*, 645-726.

Stanovich, K. E., & West, R. F. (2007). Natural myside bias is independent of cognitive ability. *Thinking and Reasoning, 13*(3), 225-247.

Steinhauser, M., Maier, M., & Hübner, R. (2007). Cognitive control under stress: how stress affects strategies of task-set reconfiguration. *Psychological Science, 18*(6), 540-545.

Stokes, P. (2004). *Philosophy: 100 essential thinkers*. Kettering: Index.

Storbeck, J., & Clore, G. L. (2005). With sadness comes accuracy; with happiness, false memory: mood and the false memory effect. *Psychological Science, 16*(10), 785-791.

Storbeck, J., & Clore, G. L. (2008). Affective arousal as information:how affective arousal influences judgements, learning, and memory. *Social and Personality Compass, 2*, 1824-1843.

Sugden, R. (2008). Nash equilibrium, team reasoning and cognitive hierachy theory. *Acta Psychologica, 128*, 402-404.

Suβ, H., Oberauer, K., Wittman, W. W., Wilhelm, O., & Schulze, R. (2002). Working-memory capacity explains reasoning ability - and a little bit more. *Intelligence, 30*, 261-288.

Symes, E., Tucker, M., Ellis, R., Vainio, L., & Ottoboni, G. (2008). Grasp preparation improves change detection for congruent objects. *Journal of Experimental Psychology: Human Perception and Performance, 34*(4), 854-871.

Tamir, M., & Robinson, M. D. (2007). The happy spotlight: positive mood and selective attention to rewarding stimuli. *Personality and Social Psychology Bulletin, 33*, 1124-1136.

Thayer, R. E. (1991). *The biopsychology of mood and activation*. Oxford: Oxford University Press.

Thompson, V. A., Striemer, C. L., Reikoff, R., Gunter, R. W., & Campbell, J. I. D. (2003). Syllogistic reasoning and time: disconfirmation disconfirmed. *Psychonomic Bulletin and Review, 10*(1), 184-189.

Tohill, J. M., & Holyoak, K. J. (2000). The impact of anxiety on analogical reasoning. *Thinking and Reasoning, 6*(1), 27-40.

Tomarken, A. J., & Keener, A. D. (1998). Frontal brain asymmetry and depression: a self-regulatory perspective. *Cognition and Emotion, 12*(3), 387-420.

Topolinski, S., & Strack, F. (2009). The architecture of inuition: Fluency and affect determine intuitive judgements of semantic and visual coherence and

judgements of grammaticality in artificial grammar learning. *Journal of Experimental Psychology: General, 138*(1), 39-63.
Torrens, D., Thompson, V. A., & Cramer, K. M. (1999). Individual differences and the belief bias effect: mental models, logical necessity, and abstract reasoning. *Thinking and Reasoning, 5*(1), 1-28.
Tucker, M. (2007). Slide Generator. [Online: http://tinyurl.com/9l52eyp].
Van Dillen, L. F., Heslenfeld, D. J., & Koole, S. L. (2009). Tuning down the emotional brain: An fMRI study of the effects of cognitive load on the processing of affective images. *NeuroImage, 45*, 1212-1219. doi: 10.1016/j.neuroimage.2009.01.016
Van Dillen, L. F., & Koole, S. L. (2007). Clearing the mind: a working memory model of distraction from negative mood. *Emotion, 7*(4), 715-723. doi: 10.1037/1528-3542.7.4.715
Venables, W. N., & Smith, D. M. (2010). R (Version 2.12.0): The R Foundation for Statistical Computing
Verbruggen, F., & DeHouwer, J. (2007). Do emotional stimuli interfere with response inhibition? Evidence from the stop signal paradigm. *Cognition and Emotion, 21*(2), 391-403.
Walliser, B. (1998). A spectrum of equalibration processes in game theory. *Journal of Evolutionary Economics, 8*, 67-87.
Warburton, N. (2008). *Philosophy: the classics*. Londond: Routledge.
Warwick, J., & Nettelbeck, T. (2004). Emotional intelligence is...? *Personality and Individual Differences, 37*, 1091-1100. doi: 10.1016/j.paid.2003.12.003
Watson, D., & Clark, L. E. (1994). The PANAS-X: manual for the positive and negative affect schedule - expanded form. [Online: http://tinyurl.com/9zdjmcg].
Watson, D., Clark, L. E., & Tellegen, A. (1988). Development and validation on brief measures of positive and negative affect: the PANAS scales. *Journal of Personality Psychology, 54*(6), 1063-1070.
Watson, D., & Tellegen, A. (1985). Toward a consensual structure of mood. *Psychological Bulletin, 98*(2), 219-235.
Weber, N. W., & Perfect, T. J. (2011). Improving eyewitness identification accuracy by screening out those who say they don't know *Law and Human Behavior, Online First*. doi: 10.1007/s10979-011-9269-1
Westermann, R., Spies, K., Stahl, G., & Hesse, F. (1996). Relative effectiveness and validity of mood induction procedures: a meta-analysis. *European Journal of Social Psychology, 26*(557-580).
Winkielman, P., & Berridge, K. C. (2004). Unconscious emotion. *Current Directions in Psychological Science, 13*(3), 120-123.
Young, H. P. (1998). Individual learning and social rationality. *European Economic Review, 42*, 651-663.
Zahra, D. (2008). Do anxiety level and anxiety-related content affect accuracy and endorsement rate on syllogistic reasoning by increasing reliance on belief-biased heuristic processing? *Plymouth Student Scientist, 1*(1), 229-295 [Online: http://tinyurl.com/298sutzj]
Zahra, D. (2008 unpublished). *Mood and syllogistic reasoning: affect as information or cognitive load?* MSc Thesis. University of Plymouth.

Zahra, D. (2012). The irrationality of logic. *Experimentation: Psychology*(April), [Online: http://tinyurl.com/cwqah8y].

Zahra, D., Bailey, C., Hedge, C., Wyles, K., & Sanders, B. G. (2012 in press). A Short Report on the Trait Meta-Mood Scale and the Importance of Scale Norms. *Social Psychological Review, xx*(xx), xx-xx.

Zahra, D., & Hedge, C. (2010). The reliable change index: Why isn't it more popular in academic psychology? *Psychology Postgraduate Affairs Group Quarterly, 76*, 14-19.

Zajonc, R. B. (1968). Attitudinal effects of mere exposure. *Journal of Personality and Social Psychology, 9*, 1-27.

Zajonc, R. B. (1980). Feeling and thinking: preferences need no inferences. *American Psychologist, 35*(2), 151-175.

Zajonc, R. B. (1984). On the primacy of affect. *American Psychologist, 39*(2), 117-123.

Appendices

A. Necessity-Possibility Paradigm Materials (Experiment 1)

Instructions

Brief

Thank you for taking part in this experiment. This experiment will consist of a series of sections intended to investigate different concepts in the shortest possible time.

In the first section will be asked to describe a life event to provide materials for a future study. This may be emotionally distressing, but you should keep in mind your right to withdraw from the study at any point, and note the contact details of counselling services at the bottom of the debrief.

After this short task, you will be presented with a series of reasoning problems which make up the main part of the current study. Each problem will require you to indicate whether a conclusion falls into one of two categories. You may work through the reasoning section at your own speed, and take breaks when you feel they are necessary.

At the end of the study, you will be required to rate a short series of jokes so that they can be evaluated for future use.

Your responses will be kept anonymous, and you have the right to withdraw from the study at any time without incurring any penalty by asking to withdraw. Even after you have completed this experiment you can withdraw your data by contacting the experimenter and providing your participant ID number.

If you have any questions, please ask the experimenter now before continuing

Mood manipulation instructions

(All conditions)

As part of a future study, researchers at the university intend to investigate how reading about people's reactions to life events can influence judgements. To fill time in the current study, please complete the following task to provide the researchers with a selection of events to use in their study.

(Positive and Negative conditions)

Please try to recall a particularly [happy/sad] event in your life. It may be, for example, [receiving good results on a difficult test, an unusually fun and memorable night out with friends, or a joyful family occasion such as a birthday or wedding/ failing an important test, the death of a loved relative or pet, or the break up of a relationship] that made you [happy/sad]. When you have decided on a memory, please write in the box below everything you can remember about the event, describing the event briefly, and then focusing on your thoughts, feelings, and reactions. Please try to write for around 10 minutes before moving on to the next section.

(Neutral condition)

Please try to recall an occasion on which you used one of the library services; for example, book loaning, computing and printing facilities, or room booking. When you have decided on a memory, please write in the box below everything you can remember about the event, describing the event briefly, and then focusing on what you noticed about your surroundings. Please try to write for around 10 minutes before moving on to the next section.

(All conditions)

All responses will remain anonymous, and you may choose to withdraw your description at any time. If you have any questions about the task, contact the experimenter now.

PANAS Instructions

The following scale consists of a number of words that describe different feelings and emotions. Please read each item and then check the appropriate box next to that word. Indicate to what extent you feel this way at this moment.

Necessity Reasoning Instructions

From this point forwards, please work through all of the sections in order at your own speed.

In the next section, you will be presented with a series of reasoning problems.

Each problem consists of three lines; the first two are premises, the third a conclusion. Each problem will relate to the relationships between the occupations of three individuals. For each problem, assume that the premises are true.

For each problem, please read the premises and the conclusion, and then indicate whether or not you think the conclusion necessarily follows;

For example:
All Cats have tails
Tabby is a Cat
Therefore, Tabby has a tail

If you think the conclusion shown must be true given that the premises are true, you should check the 'Necessary' box. In the case above, based on the premises, Tabby must have a tail, so you should indicate that the conclusion is necessary.

A necessary conclusion is one that must be true when the premises are true

Possibility Reasoning Instructions

From this point forwards, please work through all of the sections in order at your own speed.

In the next section, you will be presented with a series of reasoning problems.

Each problem consists of three lines; the first two are premises, the third a conclusion. Each problem will relate to the relationships between the occupations of three individuals. For each problem, assume that the premises are true.

For each problem, please read the premises and the conclusion, and then indicate whether or not you think the conclusion is possible;

For example:
All Cats have tails

Tabby has a tail
Therefore, Tabby is a cat

If you think the conclusion shown could be true given that the premises are true, you should check the 'Possible' box. In the case above, based on the premises, Tabby may be a cat, so you should indicate that the conclusion is possible.

A possible conclusion is one that could be true when the premises are true

Debrief

Thank you for completing the study. Your help is greatly appreciated.

The aim of this study was to investigate the effects of mood on reasoning, in the hope of providing a better understanding of how emotions interact with heuristic and analytic reasoning systems.

Specifically, whether positive and negative mood have the same, different, or no effect on the systems people use to reason.

Although the life event exercise may be used to develop mood manipulations in future, in this experiment it also served to induce a particular mood, and the joke-rating task was included in order to neutralise any negative effects the writing task may have had on your mood.

