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Reasoning About Counterfactual Conditionals:

The Role of Content, Tense and Linguistic Form

Ph.D.

2005

Suzanne Egan

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Summary

The primary aim of this thesis is to investigate reasoning from counterfactual conditionals (e.g., if Rosanna had been in Dublin then Anthony would have been in Roscommon) and to test predictions derived from the mental model theory account of reasoning from counterfactual conditionals (Johnson-Laird & Byrne, 1991; 2002). The mental model theory of reasoning proposes that people reason conditionally by keeping possibilities in mind. We aim to extend the theory to account for the role of content, tense and linguistic form in reasoning from counterfactual conditionals.

In Chapter 1, we review the literature on counterfactual thinking and describe some of its functions in daily life. We also consider a number of different theories of conditional reasoning such as the mental model theory (Johnson-Laird & Byrne, 1991; 2002), formal rule theories (Braine & O'Brien, 1991; Rips, 1994), domain-specific rule theories (Cosmides, 1989; Cheng & Holyoak, 1985) and the probabilistic theory (e.g., Oaksford & Chater, 2000). Although the experiments reported in this thesis are guided by the mental model theory the implications of the findings for other theories of conditional reasoning are considered.

In Chapter 2, we examine the role of content in reasoning from counterfactual conditionals, specifically the role of inducement content (i.e., promises and threats). Chapter 2 begins by first describing recent work investigating the role of content in reasoning from counterfactual conditionals, before reviewing some work that has investigated inducements. We report three experiments that examine the inferences that are invited by, and drawn from, inducements as well the possibilities that are judged consistent with them. We also propose and test a new account of the mental representations of factual promises and threats. We predict that people's reasoning will differ for factual promises and threats but not for counterfactual promises and

threats. The results support this hypothesis.

Chapter 3 investigates the role tense plays in reasoning from subjunctive conditionals, in particular, future tense subjunctive conditionals, that is "prefactuals", which have not been considered before (Byrne & Egan, 2004). We investigate prefactual conditionals (e.g., if David were in Belfast tomorrow the Jonathan would be in Sligo) in three experiments that examine the possibilities that are implied by and judged consistent with prefactuals and also the inferences that are drawn from them. We test the hypothesis that reasoning from prefactual conditionals is more similar to reasoning from factual conditionals than to reasoning from counterfactual conditionals. The results corroborate this prediction.

Chapter 4 examines the role of linguistic form in reasoning from counterfactual conditionals. We report two experiments that compare reasoning from counterfactual 'if then' (e.g., if Maureen is in Cork then Billy is in Galway) and 'only if' conditionals (e.g., Maureen is in Cork only if Billy is in Galway), and we also describe some work that we conducted in collaboration with colleagues on reasoning from counterfactual 'unless' assertions (Garcia-Madruga, Byrne, Egan, Moreno-Rios, Quelhas & Juhos, 2004). A new account of factual 'only if' is also proposed and tested. We show that reasoners keep more possibilities in mind from the outset to understand factual 'only if' than 'if then' but the same number of possibilities to understand counterfactual 'only if' and 'if then'.

In the final chapter, Chapter 5, we consider the implications of our findings for reasoning from counterfactual conditionals. We also consider how our findings, for both factual and counterfactual conditionals, might be accounted for by the mental model theory and by the other theories of conditional reasoning and make recommendations for future research in this area.

Chapter 1: Introduction

"The release of atom power has changed everything except our way of thinking...if only I had known, I should have become a watchmaker"

Albert Einstein

When thinking about the past people do not limit themselves to thinking about events that actually occurred. They can easily imagine alternatives to what they know to be true. In fact, people regularly and spontaneously think about how things could have turned out differently (Kahneman & Tversky, 1982). This type of thinking is called counterfactual thinking (for a review see Byrne, 2002) and our objective in this thesis is to explore how people reason about counterfactual situations and the factors that play a role in this process. There has been little research on how people reason from counterfactual assertions (e.g., if Rosanna had been in Dublin then Anthony would have been in Longford). The aim of this thesis is to address this gap in the counterfactual thinking literature by drawing on the theories and methods of conditional reasoning research. Specifically, the research presented in this thesis examines the role of content, tense and linguistic form in reasoning from counterfactual conditionals.

This chapter is divided into three sections. The first section reviews the area of counterfactual thinking and the role it plays in everyday life. The second section provides an introduction to conditional reasoning, describing the principal tasks and findings of conditional reasoning studies. Finally, the third section reviews the main theories of conditional reasoning. It focuses primarily on the mental model theory as it is the only

theory to have provided a corroborated account of reasoning from counterfactual conditionals.

Counterfactual Thinking

Counterfactual thinking is an important and pervasive part of everyday thought. The ability to think about what might have been seems to develop early in life and children as young as two years of age can consider events that almost happened (Harris, 2000). Psychologists have investigated many different aspects of counterfactual thinking and they have found that it helps people to learn from their past mistakes (Roese, 1994). It also plays an important role in social ascriptions such as blame (Creyer & Guerhan, 1997), and in emotions such as guilt, shame and regret (Mandel, 2003). People who are unable to think about how events could have turned out differently, following damage to the dorsolateral prefrontal cortex for example, seem unable to feel emotions such as regret or grief (Knight & Grabowecky, 1995).

Although people can imagine many different ways that situations could have turned out differently research shows that people tend to mentally undo reality in systematic ways. For example, people usually think about alternatives that are close to what actually happened rather than dramatically different (Hofstader, 1979). Similarly, people do not try to undo natural laws such as gravity (Seeleu, 1995). When mutating events people tend to focus on exceptional rather than routine events (Kahneman & Tversky, 1982), controllable rather than uncontrollable events (Girotto, Legrenzi & Rizzo, 1991) and the first event in a causal sequence rather than later events (Wells & Gavanski, 1989).

Counterfactual conditionals refer to something that was once a possibility, but that did not happen. They are often phrased in the subjunctive mood (e.g., if only Albert

Einstein *had* known...) which conveys information about the truth of the assertion. Most people think that the opposite is implied to what is stated in the counterfactual conditional (e.g., Albert Einstein did not know the effect the discovery of atom power would have on the world and he did not become a watchmaker) (Thompson & Byrne, 2002). These presupposed facts are also what many people recall when unexpectedly asked to remember sentences from an earlier task which used counterfactual conditionals (Fillenbaum, 1974).

Counterfactual conditionals have been studied by philosophers (e.g., Stalnaker, 1968, Lewis, 1973), linguists (e.g., Athanasiadou & Dirven, 1997), psychologists (e.g., Kahneman & Tversky, 1982) and used in history, politics (e.g. Tetlock & Belkin, 1996) and artificial intelligence (e.g., Costello & McCarthy, 1999). Philosophers have debated the truth of counterfactual conditionals and this debate led to the idea of comparing counterfactual assertions with other possible worlds to ascertain if they are true or false (e.g., Lewis, 1973; Stalnaker, 1968).

Linguists have discovered that although counterfactual conditionals typically occur in the subjunctive mood (i.e., if I *had* left earlier then I *would have* arrived on time), the use of this mood is neither necessary (Wierzbicka, 1997) nor sufficient in the forming of a counterfactual (Dudman, 1988). It has also been found that counterfactuality can be conveyed in languages that do not have a subjunctive mood or other specific linguistic markers for it (Au, 1983). In history and politics counterfactual thinking is often used to attempt to determine causes of events and to consider how these events, such as World War 2, could have been avoided (Khong, 1996). In artificial intelligence counterfactuals have proved useful in the planning of sub-goals (Costello & McCarthy, 1999) and in structural model accounts of causality (Pearl, 2000).

Even though many different aspects of counterfactual thinking have been studied in psychology and other academic disciplines there has been very little research investigating

how people reason from counterfactual conditionals, with a few notable exceptions (e.g., Byrne & Tasso, 1999; Thompson & Byrne, 2002; Quelhas & Byrne, 2003). Before describing this research however, it is necessary to introduce some of the typical tasks and findings of conditional reasoning studies.

Conditional Reasoning

The ability to reason is integral to human intelligence. People reason every day even though they may not realise that they are doing it. For example, most people know that if it rains outside then the ground is wet. When they see that it is raining outside they can very easily deduce that therefore, the ground is wet. Although this inference may seem very easy to make, and perhaps somewhat unimportant, it is essential to every day life. Imagine for example not knowing, or not being able to predict, what happens to the ground every time it rains, what happens to an object if it is dropped or what happens to plants if they are not watered. Life would be chaotic if people could not draw conclusions from what they know about the world. Without the ability to reason, people would not be able to generalise from one situation to another, consider possible outcomes or formulate rules or instructions. Johnson-Laird and Byrne (1991) state that "*A world without deduction would be a world without science, technology, social conventions, and culture*" (p. 3).

Interpretations of 'if'

Few words in the English language have generated as much debate or interest as the conditional word 'if' (see Evans & Over, in press, for a review). People regularly and spontaneously generate conditional thoughts or hypothetical utterances such as 'if I do not water the plants they will die', 'if I go to the shops then I will go to the bank as well' or 'I

would have taken the new job only if they had offered me more money'. However, for any given 'if' assertion there are a number of different interpretations people can make of it. Consider for example the assertion 'if it rained outside then the ground was wet'. There are four possible situations that could arise:

(i) it rained and the ground was wet,

(ii) it did not rain and the ground was not wet,

(iii) it did not rain and the ground was wet,

(iv) it rained and the ground was not wet.

Most people think that situations (i) and (ii) are true but that situation (iv) is false. Debate arises over situation (iii). Those people who think that it is true may have reached a conditional interpretation of the rule (i.e., they believe that the ground can be wet without it having rained). Logicians call this interpretation material implication. Those people who think that situation (iii) is false may have reached a biconditional interpretation of the rule (i.e., they believe that the ground cannot be wet without it having rained). Logicians call this interpretation material equivalence. These two interpretations, conditional and biconditional, lead reasoners to draw different inferences and we will return to this point shortly (for a review of the different interpretations people make of 'if' see Evans, Newstead & Byrne, 1993).

Researchers usually infer how people interpret conditional assertions using a truth table task or some variation of it. Truth table tasks present participants with a conditional, such as 'if it rained then the ground was wet' and then list the four possible situations that may arise from it as described above. Participants then have to evaluate whether each situation is true or false, or true, false or irrelevant/indeterminate (Johnson-Laird & Tagart, 1969). The pattern of responses across the four possible situations allows researchers to

infer how people interpret conditionals (e.g., as conditional or biconditional).

Table 1.1: Conditional and biconditional interpretations of the assertion 'if it rained then the ground was wet'

Situation	Conditional	Biconditional
(i)	T	T
(ii)	T	T
(iii)	T	F
(iv)	F	F

T = True, F = False

Variations of this basic task have also been developed. The traditional task required participants to *evaluate* possible situations, some variations require participants to generate or construct situations that make the given assertion true or false (e.g., Evans, 1972) or to generate situations that verify or falsify the assertion (e.g., Byrne & Tasso, 1999). For example Byrne and Tasso (1999) asked people to say what two shapes could be drawn on the blackboard to best fit the description 'if there was a circle on the blackboard, there was a triangle'. The majority of participants generated the situation where there was a circle and a triangle as the best situation to verify the rule.

Another variation of the traditional truth table evaluation task is known as the consistency judgement task (Byrne, Handley & Johnson-Laird, 1995) and it has been used in this body of work, in each of the three experimental chapters. Rather than asking participants to evaluate possible situations as true or false, they are asked to judge

situations as consistent or inconsistent with the conditional. Although this difference in response options may be considered small, it is important, particularly when evaluating counterfactual conditionals, which are the focus of this thesis. Counterfactual conditionals (e.g., if it had rained then the ground would have been wet) convey information about the truth of their antecedent and consequent. They convey the information that what actually happened was that it did not rain and that the ground was not wet. Thompson and Byrne (2002) point out that it may be confusing to ask people to judge possible situations as true or false following a counterfactual conditional because people may be thinking about what is actually true, or hypothetically true but actually false. Asking people if they think a possibility is consistent or not is less likely to cause confusion, and for this reason the consistency judgement task, rather than a typical truth table task, is used.