If you would like further information on this study, or wish for your data to be removed from subsequent analyses, please contact the experimenter (details below)

If you feel emotionally distressed following this experiment, or feel you might like to talk to someone about any issues raised, please do not hesitate to contact the university's counselling services (details below)

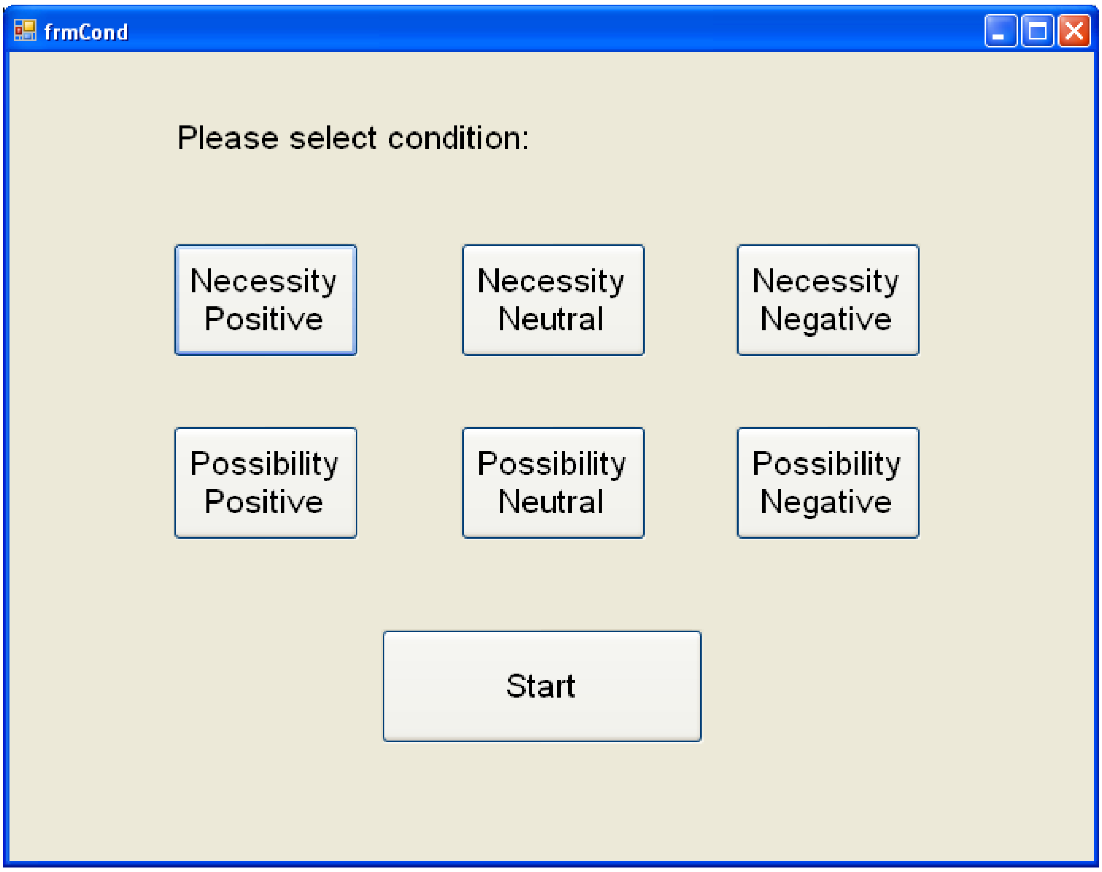
Experimenter: Daniel Zahra, daniel.zahra@plymouth.ac.uk
First Supervisor: Professor Simon Handley,
s.handley@plymouth.ac.uk

Counselling Services: studentcounselling@plymouth.ac.uk,
01752 232254

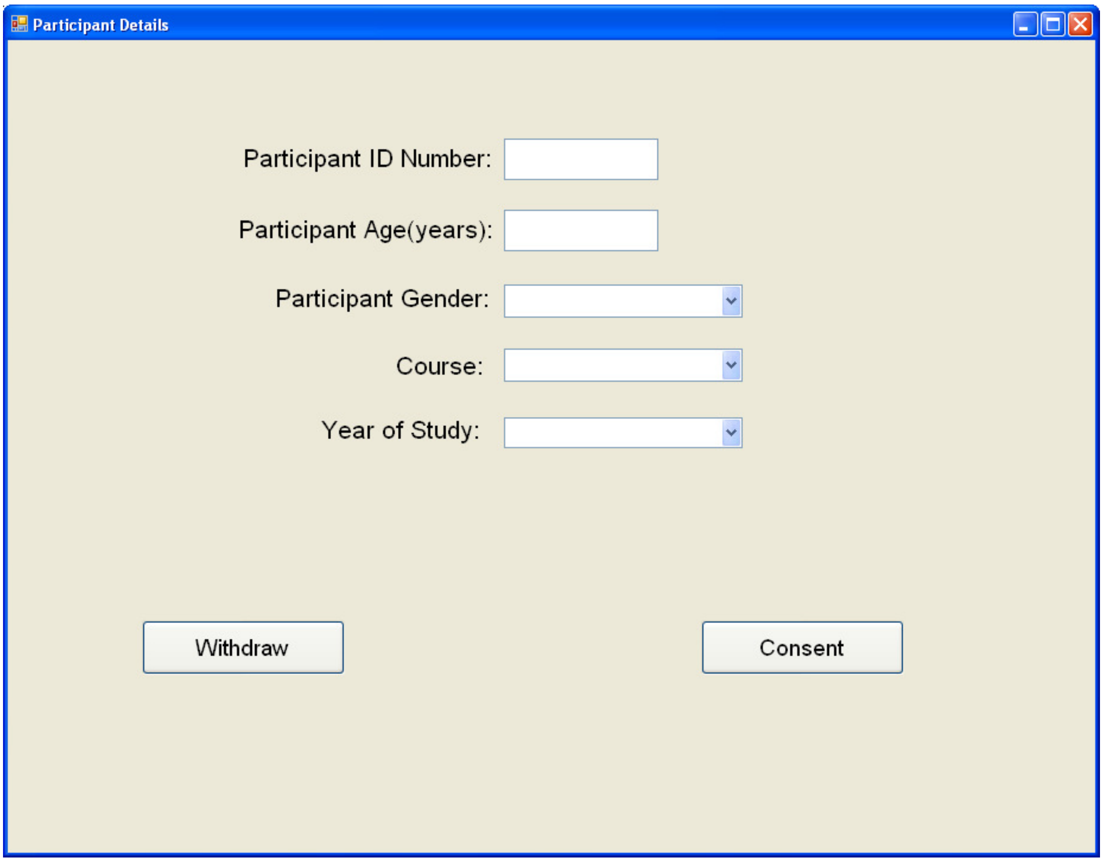
Syllogisms

Conclusion	Structure A-B, B-C, A-C	Mood	Endorsement Rate (Evans et al 1999)
Necessary	All Architects are Bankers All Bankers are Cooks All Architects are Cooks	AAa	73
	All Accountants are Builders No Builders are Cleaners No Accountants are Cleaners	AEe	83
	Some Taxi-drivers are Engineers All Engineers are Climbers Some Taxi-drivers are Climbers	IAi	87
	Some Lawyers are Priests No Priests are Students Some Lawyers are not Students	IEo	83
Impossible	All Nurses are Runners No Runners are Lecturers All Nurses are Lecturers	AEa	3
	All Musicians are Babysitters No Babysitters are Surgeons Some Musicians are Surgeons	AEi	7
	Some Astronauts are Scientists All Scientists are Carpenters No Astronauts are Carpenters	IAe	10
	Some Chemists are Surfers No Surfers are Teachers All Chemists are Teachers	IEa	0
Possible-Strong	All Journalists are Bus-drivers Some Bus-drivers are not Professors Some Journalists are not Professors	AOo	90
	Some Canoeists are Zoo-keepers Some Zoo-keepers are Policemen Some Canoeists are Policemen	IIi	80
	Some Clowns are not Sailors All Sailors are Judges Some Clowns are not Judges	OAo	83
	Some Soldiers are not Magicians Some Magicians are not Electricians Some Soldiers are not Electricians	OOo	87
Possible-Weak	Some Waiters are Managers Some Managers are Caterers No Waiters are Caterers	IIe	3
	Some Pilots are not Divers Some Divers are Painters No Pilots are Painters	OIe	3
	Some Plumbers are not Writers No Writers are Bikers All Plumbers are Bikers	OEa	3
	Some Artists are not Salesmen Some Salesmen are Cobblers All Artists are Cobblers	OO	7