In this section we have described the different interpretations of 'if' and the typical tasks researchers use to infer people's interpretations. The next section describes four inferences that may be drawn from an assertion such as 'if it rained then the ground was wet', and how the interpretation people make of a conditional assertion influences the inferences they draw from it.

Inferences from 'if'

Deductive reasoning is the ability to draw a conclusion from a specific set of assumptions. Whether or not the conclusion is logically valid can be determined by the principles of logic. In logic the form of the argument is important (Kneale & Kneale, 1962). For example, the Modus Ponens (MP) inference takes the following form:

If A then B.

A.

Therefore B.

MP is an affirmative and forwards inference because it *affirms* the information in the conditional assertion (A) and the conclusion is drawn in the *forwards* direction from the first part of the conditional, the antecedent (A), to the second part of the conditional, the consequent (B). Given premises of this form, B is a logically valid conclusion. That means that the conclusion necessarily follows from the premises and there is no situation in which the premises could be true and the conclusion false. Even if the premises are not true then the argument is still a valid form e.g.,

If Tony is tall, then he is short.

Tony is tall.

Therefore, he is short.

The conclusion that he is short necessarily follows from the premises. It is valid but very few people may agree that the conclusion is true, because the first premise is clearly not true: a person cannot be both tall and short. The MP inference is very easy to make and meta-analyses of conditional reasoning studies show that it is made almost universally (Evans, Newstead & Byrne, 1993; Schroyens, Scheaken & d'Ydewalle, 2000). Another valid inference is Modus Tollens (MT), which takes the following form:

If A then B.

Not B.

Therefore, not A.

For example, given the premises 'if it rained then the ground was wet' and 'the ground was not wet' it is valid to conclude that therefore, it did not rain. Logically, there is no possible situation in which the ground was not wet if it had rained. MT is a negative backwards inference because it negates some of the information in the conditional assertion (not B)

and the conclusion is drawn in the backwards direction of the consequent to the antecedent (from not B to not A). The MT inference is typically made less often than MP, usually between 40% and 80%. MP and MT are both valid inferences regardless of whether a person interprets a conditional assertion as conditional or biconditional.

Whether or not the remaining two types of inferences are valid depends on the interpretation of the conditional however. On a conditional interpretation affirmation of the consequent (AC) and denial of the antecedent (DA) are invalid inferences but on a biconditional interpretation they are valid. AC is an affirmative backwards inference and it takes the following form:

If A then B.

B.

Therefore, A.

For example, given an assertion such as 'if it rained then the ground was wet', and the information 'the ground was wet' the AC inference, 'therefore it rained', is valid for a biconditional interpretation of the assertion. On a biconditional interpretation the antecedent (it rained) and consequent (the ground was wet) must occur together or not at all (see Table 1.1). A person with a biconditional interpretation does not think of any other ways the ground could be wet other than by it raining. On a conditional interpretation, however, people believe that the ground can be wet without it having rained. For example, someone could have spilled a drink or a pipe might have burst. Therefore, knowing that the ground is wet does not necessarily mean that it has rained and the person should say that there is no valid conclusion. Similarly, knowing that it has not rained does not necessarily mean that the ground is not wet. This is the DA inference and like AC it is not valid on a conditional interpretation. It is valid on a biconditional interpretation. On the biconditional

interpretation the ground cannot be wet unless it has rained. DA, a negative forwards inference, takes the following form:

If A then B.

Not A.

Therefore, not B.

AC and DA occur approximately equally often but their rates of occurrence across studies are highly variable, ranging from 23% to 75% (Evans *et al.,* 1993; Schroyens *et al.*, 2000). A recent meta-analysis (Schroyens, *et al.,* 2000) however, showed that AC is usually made more frequently than DA. Table 1.2 summarises the four inferences that may be made from a conditional assertion and their classifications as affirmative or negative and forwards or backwards inferences.

Table 1.2: Four inferences and their classifications as affirmative/negative and forwards/backwards from the conditional 'if it rained then the ground was wet'

	Affirmative	Negative
Forwards	MP: it rained Therefore, the ground was wet	DA: it did not rain Therefore, the ground was not wet
Backwards	AC: the ground was wet Therefore, it rained	MT: the ground was not wet Therefore, it did not rain

In order to determine the rates at which people endorse the four inferences participants are

usually given an inference task. The inference task involves giving participants a conditional such as 'if Maureen was in Dublin then Billy was in Wexford' and an additional piece of information corresponding to one of the four logical inferences as described earlier. For example, for an MT inference participants would then be told that 'Billy was not in Wexford'. Participants are then typically either given a conclusion such as 'therefore Maureen was not in Dublin' and asked to evaluate it or given a selection of conclusions to choose from (see below), or asked to generate their own (e.g., what, if anything, follows?).

The experiments reported in the following chapters that use an inference task give people a set of three response options to choose from. Given the example above, and the MT minor premise the response options are (a) Maureen was in Dublin, (b) Maureen was not in Dublin (c) Maureen may or may not have been in Dublin. The method of conclusion selection was chosen because it was possible to use it on a computer which also allowed the measurement of latencies. It would not have been as readily possible to allow people to generate a conclusion of their own using a computer. There are a number of different theories of how people make the four inferences and this is the topic to which we now turn.

Theories of Conditional Reasoning

There are a number of different theories that attempt to explain deductive reasoning, such as the mental model theory, abstract rule theories, domain-specific rule theories and probabilistic theories. The remainder of this section reviews each of these approaches, beginning with the mental model theory.

The Mental Model Theory

The work in this thesis is guided by the principles of the mental model theory and the experimental predictions in the following chapters are derived from it. The mental model theory is the only theory of reasoning to have provided a tested account of reasoning from counterfactual conditionals, the topic of this thesis. Before outlining these studies of reasoning from counterfactual conditionals, it is necessary to describe the theory.

The mental model theory proposes that reasoning is a semantic process based on considering possibilities (Johnson-Laird & Byrne, 1991; 2002; Johnson-Laird, Byrne & Schaeken, 1992). According to the mental model theory reasoning should be characterised both at the computational level of what the mind is doing when it deduces something, and at the algorithmic level of how the mind actually makes a deduction (Johnson-Laird & Byrne, 1991).