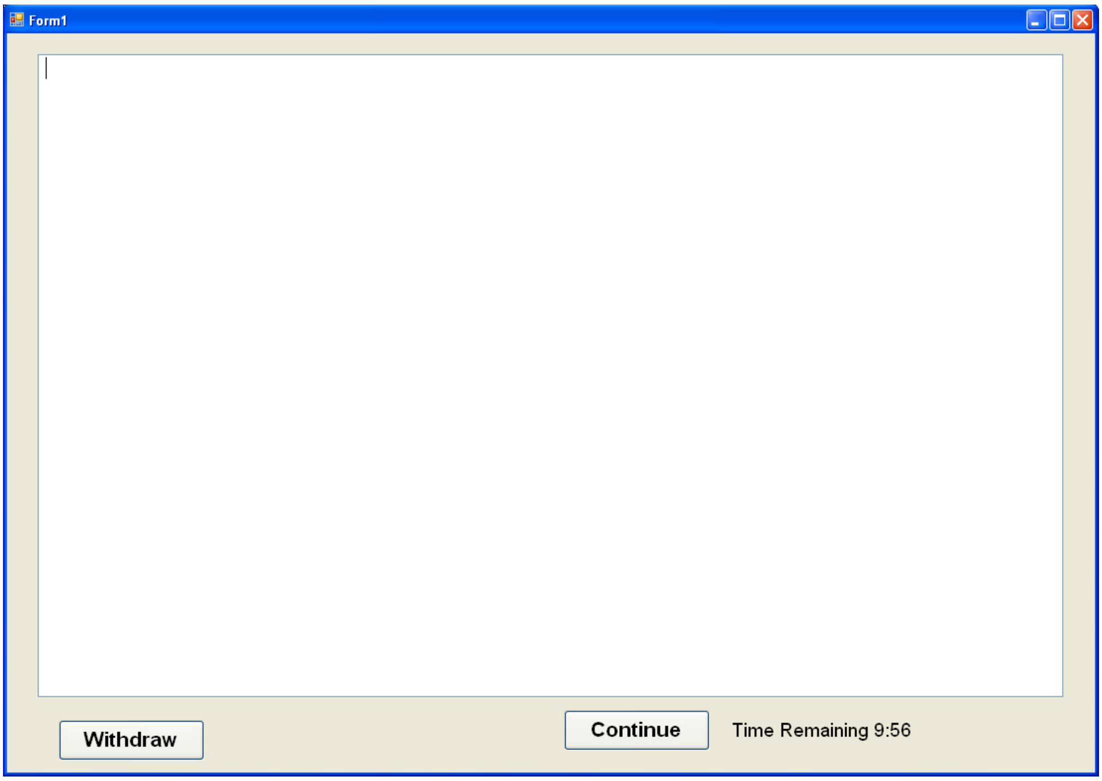
Screenshots from Experiment 1



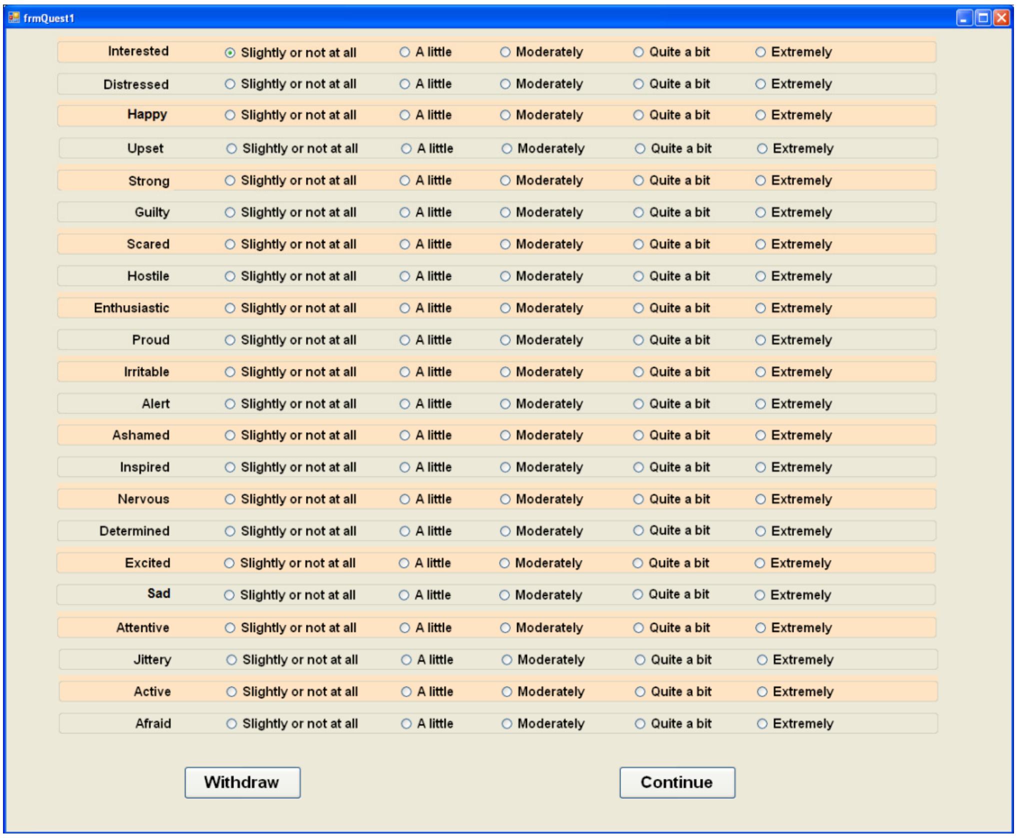
Appendix Figure 1 Condition selection screen



Appendix Figure 2 Demographic information screen



Appendix Figure 3 Mood manipulation task screen



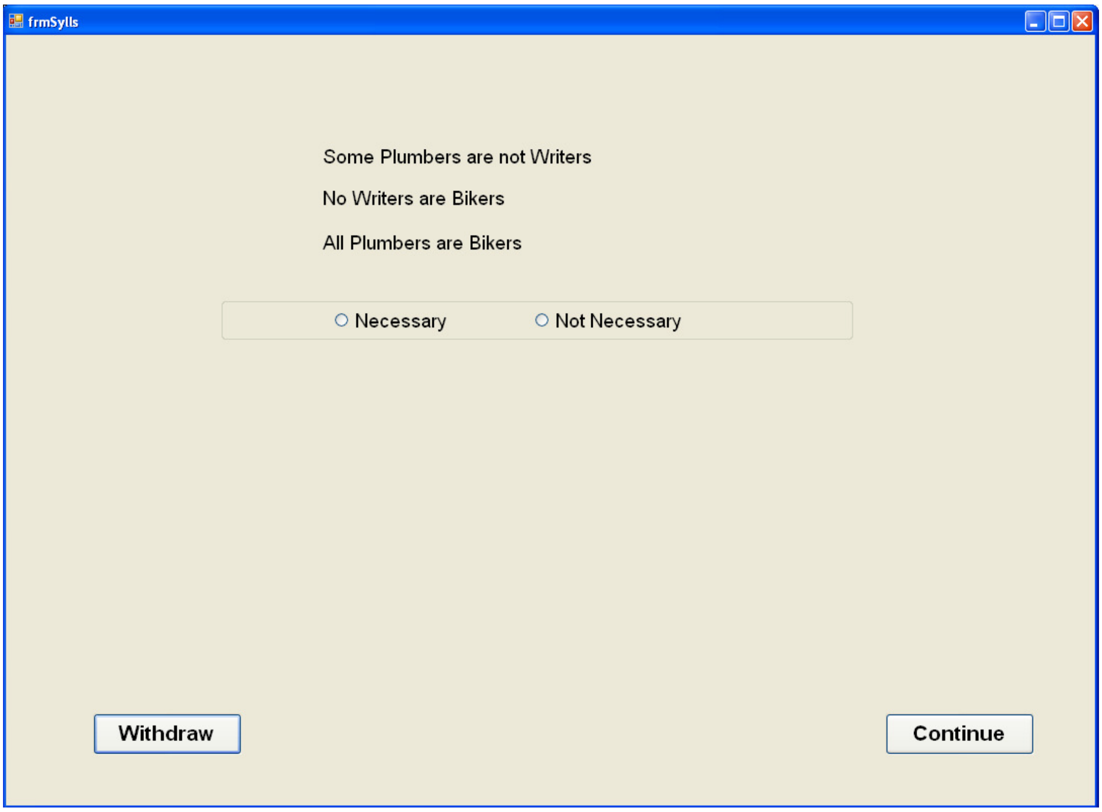
frmQuest1

Interested	Slightly or not at all	A little	Moderately	Quite a bit	Extremely
Distressed	Slightly or not at all	A little	Moderately	Quite a bit	Extremely
Happy	Slightly or not at all	A little	Moderately	Quite a bit	Extremely
Upset	Slightly or not at all	A little	Moderately	Quite a bit	Extremely
Strong	Slightly or not at all	A little	Moderately	Quite a bit	Extremely
Guilty	Slightly or not at all	A little	Moderately	Quite a bit	Extremely
Scared	Slightly or not at all	A little	Moderately	Quite a bit	Extremely
Hostile	Slightly or not at all	A little	Moderately	Quite a bit	Extremely
Enthusiastic	Slightly or not at all	A little	Moderately	Quite a bit	Extremely
Proud	Slightly or not at all	A little	Moderately	Quite a bit	Extremely
Irritable	Slightly or not at all	A little	Moderately	Quite a bit	Extremely
Alert	Slightly or not at all	A little	Moderately	Quite a bit	Extremely
Ashamed	Slightly or not at all	A little	Moderately	Quite a bit	Extremely
Inspired	Slightly or not at all	A little	Moderately	Quite a bit	Extremely
Nervous	Slightly or not at all	A little	Moderately	Quite a bit	Extremely
Determined	Slightly or not at all	A little	Moderately	Quite a bit	Extremely
Excited	Slightly or not at all	A little	Moderately	Quite a bit	Extremely
Sad	Slightly or not at all	A little	Moderately	Quite a bit	Extremely
Attentive	Slightly or not at all	A little	Moderately	Quite a bit	Extremely
Jittery	Slightly or not at all	A little	Moderately	Quite a bit	Extremely
Active	Slightly or not at all	A little	Moderately	Quite a bit	Extremely
Afraid	Slightly or not at all	A little	Moderately	Quite a bit	Extremely

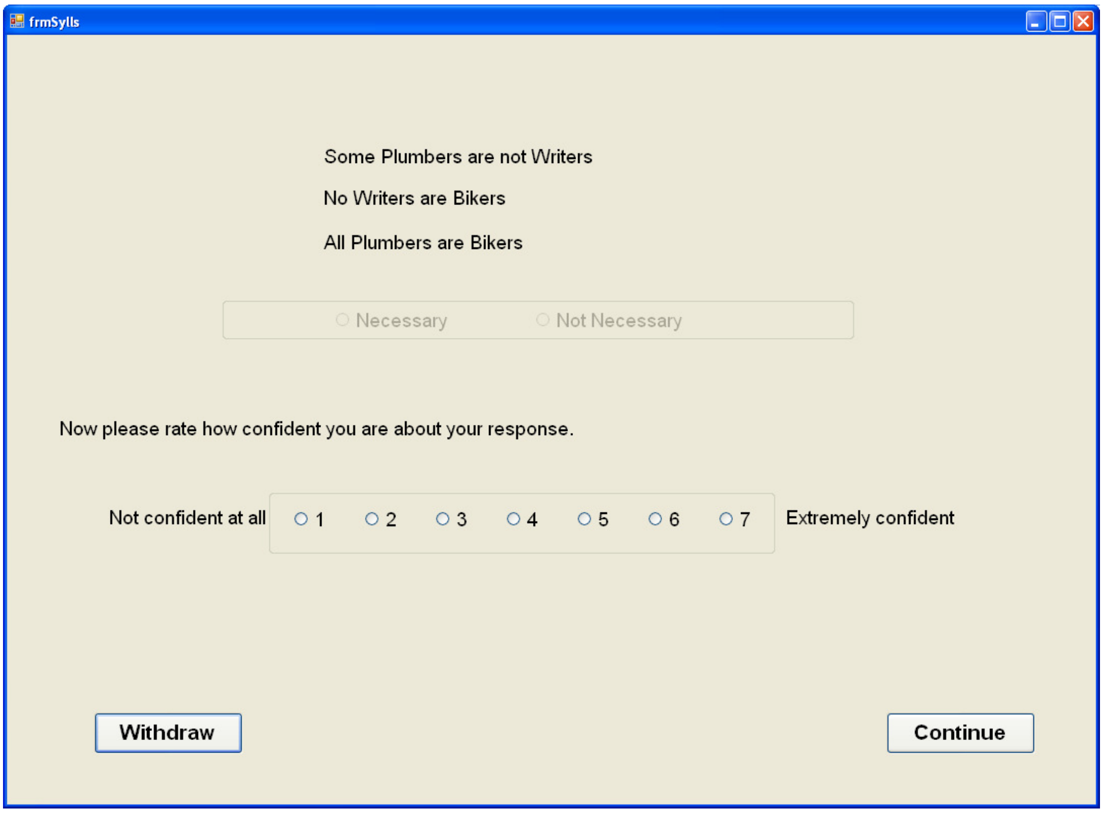
Withdraw

Continue

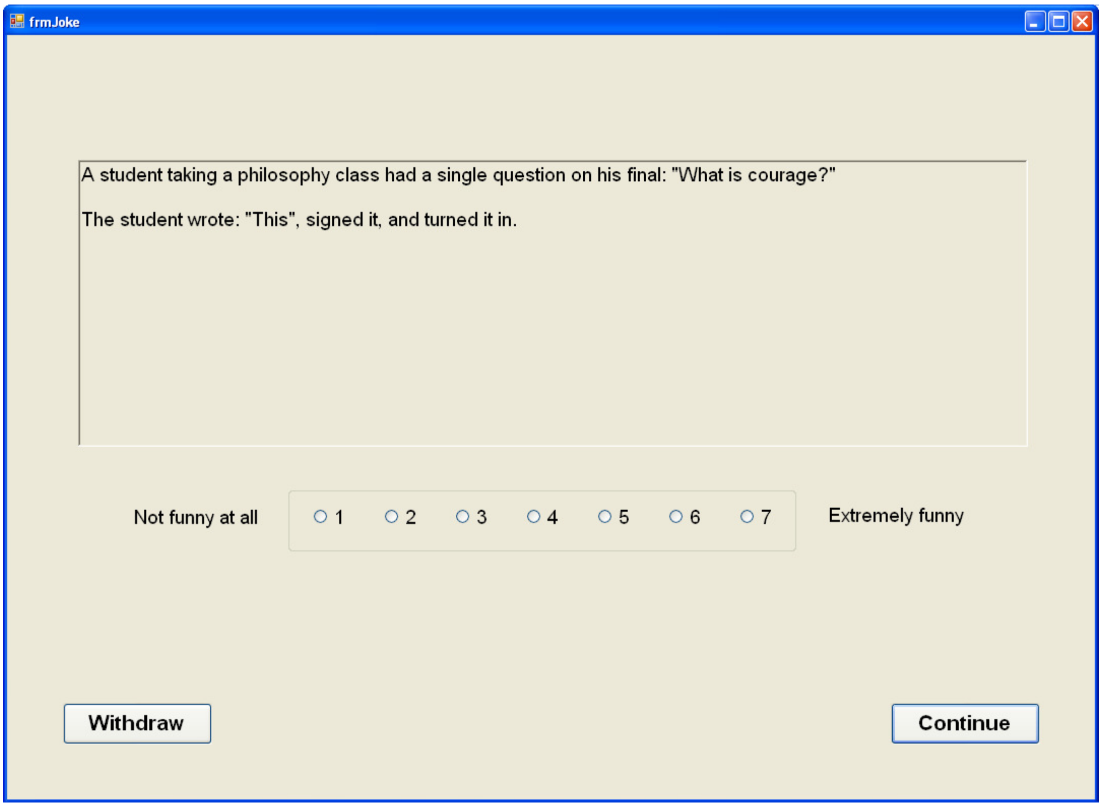
Appendix Figure 4 PANAS screen



Appendix Figure 5 Reasoning Task Judgement screen



Appendix Figure 6 Reasoning Task Confidence Rating screen



Appendix Figure 7 Joke Rating Task screen

B. Necessity-Possibility Paradigm Materials (Experiment 2)

Online Recruitment Sources

Note: Subscription numbers are as of 29th June 2009

Staff@psy.plymouth.ac.uk : University of Plymouth mailing list covering Department of Psychology staff (40 subscribers)
Pg@psy.plymouth.ac.uk: University of Plymouth mailing list covering School of Psychology MPhil and PhD students (39 subscribers).
Msc@psy.plymouth.ac.uk: University of Plymouth mailing list covering School of Psychology MSc Psychological Research Methods and Psychology conversion students (27 subscribers).
Neuroscience@plymouth.ac.uk: University of Plymouth mailing list covering members of the neuroscience department (approx. 20 subscribers).
Psy-net-research@jiscmail.ac.uk: Jiscmail mailing list covering psychologists interested in research using the internet (152 subscribers).
Psych-postgrads@jiscmail.co.uk: Jiscmail mailing list dedicated to psychology postgraduates (510 subscribers).
Cog-sci-rel-l@jiscmail.co.uk: Jiscmail mailing lists covering psychologists interested in cognitive science and religion (128 subscribers).
Criticalthinking@jiscmail.co.uk: Jiscmail mailing lists covering psychologists interested in critical thinking research (75 subscribers).
www.facebook.com: Social networking site allowing posting to friends, colleagues, family, and acquaintances from all social and educational areas and backgrounds.
http://psych.hanover.edu/research/exponnet.html: a website listing online psychology studies by topic area maintained by John H. Krantz (krantzj@hanover.edu) with the Hanover College Psychology Department
http://www.w-lab.de/lab-united/submit.php a website maintained by Anja Berger and Mirko Wendland, based at The University of Potsdam, which provides a directory of online psychology studies as well as research news.
http://www.in-mind.org/online-research/index.php: the website of the magazine *Inquisitive Mind*, hosted by One.com, and dedicated to social psychology, and which maintains a directory of online psychology studies.
Anthro-sciences@jiscmail.co.uk : This list supports an international special interest group for anthropological sciences and the development of anthropological research methods and theory (353 subscribers).
Neuromeg@jiscmail.co.uk : Mailing list for academic researchers using Magnetoencephalography (75 subscribers)
Psychologynetwork-neuro@jiscmail.co.uk : This list provides a forum for

discussing issues related to the learning and teaching of neuropsychology (106 subscribers)
SWSBC@jiscmail.co.uk: A place to discuss collaborative research in structural biology in theSouth West (12 subscribers)
UOBvisiongroup@jiscmail.co.uk: This list is used by the University of Bristol and affiliated membersvision science group to organise meetings and events (40 subscribers)
Biology-teaching@jiscmail.co.uk : Mailing list for those teaching biological sciences in higher-education (115 subscribers)
Embodiment@jiscmail.co.uk : Mailing list for Embodiment research from a philosophical perspective (212 subscribers).
All-active@jiscmail.co.uk: Information and discussion list for all branches, networks and activists within the philosophy jiscmail lists (27 subscribers)
Process-philosophy@jiscmail.co.uk: Open forum mailing list covering Process Thought. Whitehead's Metaphysics and Hartshorne's Theology (206 subscribers).
BCS-HCI@jiscmail.co.uk : British Computer Society Human-Computer Interaction Group mailing list (1,576 subscribers).

Used for TMMS/ATT/BIS-BAS SEM study questionnaire

POSTGRAD@JISCMAIL.AC.UK (560)
STUDENT-RETENTION-AND-SUCCESS@JISCMAIL.AC.UK (422)

Instructions

Brief (with consent/no consent question)

Thank you for taking part in this experiment. This experiment will consist of a series of sections intended to investigate different concepts in the shortest possible time.

Firstly, you will be presented with a series of reasoning problems which make up the main part of the current study. Each problem will require you to indicate whether a conclusion falls into one of two categories. You may work through the reasoning section at your own speed, and take breaks when you feel they are necessary.

Following this, you will be required to complete a short questionnaire.
Your responses will be kept anonymous, and you have the right to withdraw from the study at any time without incurring any penalty by closing your browser window. Even after you have completed this experiment you can

withdraw your data by contacting the experimenter and providing your participant ID number.

Demographic Instructions

Please complete the fields below.
For your participant ID number, please ender a memorable date in the MMDDYYYY format.

Necessity Reasoning Instructions

In the next section, you will be presented with a series of reasoning problems.

Each problem consists of three lines; the first two are premises, the third a conclusion. Each problem will relate to the relationships between the occupations of three individuals. For each problem, assume that the premises are true.

For each problem, please read the premises and the conclusion, and then indicate whether or not you think the conclusion necessarily follows;
or example:

All Cats have tails
Tabby is a Cat
Therefore, Tabby has a tail

If you think the conclusion shown must be true given that the premises are true, you should check the 'Necessary' box. In the case above, based on the premises, Tabby must have a tail, so you should indicate that the conclusion is necessary.

A necessary conclusion is one that must be true when the premises are true.

After indicating whether you think each conclusion is necessary or not necessary, you will then be required to indicate how confident you are in your response. Please indicate your level of confidence by selecting the appropriate option.

Possibility Reasoning Instructions

In the next section, you will be presented with a series of reasoning problems.

Each problem consists of three lines; the first two are premises, the third a conclusion. Each problem will relate to the relationships between the occupations of three individuals. For each problem, assume that the premises are true.

For each problem, please read the premises and the conclusion, and then indicate whether or not you think the conclusion is possible;

For example:
All Cats have tails
Tabby has a tail
Therefore, Tabby has is a cat

If you think the conclusion shown could be true given that the premises are true, you should check the 'Possible' box. In the case above, based on the premises, Tabby may be a cat, so you should indicate that the conclusion is possible.

A possible conclusion is one that could be true when the premises are true.

After indicating whether you think each conclusion is possible or not possible, you will then be required to indicate how confident you are in your response. Please indicate your level of confidence by selecting the appropriate option.

TMMS instructions

The following section is designed to measure a range of factors related to reasoning.

Please read each item in turn, and indicate the extent to which you agree or disagree with each.

Debrief

Thank you for completing the study. Your help is greatly appreciated.
The aim of this study was to investigate the effects of mood on reasoning, in the hope of providing a better understanding of how emotions interact with heuristic and analytic reasoning systems.

Specifically, whether positive and negative mood have the same, different, or no effect on the systems people use to reason. This was manipulated in the current study by varying problem content.

The questionnaire was designed to measure the extent to which you attend to your emotions and will be used to investigate the link between attention to emotions and the effects of problem content.

If you would like further information on this study, or wish for your data to be removed from subsequent analyses, please contact the experimenter (details below)

If you have any questions, please type them in the box below along with your email address and the experimenter will contact you as soon as possible.
If you feel emotionally distressed following this experiment, or feel you might like to talk to someone about any issues raised, please do not hesitate to contact the university's counselling services (details below)

Experimenter: Daniel Zahra, daniel.zahra@plymouth.ac.uk
First Supervisor: Professor Simon Handley, s.handley@plymouth.ac.uk
Counselling Services: studentcounselling@plymouth.ac.uk, 01752 232254

Syllogisms

Note: A, B, C, and D denote Necessary, Possible-Strong, Possible-Weak and Impossible categories respectively.

Positive Condition

Problem	Code
Some generous people are not compassionate All compassionate people are saints Some generous people are not saints	C1.3
Some cute things are kittens All cute things are babies No kittens are babies	B1.3
Some holidays are not soothing No soothing things are breaks from work All holidays are breaks from work	D1.3
All puppies are fluffy All fluffy things are cute All puppies are cute	A1.1
All weddings are celebrations No celebrations are really memorable Some weddings are really memorable	B1.2
All bunnies are friendly Some friendly animals are not fluffy Some bunnies are not fluffy	C1.1
Some exciting things are adventurous Some adventurous things are relaxing No exciting things are relaxing	D1.1
Some generous people are rich No rich people are millionaires Some generous people are not millionaires	A1.4
All successes are good No good things are worthwhile All successes are worthwhile	B1.1
Some chocolate things are tasty All tasty things are cakes Some chocolate things are cakes	A1.3
All friends are cheerful people No cheerful people are lovers No friends are lovers	A1.2
Some winners are not successful Some successful people are not gold medallists	C1.4

Some winners are not gold medallists	
Some beaches are not fantastic Some fantastic things are exhilarating No beaches are exhilarating	D1.2
Some comedians are kind No kind people are funny All comedians are funny	B1.4
Some birthdays are celebrations Some celebrations are enjoyable Some birthdays are enjoyable	C1.2
Some spa breaks are not cheerful Some cheerful things are peaceful All spa breaks are peaceful	D1.4

Control Condition

Problem	Code
Some Clowns are not Sailors All Sailors are Judges Some Clowns are not Judges	C1.3
Some Astronauts are Scientists All Scientists are Carpenters No Astronauts are Carpenters	B1.3
Some Plumbers are not Writers No Writers are Bikers All Plumbers are Bikers	D1.3
All Architects are Bankers All Bankers are Cooks All Architects are Cooks	A1.1
All Musicians are Babysitters No Babysitters are Surgeons Some Musicians are Surgeons	B1.2
All Journalists are Bus-drivers Some Bus-drivers are not Professors Some Journalists are not Professors	C1.1
Some Waiters are Managers Some Managers are Caterers No Waiters are Caterers	D1.1
Some Lawyers are Priests No Priests are Students Some Lawyers are not Students	A1.4
All Nurses are Runners No Runners are Lecturers All Nurses are Lecturers	B1.1

Some Taxi-drivers are Engineers All Engineers are Climbers Some Taxi-drivers are Climbers	A1.3
All Accountants are Builders No Builders are Cleaners No Accountants are Cleaners	A1.2
Some Soldiers are not Magicians Some Magicians are not Electricians Some Soldiers are not Electricians	C1.4
Some Pilots are not Divers Some Divers are Painters No Pilots are Painters	D1.2
Some Chemists are Surfers No Surfers are Teachers All Chemists are Teachers	B1.4
Some Canoeists are Zoo-keepers Some Zoo-keepers are Policemen Some Canoeists are Policemen	C1.2
Some Artists are not Salesmen Some Salesmen are Cobblers All Artists are Cobblers	D1.4