Johnson-Laird & Byrne (1991) propose that deduction at the computational level is governed by three extra-logical constraints. The first of these is that people usually try to maintain semantic information. Different connectives rule out different states of affairs. The second constraint is that people should draw conclusions that are simple. The third constraint is that conclusions should be informative in that they should contain information that was not given directly in the premises. These three constraints capture the very nature of deduction. Johnson-Laird and Byrne state that "*To deduce is to maintain semantic information, to simplify and to reach a new conclusion*" (1991, p. 22).

Mental models are manipulated at the algorithmic level. A mental model is a mental representation of a premise. The exact nature of the representation is unspecified but it should correspond to the way the world would be if the premise were true. Due to working memory constraints, situations where the conditional is false are not represented. Johnson-Laird and Byrne (2002) call this idea the principle of truth. For example, take the

premise "If there is a T on the board then there is a K on the board". The fully explicit models for this premise are:

T K

not T K

not T not K

where "T" stands for "there is a T on the board", "K" stands for "there is a K on the board and "not" indicates negation. Those situations that are true, that are consistent with the premise, are each represented on a separate line in mental model notation. People do not represent the situation that is false (T, not K).

Moreover, taking a limited working memory into consideration, the mental model theory proposes that people only represent the first possibility explicitly, the possibility in which the antecedent is present, while the other possibilities are maintained implicitly. This idea is called the principle of implicit models (Johnson-Laird & Byrne, 2002). The initial possibility is represented by the notation:

T K

. . .

The three dots indicate that there are alternative possibilities to the one above, but that they have not yet been fleshed out. These alternative possibilities are possibilities in which the antecedent is not satisfied (i.e., there is not a T).

The mental model theory makes a number of processing assumptions about reasoning with models (Johnson-Laird, *et al.*, 1992). Firstly, the more explicit models a reasoner must keep in mind the more difficult the task will be. Secondly, deductions will be easier if they can be made from the initially explicit model, or models, than if they must be made by fleshing out an implicit model. Thirdly, detecting inconsistencies between

elements of models requires time.

Considerable support has been found for the mental model theory of reasoning. For example, the principle that some possibilities are present in the initial representation of a conditional (e.g., T and K) while others are not and have to be fleshed out (e.g., not T and not K, not T and K), can explain why some inferences, such as MP are made more readily than others, such as MT (Johnson-Laird *et al.*, 1992). The information needed to make the MP inference (a T and a K) is present in the initial possibility and therefore the inference is easy.

Table 1.3: Initial and explicit possibilities kept in mind for different interpretations of the conditional 'if there is a T on the board then there is a K'

	Conjunction	Biconditional	Conditional
Initial	T K	T K	T K
		...	...
Explicit	T K	T K	T K
		not T not K	not T not K
			not T K

However, to gain access to the information needed to make the MT inference, reasoners must flesh out the possibilities to consider the situation that has 'not K'. As there is only

one possibility with 'not K' reasoners may then conclude 'not T'. If reasoners do not flesh out the 'not T and not K' possibility and only think about the 'T and K' possibility they may say that there is no valid conclusion to the MT inference (see Table 1.3).

The mental model theory can also explain why MT is made more frequently on a biconditional (57%) than conditional interpretation (38%) (Johnson-Laird, *et al.*, 1992). With a biconditional interpretation reasoners only have to keep two possibilities in mind but on a conditional interpretation they have to keep three possibilities in mind and keeping this additional possibility in mind increases working memory load.

Propositional reasoning using mental models requires three stages (Johnson-Laird & Byrne, 1991). First, it requires that the premises and background knowledge be taken as input and that a model of the premises be produced as output, using model constructing procedures. Second, input of two or more sets of models are combined to produce one set as output, using model combining procedures. Model describing procedures are also necessary at this point so that a parsimonious description of the input models can be produced at output. The final stage requires model revising procedures which take as input a premise or putative conclusion, and a set of models. The output is a revised model and a conclusion which, if possible, falsifies the putative conclusion.

Johnson-Laird and Byrne (1991) state that people are rational in principle but that they err in practice. Errors in reasoning arise due to the processing limitations outlined above. For example, people are more likely to make errors if they do not flesh out the implicit models sufficiently or if the initial model is not properly evaluated. Whether or not an implicit model is fleshed out depends on the meaning of the information in the conditional, its semantics, and the context in which the conditional occurs, its pragmatics. Johnson-Laird and Byrne (2002) have called these ideas the principle of semantic modulation and the principle of pragmatic modulation respectively. For example, given an

assertion such as 'if Owen is in Dublin then he is in Ireland' and the information 'Owen is not in Ireland' people draw the MT inference (therefore, Owen is not in Dublin) very readily because reasoners know that Dublin is in Ireland and if someone is not in Ireland then they cannot be in Dublin.

The Mental Model Account of Counterfactual Conditionals

The mental model account of reasoning from counterfactual conditionals (Johnson-Laird & Byrne, 1991; Byrne, 1997) proposes that making inferences from counterfactuals uses the same reasoning procedures that are used for conditional reasoning about factual situations. Counterfactuals require the imagination of an alternative to what is currently believed to be the factual situation. Johnson-Laird and Byrne suggest that when people construct a model of a counterfactual conditional they represent the information mentioned in the conditional, the counterfactual conjecture, and also the presupposed factual situation that is conveyed by the linguistic mood of the conditional. For example, given a counterfactual conditional such as 'if Maureen had been in Dublin then Billy would have been in Wexford' people think about the counterfactual conjecture that 'Maureen was in Dublin and Billy was in Wexford' as well as the presupposed facts 'Maureen was not in Dublin and Billy was not in Wexford'. (If necessary they may also flesh out their models to consider the possibility that 'Maureen was not in Dublin and Billy was in Wexford'.) People keep track of the models by adding tags about the epistemic status of the models, for example:

Factual:	Maureen not in Dublin	Billy not in Wexford
Counterfactual:	Maureen in Dublin	Billy in Wexford
	...	