Negative Condition

Problem	Code
Some deaths are not violent All violent things are painful Some deaths are not painful	C1.3
Some rats are rapists All rapists are terrorists No rats are terrorists	B1.3
Some used diapers are not vile No vile things are soiled All used diapers are soiled	D1.3
All cancers are terrifying All terrifying things are deadly All cancers are deadly	A1.1
All prisoners are criminals No criminals are drug addicts Some prisoners are drug addicts	B1.2
All bloody things are stab wounds Some stab wounds are not injuries Some bloody things are not injuries	C1.1
Some infections are irritants Some irritants are contaminated	D1.1

No infections are contaminated	
Some tumours are fatal No fatal things are treatable Some tumours are not treatable	A1.4
All criminals are murderers No murderers are violent All criminals are violent	B1.1
Some murderers are terrorists All terrorists are dishonest Some murderers are dishonest	A1.3
All poisons are toxic No toxic are cancerous No poisons are cancerous	A1.2
Some rotten fruits are not mouldy Some mouldy things are not putrid Some rotten fruits are not putrid	C1.4
Some festering wounds are poisonous Some poisons are clean No festering wounds are clean	D1.2
Some radioactive things are toxic No toxins are dangerous All radioactive things are dangerous	B1.4
Some mutilations are extremely violent Some extremely violent acts are horrific Some mutilations are horrific	C1.2
Some blemishes are not puss-filled Some puss-filled wounds are ugly All blemishes are ugly	D1.4

TMMS Items

Items adapted from Salovey, Mayer and Goldman, in Pennebaker, J.W. 1995
Emotion, Disclosure and Health.

5= agree, 4= somewhat agree, 3=Neither agree nor disagree, 2=somewhat disagree,
1= disagree

Ss column denotes subscales: R for Repair, C for Clarity, A for Attention

Sc column indicates items that need to be reverse scored

Items recommended for the 30-item short form of the TMMS are in bold

#	Ss	Sc	Item	Rating
01			The variety of human feelings makes life more interesting	
02	**R**		**I try to think good thoughts no matter how badly I'm feeling**	
03			I don't have much energy when I am happy	
04	**A**	**r**	**People would be better off if they felt less and thought more**	
05			I usually don't have much energy when I'm sad	
06			**When I'm angry, I usually let myself feel that way**	
07	**A**	**r**	**I don't think it's worth paying attention to your emotions or moods**	
08	**A**	**r**	**I don't usually care much about what I'm feeling**	
09	**C**	**r**	**Sometimes I can't tell what my feelings are**	
10			If I find myself getting mad, I try to calm myself down	
11			I have lots of energy when I feel sad	
12	**C**		**I am rarely confused about how I feel**	
13			I think about my mood constantly	
14			I don't let my feelings interfere with what I am thinking	
15	**A**		**Feelings give direction to life**	
16	**R**		**Although I am sometimes sad, I have a mostly optimistic outlook**	
17	**R**	**r**	**When I am upset I realise that 'the good things in life' are illusions**	
18	A		I believe in acting from the heart	
19	**C**	**r**	**I can never tell how I feel**	
20			When I am happy I realise how foolish most of my worries are	
21			I believe it's healthy to feel whatever emotion you feel	
22	**A**		**The best way for me to handle my feelings is to experience them to the fullest**	
23	**R**		**When I become upset I remind myself of all the pleasures in life**	
24	**C**	**r**	**My belief and opinions always seem to change depending on how I feel**	
25			I usually have lots of energy when I'm happy	
26	**C**		**I am often aware of my feelings on a matter**	
27			When I'm depressed, I can't help but think bad thoughts	
28	**C**	**r**	**I am usually confused about how I feel**	
29	**A**	**r**	**One should never be guided by emotions**	
30			If I'm in too good a mood, I remind myself of reality to bring myself down	
31	**A**	**r**	**I never give in to my emotions**	

32	**R**	**r**	**Although I am sometimes happy, I have a mostly pessimistic outlook**	
33	**C**		**I feel at ease about my emotions**	
34			It's important to block out some feelings in order to preserve your sanity	
35	**A**		**I pay a lot of attention to how I feel**	
36			When I'm in a good mood, I'm optimistic about the future	
37	**C**	**r**	**I can't make sense out of my feelings**	
38	**A**	**r**	**I don't pay much attention to my feelings**	
39			Whenever I'm in a bad mood, I'm pessimistic about the future	
40			I never worry about being in too good a mood	
41	**A**		**I often think about my feelings**	
42	**C**		**I am usually very clear about my feelings**	
43	**R**		**No matter how badly I feel, I try to think about pleasant things**	
44	**A**	**r**	**Feelings are a weakness humans have**	
45	**C**		**I usually know my feelings bout a matter**	
46	**A**	**r**	**It is usually a waste of time to think about your emotions**	
47			When I am happy I sometimes remind myself of everything that could go wrong	
48	**C**		**I almost always know exactly how I am feeling**	

C. Belief-Bias Materials (Experiment 3)

Instructions

Brief

This study aims to investigate factors that affect reasoning. During this study you will be required to complete a short series of reasoning problems. Your responses will remain anonymous, will only be used for the purposes of the current study, and will only be seen by the experimenter.

If you wish to withdraw from the study, you may do so without consequence at any point by closing this form. If you wish to withdraw your data after it has been submitted, please email daniel.zahra@plymouth.ac.uk stating your memorable number.

Reasoning task instructions for all conditions

After entering a memorable date and confirming your consent to participate, you will be required to respond to a short series of reasoning problems.

Each sentence is broken up into three sections. Please read the whole sentence, and then indicate whether or not you think that the final part (that following 'therefore') follows logically from the first two.

Please assume that the first parts of each sentence are true.

If you think the final part follows logically, then select Valid.
If you think the final part does not follow logically, the select Invalid.

If you have any questions, please email daniel.zahra@plymouth.ac.uk before completing this form.

Thank you.

Debrief

Thank you for your help with that.

The purpose of this study was to investigate the effects of emotional content on reasoning, which is why different participants received problems with different words in.

If you have any questions, would like to know more about the study, or would like to withdraw your data or receive details of the university counselling services if you found the content traumatic, please email daniel.zahra@plymouth.ac.uk.

Thank you,

-Daniel

Your data has been submitted and you can now close this window.

Syllogisms

Abstract Forms

Valid Believable	Valid Unbelievable	Invalid Believable	Invalid Unbelievable
No A are B Some B are C Some C are not A	No A are B Some B are C Some C are not A	No A are B Some B are C Some A are not C	No A are B Some B are C Some A are not C
Some A are B No B are C Some A are not C	Some A are B No B are C Some A are not C	Some A are B No B are C Some C are not A	Some A are B No B are C Some C are not A
No B are A Some C are B Some C are not A	No B are A Some C are B Some C are not A	No B are A Some C are B Some A are not C	No B are A Some C are B Some A are not C
Some B are A No C are B Some A are not C	Some B are A No C are B Some A are not C	Some B are A No C are B Some C are not A	Some B are A No C are B Some C are not A

Positive Content

VB01	No B are A Some C are B Some C are not A	No cute things are fluffy, Some fluffy things are puppies, therefore Some puppies are not cute
VB02	Some A are B No B are C Some A are not C	Some friends are cheerful, No cheerful people are lovers, therefore Some friends are not lovers
IB02	Some A are B No B are C Some C are not A	Some chocolate things are tasty, No tasty things are cakes, therefore Some cakes are not chocolate
VU03	No B are A Some C are B Some C are not A	No generous people are rich, Some millionaires are generous, therefore Some millionaires are not rich
IU01	No A are B Some B are C Some A are not C	No personal successes are happy, Some happy things are cause for celebration, therefore Some personal successes are not cause for celebration
VU01	No A are B Some B are C Some C are not A	No cute things are cheerful, Some cheerful things are babies, therefore Some babies are not cute
VU04	Some B are A No C are B Some A are not C	Some friendly animals are puppies, No playful animals are friendly animals, therefore Some puppies are not playful
VB03	No B are A Some C are B	No happy people are genuine, Some smiles are happy, therefore Some smiles are not genuine

	Some C are not A	
IU03	No B are A Some C are B Some A are not C	No parties are graduation ceremonies, Some celebrations of success are parties, therefore Some graduation ceremonies are not celebrations of success
VU02	Some A are B No B are C Some A are not C	Some people with good friends are lucky, No lucky people are fortunate, therefore Some people with good friends are not fortunate
IB03	No B are A Some C are B Some A are not C	No happy people are friends, Some relations are happy, therefore Some friends are not related
IB04	Some B are A No C are B Some C are not A	Some unlucky people are considerate, No lucky people are unlucky, therefore Some lucky people are not considerate
VB04	Some B are A No C are B Some A are not C	Some bright things are presents, No surprises are bright, therefore Some presents are not surprises
IU02	Some A are B No B are C Some C are not A	Some happy occasions are birthdays, No birthdays are weddings, therefore Some weddings are not happy occasions
IU04	Some B are A No C are B Some A are not C	Some family occasions are births, No happy occasions are family occasions, therefore Some births are not happy occasions
IB01	No A are B Some B are C Some A are not C	No happy people are boring, Some boring people are cheerful, therefore Some happy people are not cheerful

Control Content

VB01	No A are B Some B are C Some C are not A	No silver things are mechanical, Some mechanical things are cars, therefore Some cars are silver
VB02	Some A are B No B are C Some A are not C	Some shops are open 24/7, No shops open 24/7 are clothes shops, therefore Some shops are not clothes shops
IB02	Some A are B No B are C Some C are not A	Some orange things are metal, No metal things are vegetables, therefore Some vegetables are not orange
VU03	No B are A Some C are B Some C are not A	No edible things are aquatic, Some fish are edible, therefore Some fish are not aquatic
IU01	No A are B Some B are C Some A are not C	No cats are dogs, Some dogs are mammals, therefore Some cats are not mammals
VU01	No A are B Some B are C Some C are not A	No vehicles are blue, Some blue things are cars, therefore Some cars are not vehicles
VU04	Some B are A No C are B	Some blue things are drinks, No liquids are blue things, therefore Some drinks are not liquid

	Some A are not C	
VB03	No B are A Some C are B Some C are not A	No things with gelatine in are vegetarian, Some sweets are gelatine based, therefore Some sweets are not vegetarian
IU03	No B are A Some C are B Some A are not C	No rubber things are wheels, Some round things are rubber, therefore Some wheels are not round
VU02	Some A are B No B are C Some A are not C	Some Seagulls are quiet, No quiet things are birds, therefore Some Seagulls are not birds
IB03	No B are A Some C are B Some A are not C	No t-shirts are animals, Some spotted things are t-shirts, therefore Some animals are not spotted
IB04	Some B are A No C are B Some C are not A	Some teas are fair trade, No coffees are teas, therefore Some coffees are not fairtrade
VB04	Some B are A No C are B Some A are not C	Some yellow things are flowers, No red things are yellow things, therefore Some flowers are not red
IU02	Some A are B No B are C Some C are not A	Some vegetarian things are healthy, No healthy things are carrots, therefore Some carrots are not vegetarian
IU04	Some B are A No C are B Some A are not C	Some alligators are reptiles, No snakes are alligators, therefore Some snakes are not reptiles
IB01	No A are B Some B are C Some A are not C	No trains are planes, Some planes are owned by Virgin, therefore Some trains are not owned by Virgin

Negative Content

VB01	No A are B Some B are C Some C are not A	No deadly things are treatable, Some treatable things are infectious, therefore Some infections are not deadly
VB02	Some A are B No B are C Some A are not C	Some diseases are disabling, No disabling things are curable, therefore Some diseases are not curable
IB02	Some A are B No B are C Some C are not A	Some harmless things are pleasant, No pleasant things are injuries, therefore Some injuries are not harmless
VU03	No B are A Some C are B Some C are not A	No loud things are aggressive, Some muggings are loud, therefore Some muggings are not aggressive
IU01	No A are B Some B are C Some A are not C	No tumours are cancerous, Some cancers are worrying, therefore Some tumours are not worrying
VU01	No A are B Some B are C Some C are not A	No dangerous things are metal, Some metal things are guns, therefore Some guns are not dangerous

VU04	Some B are A No C are B Some A are not C	Some terrorists are violent people, No threatening people are terrorists, therefore Some violent people are not threatening
VB03	No B are A Some C are B Some C are not A	No stressful things are easy, Some exams are stressful, therefore Some exams are not easy
IU03	No B are A Some C are B Some A are not C	No car accident injuries are brain injuries, Some serious injuries are car accident injuries, therefore Some brain injuries are not serious
VU02	Some A are B No B are C Some A are not C	Some types of nuclear radiation are deadly, No deadly things are dangerous, therefore Some types of nuclear radiation are not dangerous
IB03	No B are A Some C are B Some A are not C	No things available in shops are chemicals, Some safe things are available in shops, therefore Some chemicals are not safe
IB04	Some B are A No C are B Some C are not A	Some criminals are friendly, No murderers are criminals, therefore Some murderers are not friendly
VB04	Some B are A No C are B Some A are not C	Some medicines are drugs, No safe things are medicines, therefore Some drugs are not safe
IU02	Some A are B No B are C Some C are not A	Some drug addicts are schizophrenic, No schizophrenics are heroin users, therefore Some heroin users are not drug addicts
IU04	Some B are A No C are B Some A are not C	Some major injuries are painful, No stab wounds are major injuries, therefore Some stab wounds are not painful
IB01	No A are B Some B are C Some A are not C	No hospices are clean, Some clean places are nice places, therefore Some hospices are not nice places

D. Conditional Reasoning Materials

Instructions and Response Table

For the following section please work through the booklet of reasoning problems. On each page you will be presented two statements, and then asked to what extent a third follows given the previous two.

Please read each set of statements carefully, and then write a number between 0 and 100 for each question in the boxes below to indicate to what extent you feel the third statement follows, where 0 represents “does not follow at all”, and 100 represents “definitely follows”

Question Number	Response
01	
02	
03	
04	
05	
06	
07	
08	

Question Number	Response
09	
10	
11	
12	
13	
14	
15	
16	

Conditional Statements (Ch6)

The believability ratings of each of the six statements (High believability; A,B,C, and low Believability; X,Y,Z) are taken from Evans *et al* (2009).

High Believability: A

Belief in the conditional statement rated as 87%

Question	HBAMP
Supposing the following: **If oil prices continue to rise, then UK petrol prices will rise** and **Oil prices rise** To what extent does it follow that: **UK petrol prices will rise**	

Question	HBAMT
Supposing the following: **If oil prices continue to rise, then UK petrol prices will rise** and **UK petrol prices will not rise** To what extent does it follow that: **Oil prices rise**	

Question	HBAAC
Supposing the following: **If oil prices continue to rise, then UK petrol prices will rise** and **UK petrol prices rise** To what extent does it follow that: **Oil prices will have risen**	

Question	HBADA
Supposing the following: **If oil prices continue to rise, then UK petrol prices will rise** and **Oil prices will not rise** To what extent does it follow that: **UK petrol prices will rise**	

High Believability: B

Belief in the conditional statement rated as 82%

Question	HBBMP
Supposing the following: **If car ownership increases, then congestion will get worse** and **Car ownership increases** To what extent does it follow that: **Congestion will increase**	

Question	HBBMT
Supposing the following: **If car ownership increases, then congestion will get worse** and **Congestion does not get worse** To what extent does it follow that: **Car ownership will increase**	

Question	HBBAC

Supposing the following: **If car ownership increases, then congestion will get worse** and **Congestion gets worse** To what extent does it follow that: **Car ownership will increase**

Question	HBBDA
Supposing the following: **If car ownership increases, then congestion will get worse** and **Car ownership does not increase** To what extent does it follow that: **Congestion will get worse**	

High Believability: C

Belief in the conditional statement rated as 79%

Question	HBCMP
Supposing the following: **If Nurse's salaries are improved, the recruitment of nurses will increase** and **Nurses salaries improve** To what extent does it follow that: **Recruitment of Nurses will increase**	

Question	HBCMT
Supposing the following: **If Nurse's salaries are improved, the recruitment of nurses will increase**	

and **Recruitment of Nurses does not increase** To what extent does it follow that: **Nurse's salaries will have improved**

Question	HBCAC
Supposing the following: **If Nurse's salaries are improved, the recruitment of nurses will increase** and **Recruitment of nurses increases** To what extent does it follow that: **Nurse's salaries will have improved**	

Question	HBCDA
Supposing the following: **If Nurse's salaries are improved, the recruitment of nurses will increase** and **Nurse's salaries have not improved** To what extent does it follow that: **Recruitment of Nurses will increase**	

Low Believability: X

Belief in the conditional statement rated as 19%

Question	LBXMP
Supposing the following: **If UK quarantine laws are strengthened, then rabies will spread to the UK** and **UK quarantine laws are strengthened** To what extent does it follow that:	

Rabies will spread to the UK

Question	LBXMT
Supposing the following: **If UK quarantine laws are strengthened, then rabies will spread to the UK** and **Rabies has not spread to the UK** To what extent does it follow that: **UK quarantine laws will have been strengthened**	

Question	LBXAC
Supposing the following: **If UK quarantine laws are strengthened, then rabies will spread to the UK** and **Rabies has spread to the UK** To what extent does it follow that: **UK quarantine laws will have been strengthened**	

Question	LBXDA
Supposing the following: **If UK quarantine laws are strengthened, then rabies will spread to the UK** and **UK quarantine laws are not strengthened** To what extent does it follow that: **Rabies will spread to the UK**	

Low Believability: Y

Belief in the conditional statement rated as 25%

Question	LBYMP
Supposing the following: **If fast food is taxed, then childhood obesity will increase** and **Fast food is taxed** To what extent does it follow that: **Childhood obesity will increase**	

Question	LBYMT
Supposing the following: **If fast food is taxed, then childhood obesity will increase** and **Childhood obesity does not increase** To what extent does it follow that: **Fast food will be taxed**	

Question	LBYAC
Supposing the following: **If fast food is taxed, then childhood obesity will increase** and **Childhood obesity increases** To what extent does it follow that: **Fast food will be taxed**	

Question	LBYDA
Supposing the following: **If fast food is taxed, then childhood obesity will increase** and **Fast food is not taxed** To what extent does it follow that: **Childhood obesity will increase**	

Low Believability: Z

Belief in the conditional statement rated as 29%

Question	LBZMP
Supposing the following: **If parenting is taught in schools, then juvenile crime will increase** and **Parenting is being taught in school** To what extent does it follow that: **Juvenile crime will increase**	

Question	LBZMT
Supposing the following: **If parenting is taught in schools, then juvenile crime will increase** and **Juvenile crime does not increase** To what extent does it follow that: **Parenting is being taught in school**	

Question	LBZAC

Supposing the following:

If parenting is taught in schools, then juvenile crime will increase
and
Juvenile crime increases

To what extent does it follow that:
Parenting is being taught in school

Question	LBZDA

Supposing the following:

If parenting is taught in schools, then juvenile crime will increase
and
Parenting is not taught in schools

To what extent does it follow that:
Juvenile crime will increase

The BIS/BAS Scale

The following BIS/BAS scale is adapted from that used by Carver and White (1994), which is available online at:
http://www.psy.miami.edu/faculty/ccarver/sclBISBAS.html

Instructions

The following items are statements that a person may either agree with or disagree with. For each item, please indicate how much you agree or disagree with what the item says by writing the appropriate number in the each box. Please respond to all the items; do not leave any blank. Choose only one response to each statement. Please be as accurate and honest as you can be. Respond to each item as if it were the only item. That is, don't worry about being "consistent" in your responses. Choose from the following four response options:

1 = very true for me
2 = somewhat true for me
3 = somewhat false for me
4 = very false for me

01	A person's family is the most important thing in life	
02	Even if something bad is about to happen to me, I rarely experience fear or nervousness	
03	I go out of my way to get things I want	
04	When I'm doing well at something I love to keep at it	

05	I'm always willing to try something new if I think it will be fun	
06	How I dress is important to me	
07	When I get something I want, I feel excited and energised	
08	Criticism or scolding hurts me quite a bit	

09	When I want something I usually go all-out to get it	
10	I will often do things for no other reason than that they might be fun	
11	It's hard for me to find the time to do things such as get a haircut	
12	If I see a chance to get something I want I move on it right away	

13	I feel pretty worried or upset when I think or know somebody is angry at me	
14	When I see an opportunity for something I like I get excited right away	
15	I often act on the spur of the moment	
16	If I think something unpleasant is going to happen I usually get pretty "worked up"	

17	I often wonder why people act the way they do	
18	When good things happen to me, it affects me strongly	
19	I feel worried when I think I have done poorly at something important	

20	I crave excitement and new sensations	

21	When I go after something I use a "no holds barred" approach	
22	I have very few fears compared to my friends	
23	It would excite me to win a contest	
24	I worry about making mistakes	

Scoring

Of the 24 items, all are reverse-scored except for items 2 and 22. Scores can then be summed to give four subscales; BAS Drive: 3, 9, 12, 21; BAS Fun Seeking: 5, 10, 15, 20; BAS Reward Responsiveness: 4, 7, 14, 18, 23; and BIS: 2, 8, 13, 16, 19, 22, 24. Items 1, 6, 11, 17, are filler items (Carver & White, 1994)

AOMT Scale

Instructions

This questionnaire lists a series of statements about various topics. Read each statement and decide whether you agree or disagree with each statement as follows:

6 - Agree strongly
5 - Agree moderately
4 - Agree slightly
3 - Disagree slightly
2 - Disagree moderately
1 - Disagree strongly

Mark the alternative that best describes your opinion. There are no right or wrong answers so do not spend too much time deciding on an answer. The first thing that comes to mind is probably the best response. Be sure the number on the answer sheet corresponds to the number of the statement to which you are responding. There is no time limit, but work as quickly as possible.