A number of studies have been reported in the last five years that support this account

(e.g., Byrne & Tasso, 1999; Thompson & Byrne, 2002; Quelhas & Byrne, 2003). The mental model account of counterfactual conditionals leads to some specific predictions regarding reasoning performance, particularly when counterfactual conditionals are compared to factual ones. For factual conditionals (e.g., if Maureen was in Dublin then Billy was in Wexford) people keep in mind just one possibility from the outset, the affirmative possibility (Maureen in Dublin and Billy in Wexford) although they can think about other possibilities if necessary. For counterfactual conditionals people keep two possibilities in mind from the outset, as outlined above. They keep in mind the counterfactual conjecture, which corresponds to the affirmative possibility, and the presupposed facts, which corresponds to the negative possibility. Accordingly, on an inference task the theory predicts that people should make the same rate of affirmative inferences (MP and AC) but more negative inferences (MT and DA) from counterfactual than factual conditionals. These predictions have been tested and supported in more than one study.

Byrne and Tasso (1999) were the first to compare reasoning from factual and counterfactual conditionals. Using neutral content such as 'if Maureen had been in Dublin then Billy would have been in Wexford', Byrne and Tasso found that people made more negative inferences from counterfactual than factual conditionals for both MT (66% versus 42%) and DA (59% versus 39%) but that there were no reliable differences for the affirmative inferences MP (81% versus 94%) and AC (50% versus 32%). This finding was replicated by Quelhas and Byrne (2003, Experiment 1) and by Thompson and Byrne (2002, Experiment 1). Quelhas and Byrne (2003) and Thompson and Byrne (2002) also investigated content effects of deontic, causal and definitional conditionals in reasoning from counterfactual conditionals. These results will be discussed in Chapter 2 which considers the role of content in reasoning from counterfactual conditionals.

Byrne and Tasso (1999, Experiment 4) also found that reasoners consider different situations when asked to verify and falsify factual and counterfactual conditionals. For example, when verifying a factual conditional (e.g., if there was a triangle on the board then there was a square) people usually think of the hypothesised case of what was stated in the premise (e.g., a triangle and a square, 78%) but when verifying a counterfactual (e.g., if there had been a triangle on the board then there would have been a square) they think of the counterfactual conjecture (e.g., a triangle and a square, 50%) or just as often, the presupposed factual case (e.g., not a triangle and not a square, 50%). When falsifying a factual conditional reasoners think either of the logically prudent case (e.g., not a triangle and a square, 44%) or of a case where both the antecedent and the consequent of the premise are negated (e.g., not a triangle and not a circle, 44%). However, for counterfactual conditionals people indicate that the counterfactual conjecture falsifies the conditional (e.g., a triangle and a circle, 30%), as well as those situations mentioned for falsifying a factual conditional (also 30% each). In a similar vein, Thompson and Byrne (2002, Experiment 1) found that when given a consistency judgement task more people indicate that the affirmative possibility (e.g., a triangle and a square) is inconsistent with a counterfactual than factual conditional (23% versus 6%).

The results of the experiments outlined above provide strong support for the suggestion that people keep two possibilities in mind from the outset for a counterfactual conditional (affirmative and negative) but just one possibility for a factual conditional (affirmative). However, there are some people, a sizeable minority, who seem to consider just the negative possibility for a counterfactual conditional, that is the presupposed factual situation (Thompson & Byrne, 2002). These people make a high amount of negative inferences and fewer affirmative inferences, suggesting that there are individual differences in how people represent counterfactual conditionals.

Although research has begun to investigate how people understand and reason from counterfactual conditionals there is still much work to be done. This thesis aims to address this gap in the literature using the mental model theory.

Criticisms of the Mental Model Theory

The mental model theory of reasoning has been the subject of many criticisms since it was proposed. Goldman (1986), for instance, has claimed that there is not much difference between the abstract rules and mental models approaches to reasoning (see Rips, 1990 for a similar claim). The argument is that because models are constructed and represented in an abstract fashion, there is nothing to stop some kind of mental rules being the mechanism by which models are constructed. However, Johnson-Laird *et al.* (1992) have pointed out that while it might be possible to create an abstract rule theory which makes the same predictions as the mental models theory, it would be very different to the kinds of rule theory that exist at the moment because the mental logic of abstract rules is syntactic, it is only the form of the logical proof that matters (see the discussion of abstract rule theories below). But the mental models theory is a semantic theory of reasoning. In mental models, it is the content that matters which leads to the differences between mental models and rules theories. For example, according to mental model theory people do not try to search for a mental proof, but to think of possibilities that are either consistent or inconsistent with the premises.

Bonatti (1994) argued that the mental models approach cannot accurately predict how many models will actually be constructed in any case. Without being able to do that, the model theory might be able to say why someone might have difficulty with an inference, but will not be able to predict that they will have difficulty. Johnson-Laird, Byrne & Schaeken (1994), however, have responded that it is not the number of models

that *might* be used in representing the premises, but the number of models which *must* be used to construct the conclusions. Johnson-Laird & Savary (1996) have put forward a computer program which predicts the appropriate number of models for a given set of premises, which reasserts the predictive power of the theory. The mental model theory has also been criticised for not detailing how people validate their models by using counterexamples (e.g., Polk & Newell, 1995). However, Byrne, Espino and Santamaria (1999) have recently used inference suppression to investigate this matter.