#	Item	Rating
01	Even though freedom of speech for all groups is a worthwhile goal, it is unfortunately necessary to restrict the freedom of certain political groups	
02	What beliefs you hold have more to do with your own personal character than the experiences that may have given rise to them	
03	I tend to classify people as either for me or against me	
04	A person should always consider new possibilities	
05	There are two kinds of people in this world: those who are for the truth and those who are against the truth	
06	Changing your mind is a sign of weakness	
07	I believe we should look to our religious authorities for decisions on moral issues	
08	I think there are many wrong ways, but only one right way, to almost anything	
09	It makes me happy and proud when someone famous holds the same beliefs that I do	
10	Difficulties can usually be overcome by thinking about the problem, rather than through waiting for good fortune	
11	There are a number of people I have come to hate because of the things they stand for	
12	Abandoning a previous belief is a sign of strong character	
13	No one can talk me out of something I know is right	
14	Basically, I know everything I need to know about the important things in life	
15	It is important to persevere in your beliefs even when evidence is brought to bear against them	
16	Considering too many different opinions often leads to bad decisions	

17	There are basically two kinds of people in this world, good and bad	
18	I consider myself broad-minded and tolerant of other people's lifestyles	
19	Certain beliefs are just too important to abandon no matter how good a case can be made against them	
20	Most people just don't know what's good for them	
21	. It is a noble thing when someone holds the same beliefs as their parents	
22	Coming to decisions quickly is a sign of wisdom	
23	I believe that loyalty to one's ideals and principles is more important than "open-mindedness	
24	Of all the different philosophies which exist in the world there is probably only one which is correct	
25	My beliefs would not have been very different if I had been raised by a different set of parents	
26	If I think longer about a problem I will be more likely to solve it	
27	I believe that the different ideas of right and wrong that people in other societies have may be valid for them	
28	Even if my environment (family, neighbourhood, schools) had been different, I probably would have the same religious views	
29	There is nothing wrong with being undecided about many issues	
30	I believe that laws and social policies should change to reflect the needs of a changing world	
31	My blood boils over whenever a person stubbornly refuses to admit he's wrong	
32	I believe that the "new morality" of permissiveness is no morality at all	
33	One should disregard evidence that conflicts with your established beliefs	
34	Someone who attacks my beliefs is not insulting me personally	
35	A group which tolerates too much difference of opinion among its members cannot exist for long	
36	Often, when people criticise me, they don't have their facts straight	
37	Beliefs should always be revised in response to new information or evidence	
38	I think that if people don't know what they believe in by the time they're 25, there's something wrong with them	
39	I believe letting students hear controversial speakers can only confuse and mislead them	
40	Intuition is the best guide in making decisions	
41	People should always take into consideration evidence that goes against their beliefs	

Conditional Statements (Ch7)

High Believability, Positive

If you enjoy work, then you will do well at your job.

X01 MP You enjoy work. Do you do well at your job?
X02 DA You do not enjoy your work. Do you do well at your job?
X03 AC You do well at your job. Do you enjoy your work?
X04 MT You do not do well at your job. Do you enjoy your work?

If you pass all of your exams then you will graduate

X05 MP You pass all of your exams. Do you graduate?
X06 DA You do not pass all of your exams. Do you graduate?
X07 AC You graduate. Did you pass all of your exams?
X08 MT You do not graduate. Did you pass all of your exams?

Low Believability, Positive

If you do well on the test then you will win the lottery

X09 MP You do well on the test. Do you win the lottery?
X10 DA You do not do well on the test. Do you win the lottery?
X11 AC You win the lottery. Did you do well on the test?
X12 MT You do not win the lottery. Did you do well on the test?

If you eat fruit and vegetables then you will be clever

X13 MP You eat fruit and vegetables. Are you clever?
X14 DA You do not eat fruit and vegetables. Are you clever?
X15 AC You are clever. Do you eat fruit and vegetables?
X16 MT You are not clever. Do you eat fruit and vegetables?

High Believability, Negative

If you get bitten by a venomous snake then you will be in pain

X17 MP You get bitten by a venomous snake. Will you be in pain?
X18 DA You do not get bitten by a venomous snake. Will you be in pain?
X19 AC You are in pain. Did you get bitten by a venomous snake?
X20 MT You are not in pain. Did you get bitten by a venomous snake?

If you are morbidly obese then you will have clogged arteries

X21 MP You are morbidly obese. Do you have clogged arteries?
X22 DA You are not morbidly obese. Do you have clogged arteries?
X23 AC You have clogged arteries. Are you morbidly obese?
X24 MT You do not have clogged arteries. Are you morbidly obese

Low Believability, Negative

If you commit murder then you will be electrocuted

X25 MP You commit murder. Do you get electrocuted?
X26 DA You do not commit murder. Do you get electrocuted?
X27 AC You get electrocuted. Did you commit murder?
X28 MT You do not get electrocuted. Did you commit murder?

If you start a fight then you will get stabbed to death

X29 MP You start a fight. Do you get stabbed to death?
X30 DA You do not start a fight. Do you get stabbed to death?
X31 AC You get stabbed to death. Did you start a fight?
X32 MT You do not get stabbed to death. Did you start a fight?

High Believability, Neutral (mean belief ratings shown in brackets*)

If Sony releases a new console, then their profits will rise (79)

X33 MP Sony releases a new console. Do their profits increase?
X34 DA Sony do not release a new console. Do their profits increase?
X35 AC Their profits rise. Did Sony release a new console?
X36 MT Their profits do not rise. Did Sony release a new console?

If fertility treatment improves, then the population will rise (65)

X37 MP Fertility treatment improves. Does the population rise?
X38 DA Fertility treatment does not improve. Does the population rise?
X39 AC The population rises. Did fertility treatment improve?
X40 MT The population does not rise. Did fertility treatment improve?

Low Believability, Neutral

If space exploration continues, then aliens will be discovered (42)

X41 MP Space exploration continues. Are aliens discovered?
X42 DA Space exploration does not continue. Are aliens discovered?
X43 AC Aliens are discovered. Did space exploration continue?
X44 MT Aliens are not discovered. Did space exploration continue?

If grammar schools are reintroduced, then applications to university will decrease (33)

X45 MP Grammar school are reintroduced. Do university applications decrease?
X46 DA Grammar schools are not reintroduced. Do university applications decrease?
X47 AC University applications decrease. Did grammar schools get reintroduced?
X48 MT University applications do not decrease. Did grammar schools get reintroduced?

*Based on Evans et al 2009 paper.

Visual Conditionals (Experiment 8)

Instructions

On each screen you will be presented with a statement made up of words and pictures, such as ‘If (picture A), then (picture B)’. Following this will be another piece of information, for example, '(Picture A)', and a question, 'Does it follow that (Picture B)?’

Your task is to answer Yes, No, or Maybe to each of the questions.
For each problem, please assume that the statements preceding each question are true

At random intervals, you will be asked to rate your mood. Please follow the instructions presented on the screen when these sections occur.

Conditionals and their Converse (Chapter 8)

Conditional statements and their converse, with emotive content, presented for pre-testing in order to obtain a selection which were matched for conditional and converse probabilities. Those selected for use in the study described in Chapter 8 are in grey.

01	Assuming you enjoy your work, what is the probability that you will do well at your job?
02	Assuming you do well at your job, what is the probability that you will enjoy your work?
03	Assuming you pass all of your exams, what is the probability that you will graduate?
04	Assuming you graduate, what is the probability that you will have passed all of your exams?
05	Assuming you are smiling, what is the probability that you are happy?
06	Assuming you are happy, what is the probability that you are smiling?
07	Assuming you are in love, what is the probability that someone cares about you?
08	Assuming someone cares about you, what is the probability that you are loved?
09	Assuming you find a cure for cancer, what is the probability that you will save thousands of lives?
10	Assuming you save thousands of lives, what is the probability that you will have found a cure for cancer?
11	Assuming you do well on the test what is the probability that you will win the lottery?
12	Assuming you win the lottery, what is the probability that you will have done well on the test?
13	Assuming world peace is achieved, what is the probability that all fighting will have stopped?
14	Assuming that all fighting is stopped, what is the probability that world peace will be achieved?
15	Assuming you eat fruit and vegetables what is the probability that you will be clever?
16	Assuming you are clever, what is the probability that you will eat fruit and vegetables?
17	Assuming you are a famous scientist, what is the probability that you will be a brilliant sportsperson?
18	Assuming you are a brilliant sportsperson, what is the probability that you will be a famous scientist?
19	Assuming world hunger is solved, what is the probability that AIDS will be eliminated?
20	Assuming AIDS is eliminated, what is the probability that world hunger will be solved?
21	Assuming you are healthy, what is the probability that you will have lots of friends?

22	Assuming you have lots of friends, what is the probability that you will be healthy?
23	Assuming you have lots of money, what is the probability that you will do well on your course?
24	Assuming you do well on your course, what is the probability that you will have lots of money?
25	Assuming you get bitten by a venomous snake what is the probability that you will be in pain?
26	Assuming you are in pain, what is the probability that you will have been bitten by a venomous snake?
27	Assuming you are morbidly obese what is the probability that you will have clogged arteries?
28	Assuming you have clogged arteries, what is the probability that you will be morbidly obese?
29	Assuming a nuclear bomb is dropped on Plymouth, what is the probability that everyone in Plymouth will die?
30	Assuming that everyone in Plymouth has died, what is the probability that a nuclear bomb was dropped on Plymouth?
31	Assuming you get shot in the chest, what is the probability that you will be seriously injured?
32	Assuming you are seriously injured, what is the probability that you will have been shot in the chest?
33	Assuming you are a nasty person, what is the probability that no-one will like you?
34	Assuming that no-one likes you, what is the probability that you are a nasty person?
35	Assuming you are a failure, what is the probability that you will have few friends?
36	Assuming you have few friends, what is the probability that you are a failure?
37	Assuming you commit murder what is the probability that you will be sentenced to death?
38	Assuming you are sentenced to death, what is the probability that you will have committed murder?
39	Assuming you start a fight then what is the probability that will get stabbed to death?
40	Assuming you are stabbed to death, what is the probability that you started a fight?
41	Assuming you eat mouldy meat, what is the probability that you will be tortured by kidnappers?
42	Assuming you are tortured by kidnappers, what is the probability that you will have eaten mouldy meat?
43	Assuming a loved one dies, what is the probability that you will be ran over by a car?
44	Assuming you are ran over by a car, what is the probability that a loved one dies?
45	Assuming you break a kitten's neck, what is the probability that you will contract leprosy?
46	Assuming you have leprosy, what is the probability that you will break a kitten's neck?
47	Assuming you are violently sick, what is the probability that you will be murdered?
48	Assuming you are murdered, what is the probability that you will have been violently sick?
49	Assuming Sony releases a new console, what is the probability that their profits

	will rise?
50	Assuming Sony's profits rise, what is the probability that they will have released a new console?
51	Assuming fertility treatment improves, what is the probability that the population will rise?
52	Assuming the population rises, what is the probability that the fertility treatments will have been improved?
53	Assuming it rains, what is the probability that the clouds will be grey?
54	Assuming the clouds are grey, what is the probability that it will rain?
55	Assuming you don't water a plant, what is the probability that it will die?
56	Assuming a plant dies, what is the probability that you didn't water it?
57	Assuming you don't eat, what is the probability that you will be hungry?
58	Assuming you are hungry, what is the probability that you don't eat?
59	Assuming a light is lit, what is the probability that the light-switch will be on?
60	Assuming a light-switch is on, what is the probability that the light will be lit?
61	Assuming space exploration continues, what is the probability that aliens will be discovered?
62	Assuming aliens are discovered, what is the probability that space exploration will have continued?
63	Assuming grammar schools are reintroduced, what is the probability that applications to university will decrease?
64	Assuming applications to university will decrease, what is the probability that grammar schools have been reintroduced?
65	Assuming something is alive, what is the probability that it is metal?
66	Assuming something is metal, what is the probability that it is alive?
67	Assuming something is a mammal, what is the probability that it is an alligator?
68	Assuming something is an alligator, what is the probability that it is a mammal?
69	Assuming you go outside, what is the probability that you will wear a jacket?
70	Assuming you are wearing a jacket, what is the probability that you will go outside?
71	Assuming you are reading a book, what is the probability that you will be in the library?
72	Assuming you are in the library, what is the probability that you will be reading a book?