Despite these criticisms the mental model theory is still the most comprehensive theory of human reasoning to date. Even critics of the theory acknowledge that *"...the mental model theory is by far the most popular in the study of conditionals and constitutes in effect the dominant paradigm for this field of study"*, (Evans & Over, in press, p. 98). It has provided accounts for a range of phenomena in conditional reasoning that no other single theory has been able to do. To date the mental model theory has also provided an account of probabilistic reasoning (Johnson-Laird, Legrenzi, Girotto, Legrenzi & Caverni, 1999), relational reasoning (Byrne & Johnson-Laird, 1989; Goodwin & Johnson-Laird, 2005; Vandierendonck, Dierckx & De Vooght, 2004) inductive reasoning (Johnson-Laird, 1993), creativity (Johnson-Laird, 1989; Schaeken, Johnson-Laird & D'Ydewalle, 1996), belief revision (Legrenzi, Girotto & Johnson-Laird, 2003; Klauer & Musch, 2005), the development of conditional reasoning (Markovits, Schleifer & Fortier, 1989; Barrouillet, Grosset, & Lecas, 2000) and the Wason selection task (Johnson-Laird & Byrne, 1991). It has also been used to explain aspects of reasoning from counterfactual conditionals (Byrne & Tasso, 1999) and it is this work that the experiments reported in this thesis builds upon. Although the primary aim of the thesis is to investigate how people reason from counterfactual conditionals and the experiments are guided by the predictions of mental model theory, factual conditionals (e.g., If Laura is in Dublin then Mary is in Galway) are

also investigated and considered. For this reason, some of the other main theories of reasoning are described below.

Formal Rule Theories

Formal rule theories of conditional reasoning (e.g., Rips, 1994; Braine & O'Brien, 1998) suggest that people reason by constructing proofs using an internal set of abstract general-purpose rules. These logic-like rules can be applied to any area of knowledge. Conclusions are reached by constructing proofs that are similar to proofs in logic. Simple logical rules are added together in a consistent way that ensures a given conclusion from a given set of premises. According to this type of theory people are rational in that they have a mental logic. Errors and invalid inferences are arrived at only because of a misunderstanding of the reasoning task or an error in accessing the rules, rather than by an error in reasoning. Although there are a number of different formal rule theories their commonalites are greater than their differences (see Johnson-Laird & Byrne, 1991) and for this reason we will only focus on one of these theories in any detail, that of Braine & O'Brien (1991; 1998).

Braine and O'Brien (1991) propose that people comprehend natural language premises of an argument and encode them as mental representations in working memory using "comprehension mechanisms". A mental repertory of inference rules is then applied to the premises in order to construct a proof of a conclusion. These rules do not take into consideration the content of the premises. The content free conclusion is finally translated into the content of the premises. The mental repertory of inference rules does not contain all of the rules found in standard logic. It consists only of elementary rules which are those that can be used alone to solve a problem. It is hypothesised that there are separate inference rules for each logical connective, such as "and", "or" and "if" (Braine &

O'Brien, 1998).

Braine and O'Brien (1991) suggest that differences in response to the connectives on problems that are the same in context, content and problem form, arise from information in semantic memory which they call the "lexical entry". The lexical entry for a connective provides truth functional information about it and it gives instructions as to how truth may be inherited from the premises of the argument, to the conclusion. For example, they suggest that the lexical entry for the conditional connective "if" consists of a rule for MP (e.g., if A then B; A therefore A) and a schema for conditional proof. The schema is the procedure to be followed in the execution of the MP rule (e.g. given "if A then B", suppose A and B along with other information taken together with these propositions). The lexical entry is the first part of a three part theory they propose.

The second part of the theory is a propositional-logic reasoning program. This uses the inference schema to specify a routine for reasoning from the premises to the conclusions. It controls how the proof is constructed. Specifically it selects the rules at various stages in the proof, and how to move from one step to the next. Braine, Reiser and Rumain (1984) distinguish between direct and indirect reasoning. Direct reasoning involves the application of abstract rule schemas to premises. If this method does not work indirect reasoning strategies, which rely on heuristics, are used. The third part of the theory, the comprehension component, involves a set of pragmatic principles that govern how a sentence is interpreted in context.

Rule theories explain the distinct pattern of the four inferences (MP, MT, DA, AC) by proposing that the easy valid inferences are made without difficulty because people have a corresponding mental rule to deal with it, for example MP. The poorer performance on the equally valid MT is explained by people not having a specific rule for it. As a result they must construct a proof involving several different rules in order to reach the correct

conclusion, for example (from Braine & O'Brien, 1998, p. 207):

1. if A then B
2. suppose not B
3. suppose A
4. if A then B (1, reiteration)
5. B (3, 4 modus ponens)
6. not B (2, reiteration)
7. Incompatible
8. Therefore, not A (reductio)

Since this is an indirect form of reasoning, involving several different steps, MT is a more difficult inference to make than MP (if A then B, A therefore B). People are more likely to conclude that nothing follows from the premises or make an error in their conclusion. This hypothesis has been supported by several experiments in which participants were given one-step (e.g., if there is a T then there is an L, there is a T; there is an L?) and multi-step (e.g., if there is a D then there is a J, if there is a Q then there is an X; if there is a D or a Q, then there is either a J or an X?) problems to solve. It was found that the difficulty of the problem was dependent on the number of steps involved (Braine *et al.*, 1984).

In relation to the fact that invalid inferences (DA and AC) are regularly made Braine and O'Brien (1991) suggest that this is due to comprehension errors rather than a fault in reasoning. Rumain, Connell and Braine (1983) showed that invalid inferences could be suppressed by providing alternative antecedents. For example, participants were given a conditional such as 'if there is a dog in the box then there is an orange in the box' and the additional information that 'if there is a tiger in the box then there is an orange in

the box'. The participants were then told that there was an orange in the box (the AC inference) and asked if they could conclude that there was a dog in the box. The majority (75%) said they could not tell, which is the logically correct answer. When participants were not given the additional information (if there is a tiger in the box then there is an orange in the box) only 33% said they could not tell. A similar pattern was found for DA. Braine *et al.*,(1984) interpreted this finding as evidence that there could not be mental rules for invalid inferences.

However, Byrne (1989) has shown that valid inferences (e.g., MP) may be suppressed as well, using additional antecedents. For example, participants were told that 'if Lisa met her friend then she went to a play' and 'if Lisa had enough money then she went to a play'. They were then told that 'Lisa met her friend' and asked if they could conclude that she went to a play. Only 51% made the MP inference and said 'Lisa went to the play' compared with 98% that made the MP inference when they were not given the information that if Lisa had enough money she went to the play. This finding could lead to the conclusion that people do not have mental rules for valid inferences, which is a serious problem for abstract rule theories. Although Politzer and Braine (1991) have criticised Byrne's findings on various grounds, for example they propose that the participants doubted the truth of the premises. However, Byrne has shown that doubt in the premises do not explain that data. (Byrne, 1991; Byrne, Espino & Santamaria, 1999).

Criticisms of Formal Rule Theories

There are a number of empirical findings that formal rules theories cannot explain. For example, these theories cannot explain why the MT inference is made more readily from a biconditional than a conditional, while performance of MP remains the same (Johnson-Laird, *et al.*,1992). The mental model theory predicted this finding. According to abstract

rule theories the number of derivational steps for MT should be the same regardless of whether it is made from a conditional or biconditional.

Abstract rule theories cannot adequately account for contextual effects in reasoning. Further, the comprehension component plays a significant role in the formal rules approach. However, this component is underspecified. Although the comprehension component is responsible for the production of the syntactic form of input to the reasoning system and is held responsible for much of the errors produced by the system, there is little detail offered as to how this component actually works.

Finally, and most importantly for this thesis, rule theorists have not provided a tested account of reasoning from counterfactual conditionals. The formal inference rule theory does consider counterfactual conditionals but it is primarily in relation to their role in social discourse and argumentation (Braine & O'Brien, 1991; 1998). However, given the importance of form for rule theorists, and given that a counterfactual conditional (if A had been then B would have been) has the same basic form as a factual conditional (if A then B) one possibility is that rule theorists should predict that there would be no difference in reasoning from factual and counterfactual conditionals. The results of studies investigating reasoning from counterfactual conditionals have not found this result as described earlier (e.g., Byrne & Tasso, 1999). Alternatively, rule theories might predict that counterfactuals are interpreted as 'if A B, not A and not B', that is, the background knowledge that not A and not B is added as a fact to the proof. In that case rule theories should predict that reasoners will not make MP from counterfactuals. However, research shows that reasoners readily make an MP inference from counterfactual premises (e.g., Byrne & Tasso, 1999).

Domain Specific Rule Theories

Domain specific rule theories (e.g., Holyoak & Cheng, 1995; Fiddick, Cosmides & Tooby, 2000) have not considered reasoning from counterfactual conditionals. In fact, these theories are quite limited in scope. Domain specific rule theories suggest that reasoning in real world domains is achieved with the aid of domain specific rules or context sensitive schemas which are retrieved and applied. Schemas include rules for reasoning in particular pragmatic contexts such as in situations involving permissions, obligations (e.g., Cheng & Holyoak, 1985) (e.g., if you prepare food then you must wash your hands) or social contracts (e.g., Cosmides, 1989) (e.g., if you make my dinner today then I will make your dinner tomorrow). These schemas were proposed to explain content effects in reasoning, particularly on the Wason selection task.

The selection task was developed by Peter Wason (1966). The standard abstract form of the selection task presents participants with four cards, each of which has a letter on one side and a single digit number on the other. The four cards are laid out so that two of the cards present letters (e.g., one showing the letter A and one showing the letter D) and the other two present numbers (e.g., one showing the number 3 and one showing the number 7). The participant is then told the rule 'if there is an A on one side of the card then there is a 3 on the other side of the card' and is required to decide which card or cards they must turn over to know if the rule is true or false. The logically correct answer is to turn over the card with the A and the card with the 7, because the only situation that can falsify the rule is a card with an A on one side and not a 3 on the other. Using the logically valid MP inference the A card must have a 3 on the back of it or the rule is false. Using the MT inference the 7 card (which can also be thought of as 'not 3') must have 'not A' on the back of it or the rule is false. On a conditional interpretation of the rule the AC and DA inferences are invalid. These correspond to the 3 and D cards respectively. This means that the rule says nothing about a 3 always having to be preceded by an A or about what

number can occur with a D (which can also be thought of as 'not A').

Less than 10% of people turn over the correct combination of cards using this version of the selection task (Wason & Johnson-Laird, 1972). Most people tend to select just the A card or the A and the 3. This finding is robust regardless of whether the task is conducted using real cards, or pictures of them with pencil and paper studies or computer studies (for a review of the Wason selection task see Evans, *et al.*, 1993).

One factor that does improve performance on the selection task is using a more concrete content such as 'if a person is drinking alcohol then they must be over 18 years of age' (e.g., Griggs & Cox, 1982). The problem and the options on the four cards ('drinking beer', 'drinking coke', '16 years of age' and '19 years of age') is logically equivalent to the abstract task, but given this type of content 74% of participants were able to identify the two cards they had to turn over to determine if the rule was true or false (i.e., the 'drinking beer' card and the '16 years of age' card. This effect has also been demonstrated with other concrete contents such postal rules (Johnson-Laird, Legrenzi & Legrenzi, 1972), social contracts (e.g., Cosmides, 1989) and inducements (Manktelow & Over, 1991).

The finding that a concrete content can improve reasoning performance on the selection task has led to a number of different explanations. One hypothesis is that people can remember specific counterexamples and use this information to guide their reasoning (Griggs & Cox, 1982). Another hypothesis is that people use analogies (e.g. Manktelow & Evans, 1979). A third hypothesis, made by the pragmatic reasoning schema theory (Cheng & Holyoak, 1985), suggests that a general real-world pragmatic (or deontic) framework improves performance.

According to the pragmatic reasoning schema theory (Cheng & Holyoak, 1985; Cheng, Holyoak, Nisbett & Oliver, 1986; Holyoak & Cheng, 1995) people reason using knowledge structures. These knowledge structures are induced from ordinary life

experiences, such as those involving permissions, obligations, causations, rights and duties. They are a generalised set of context-specific rules defined in relation to classes or goals, so the schema are only activated when the class or goal is present (e.g., in a situation that involves permission such as being permitted to drink alcohol once you are over 18 years of age). Cheng and Holyoak suggest that people typically use this method to reason rather than using content-free inference rules or memory of specific experiences.

For example, the permission schema is used for reasoning about situations that involve permissions. This schema consists of four rules about actions and preconditions. These are:

1. If the action is to be taken then the precondition must be satisfied.
2. If the action is not to be taken then the precondition need not be satisfied.
3. If the precondition is satisfied then the action may be taken.
4. If the precondition is not satisfied then the action must not be taken.