E. Ratio-Bias Materials

Brief Text

Thank you for participating in this study. The aim of the current research is to investigate factors affecting decision making, and as such, you will be required to complete a series of decision tasks and a selection of short written tasks.

The decision tasks require you to choose between a set of alternatives based on probabilities.

The writing tasks require you to describe your feeling towards a life event. These tasks may be distressing and personal, but you should keep in mind that you have the right-to withdraw without penalty at any time, and your data will be stored anonymously. You can also choose to withdraw your data at any time between completing the study and the time the data is analysed by contacting the experimenter at daniel.zahra@plymouth.ac.uk.

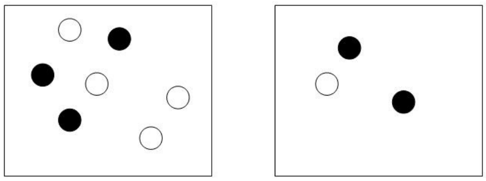
If you have any questions, please ask the experimenter now.

If you agree to participate, please sign the consent form, click the consent box below, enter your gender, age and participant ID (the number you signed next to on the consent for), and then click continue.

Thank you.

Instruction Text

> The main part of this experiment if a series of decision tasks, interspersed with short writing tasks.
>
> Instructions for the writing tasks will be given when they appear.
>
> This page focuses on the decision task.
>
> In the experiment you will be presented with sets of two boxes. Each box contains a certain amount of black and white marbles like in the example below:



Your job is to decide whether the left or the right box has the highest probability of picking a black marble. In other words, if you were to pick a marble at random from either of these boxes, for which box would you have the highest chance of drawing out a black one?

In this particular example the correct answer would be the right box.

If you have any questions, please contact the experimenter now. Otherwise, if you are happy to begin, please click continue.

Mood Manipulation Instruction Text

Positive Condition:

As part of a future study, researchers at the university intend to investigate how reading about people's reactions to life events can influence judgements. To fill time in the current study, please complete the following task to provide the researchers with a selection of events to use in their study.

Please try to recall a particularly happy event in your life. It may be, for example, receiving good results on a difficult test, an unusually fun and memorable night out with friends, or a joyful family occasion such as a birthday or wedding that made you happy. When you have decided on a memory, please write in the box below everything you can remember about the event, describing the event briefly, and then focusing on your thoughts, feelings, and reactions. Please try to write for around 10 minutes before moving on to the next section.

All responses will remain anonymous, and you may choose to withdraw your description at any time. If you have any questions about the task, contact the experimenter now.

When you have finished or the time has elapsed, click continue to proceed.

Negative Condition:

As part of a future study, researchers at the university intend to investigate how reading about people's reactions to life events can influence judgements. To fill time in the current study, please complete the following task to provide the researchers with a selection of events to use in their study.

Please try to recall a particularly sad event in your life. It may be, for example, failing an important test, the death of a loved relative or pet, or the break up of a relationship that made you sad. When you have decided on a memory, please write in the box below everything you can remember about the event, describing the event briefly, and then focusing on your thoughts, feelings, and reactions. Please try to write for around 10 minutes before moving on to the next section.

All responses will remain anonymous, and you may choose to withdraw your description at any time. If you have any questions about the task, contact the experimenter now.

When you have finished or the time has elapsed, click continue to proceed.

Control Condition:

As part of a future study, researchers at the university intend to investigate how reading about people's reactions to life events can influence judgements. To fill time in the current study, please complete the following task to provide the researchers with a selection of events to use in their study.

Please try to recall an occasion on which you used one of the library services; for example, book loaning, computing and printing facilities, or room booking. When you have decided on a memory, please write in the box below everything you can remember about the event, describing the event briefly, and then focusing on what you noticed about your surroundings. Please try to write for around 10 minutes before moving on to the next section.

All responses will remain anonymous, and you may choose to withdraw your description at any time. If you have any questions about the task, contact the experimenter now.

When you have finished or the time has elapsed, click continue to proceed.

Debrief Text

Thank you for completing the study. Your help is greatly appreciated.

The aim of this study was to investigate the effects of mood on reasoning, in the hope of providing a better understanding of how emotions interact with heuristic and analytic reasoning systems.

Specifically, whether positive and negative mood have the same, different, or no effect on the systems people use to reason.

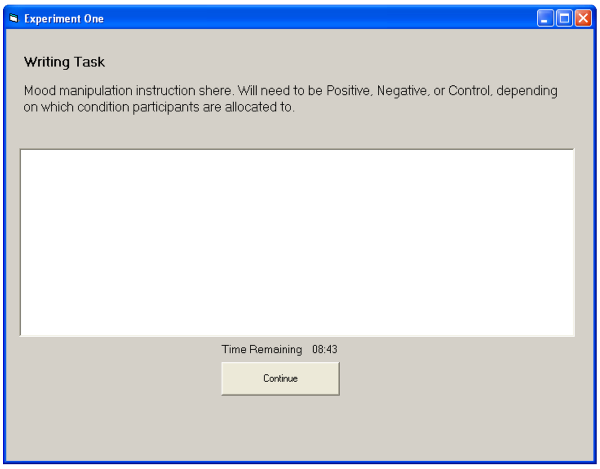
Although the life event exercise may be used to develop mood manipulations in future, in this experiment it also served to induce a particular mood.

If you would like further information on this study, or wish for your data to be removed from subsequent analyses, please contact the experimenter (details below)

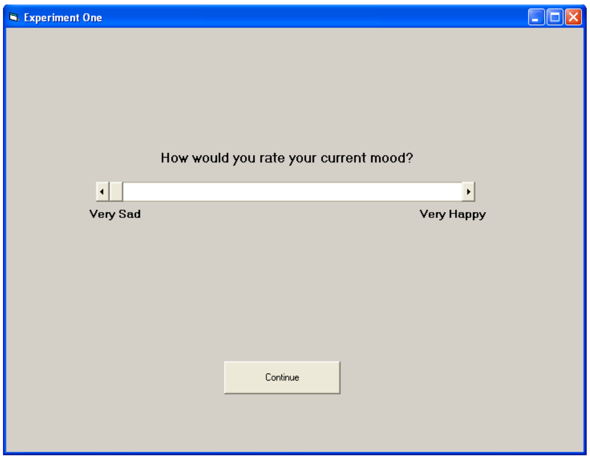
If you feel emotionally distressed following this experiment, or feel you might like to talk to someone about any issues raised, please do not hesitate to contact the university's counselling services (details below)

Experimenter:	Daniel Zahra, daniel.zahra@plymouth.ac.uk
First Supervisor:	Professor Simon Handley, s.handley@plymouth.ac.uk
Counselling Services:	studentcounselling@plymouth.ac.uk, 01752 232254

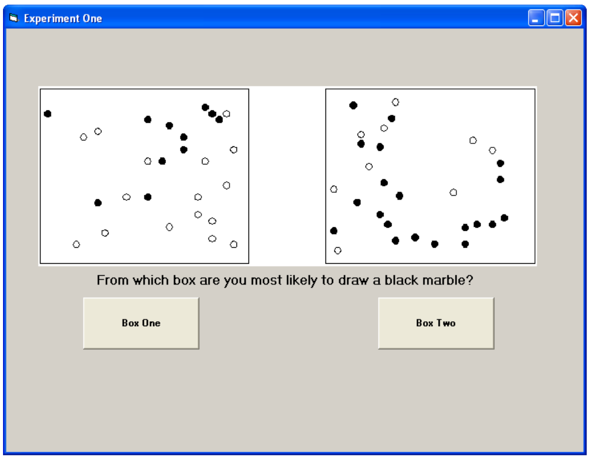
Example Mood Manipulation Screen



Example Mood Rating Screen



Example Trial Screen



F. Equations

Cohen's *d*:

$$d = \frac{\bar{x}_1 - \bar{x}_2}{\sqrt{(\sigma_1^2 - \sigma_2^2)/2}}$$

Hedges' $\hat{g}$, which corrects *d* for sample size:

$$\hat{g} = \left(\frac{\bar{x}_1 - \bar{x}_2}{\sqrt{(\sigma_1^2 - \sigma_2^2)/2}}\right) / \left(\sqrt{\frac{N}{df}}\right)$$

Hedges' $\hat{g}$ for groups of different sizes:

$$\hat{g} = t\left(\frac{\sqrt{(n_{1+}n_2)}}{\sqrt{(n_1 n_2)}}\right)$$

Hedges' g*, which corrects *g* for small sample bias when estimating population effect size:

$$g^* = \left(\bar{x}_1 - \bar{x}_2 / \sqrt{\frac{(n_1 - 1)\sigma_1^2 + (n_2 - 1)\sigma_2^2}{(N_{total} - 2)}}\right)\left(1 - \frac{3}{4(n_1 + n_2) - 9}\right)$$

or alternatively:

$$g^* = \left[\left(\frac{\bar{x}_1 - \bar{x}_2}{\sqrt{(\sigma_1^2 - \sigma_2^2)/2}}\right) / \left(\sqrt{\frac{N}{df}}\right)\right]\left(1 - \frac{3}{4(n_1 + n_2) - 9}\right)$$

Comparison of independent regression models using *t*:

$$t = \frac{(b_1 - b_2)}{SE(b_1 - b_2)}$$

Where b_1 and b_2 are regression coefficients of the models being compared.

$$SE(b_1 - b_2) = s^2_{residual}\sqrt{\left(\frac{1}{s_1^2(N_1 - 1)}\right) + \left(\frac{1}{s_2^2(N_2 - 1)}\right)}$$

Where s_1^2 and s_2^2 are predictor variable variances from each regression model.

$$s^2_{residual} = \frac{(\mathrm{SS_{residual1}} + \mathrm{SS_{residual2}})}{((\mathrm{N}_1 - 2) + (\mathrm{N}_2 - 2))}$$

Degrees of freedom for use in comparing regression models with the above equations:

$$df = (df_1 + df_2) = (N_1 - 2) + (N_2 - 2)$$

Spearman-Brown Correction Formula:

$$\frac{j(i)}{1 + (j - 1)i}$$

Where *j* is the number of judges or raters, and *i* is the intraclass correlation coefficient

The Reliable Change Index (*RCI*):

$$RCI = \frac{x_2 - x_1}{\sqrt{2\left(s_1\sqrt{1 - r_{xx}}\right)^2}}$$

Where s_1 is the standard deviations for the pre-test groups; r_{xx} is the test-retest reliability of measure used; and x_1 and x_2 are the pre- and post-test scores of the participants for whom you're calculating the RCI.

List of Published Papers

A psychometric paper which was written based on a large scale sample of students who completed the TMMS in order to better understand the scale norms in a student population:

Zahra, D., Bailey, C., Hedge, C., Wyles, K., & Sanders, B. G. (2012 in press). A Short Report on the Trait Meta-Mood Scale and the Importance of Scale Norms. *Social Psychological Review, xx*(xx), xx-xx.

A paper written to explain in more detail the application of the Reliable Change Index in academic psychology which came about as a result of exploring its potential for use in the current work:

Zahra, D., & Hedge, C. (2010). The reliable change index: Why isn't it more popular in academic psychology? *Psychology Postgraduate Affairs Group Quarterly, 76*, 14-19.