Cheng and Holyoak (1985) examined the effects of the permission schema on deductive reasoning by giving people versions of the Wason selection task. One version used the price of a stamp on an envelope and whether or not the envelope was sealed, and the other version used a tropical disease and whether or not a person was entering a country. They found that people performed much better on the task when they were given a reason for the task than when they were not. However, half the group were familiar with the idea of having to pay more postage for an envelope that was sealed (those people from Hong Kong) and they performed equally well on this task whether or not a rationale was provided. Cheng and Holyoak suggested that the effect of the rationales could not be due to the amount of specific experience since experience on the given domains did not differ between the rationales. They state that the formal inference rule theory is unable to explain

this finding.

Cosmides (1989; Fiddick, Cosmides & Tooby, 2000) has advanced a form of the domain-specific schema approach called social contract theory. Cosmides takes an evolutionary perspective, and points out that being able to spot a cheat, and avoid being used or cheated in social groups would confer considerable evolutionary advantage. She suggests that people have developed a specific inferential module which detects whether people are trying to cheat on social contracts. Social contracts specify that in social exchanges, if one takes a benefit then one is expected to pay the cost. Cosmides suggests that improved performance on the concrete version of the Wason selection task can be explained by interpreting the selection rule as a social contract (e.g., if a man eats cassava root then he must have a tattoo on his face). People are able to select the correct cards because they have a built in capacity to detect cheaters. This finding is even more pronounced when people are cued to take the perspective of someone who can be cheated (see Gigerenzer & Hug, 1992).

Criticisms of Domain-Specific Rule Theories

It has recently been argued that asking people to detect cheaters removes the normal inferential demands of the selection task and changes the task to a simple classification task (Sperber & Girotto, 2002). Moreover, a number of authors have also pointed out (e.g. Pollard, 1990; Politzer & Nguyen-Xuan, 1992) that many of the contexts that improve performance on the Wason selection task do not actually involve socially exchanged costs and benefits.

Both the social contract theory and the pragmatic reasoning schemas theory can be criticised on the grounds that they are very narrow in scope. They were developed in response to content effects found using the Wason selection task and most research on

these domain-specific theories has continued to focus on this task. Although other tasks (e.g., the inference task) have been used on occasion the predictions and findings are less than clearly explained by these theories (e.g., Cheng & Nisbett, 1993). Also, domain specific rule theories do not account for differences that arise in reasoning which are not due to content, such as differences that arise using different linguistic forms, for example, 'if' and 'only if' (e.g., Evans, 1977)

A further criticism is that the domain specific theories are not complete enough in their proposals. They do not generate predictions involving logical connectives such as "and" or "or", and although they can account for how people reason using certain types of content on a certain type of task they do not detail how people reason in general. For example Cheng and Holyoak (1985) state that "people *often* reason using...abstract knowledge structures...", (p. 395, italics added) yet they do not state how people reason when they are not using abstract knowledge structures. Finally, the theory says little about issues such as comprehension, or the effects of processing limitations such as working memory.

Probabilistic Theory

Probabilistic theories of reasoning suggest that people reason by making choices that maximise the information available to them while trying to reduce uncertainty about situations (e.g., Oaksford & Chater, 1994; Chater & Oaksford, 1999). Oaksford and Chater suggest that people make these choices by using probability calculations to ascertain the amount of information gain of a choice. This theory has primarily been applied to the Wason selection task and it has had some success in explaining the pattern of cards people select (i.e., people typically select the 'A' card or the 'A' and '3' cards, rather than the logically valid 'A' and '7' cards; see Evans *et al.* (1993) for a review).

Probabilities are computed using a Bayesian probability model that indicates the amount of information a particular choice will provide given a condition (a function of the probability of B and the probability of B given A). For example, imagine a participant has to decide which cards (A, D, 3, 7) to turn over in order to test the rule "if there is an A on one side, then there is a 3 on the other". The probability model suggests the following: turning over the A will definitely provide information, while turning over the D will provide no information at all. Turning over the 7 may or may not be informative (depending on the letter on the other side), and the same is true for the 3. In order of usefulness (given a further assumption that rare events are more informative than common ones, Oaksford & Chater, 1994; 1998) participants should first select the A card, and then the 3 card, the 7 card and finally the D card. The idea of information gain is one explanation for the pattern of cards that people chose in the selection task, and Oaksford & Chater (1994) have published a meta-analysis that suggests that the rates of card choice match these probabilities of usefulness.

The probabilistic theory has been criticised on the grounds that it is narrow in scope in that it has only modelled performance on the selection task (e.g., Eysenck & Keane, 2000). Recent work, however, has begun to address this shortcoming. Oaksford, Chater and Larkin (2000) have put forward a formal probability model of conditional inference. This model assumes that the perceived strength of the argument is directly related to the conditional probability of the conclusion given the minor premise. For example, confidence in the MT inference for the conditional 'if the key is turned then the car starts', should be equal to the probability of the car not starting given that the key is turned. In support of this suggestion Oaksford *et al.*, found that people endorsed more inferences whose conclusions were computed under the model to have high probabilities rather than low probabilities.

The probabilistic model has also been applied to the standard pattern of results of suppression effects on the inference task. Oaksford & Chater (2003) showed using a computational model that the probabilistic approach can account for suppression effects, explaining that new information changes the subjective probabilities of the outcomes. Additional information given to participants to suppress inferences alters the probability of an inference being endorsed. Given a premise such as 'if A then B', extra premises such as 'if C then B', affect people's expected probabilities of A and B. Oaksford and Chater's computational model, in finding the most informative choices, produced a pattern of inferences that was similar to those found in previous studies of the suppression effect (e.g., Byrne, 1989; Cummins, Lubart, Alksnis & Rist, 1991).

Criticisms of the Probabilistic Theory

Johnson-Laird (1999) has criticised the theory because it does not have a performance component. The lack of a performance component means that although the model can account for patterns of inferences across experiments, there is no attempt to explain the mechanisms of reasoning in the individual case. For example, how do reasoners produce options to choose between, or how do memory and other cognitive processes produce from prior experiences the probabilities of everyday events? Without a performance component to suggest answers to these questions, the probabilistic theory is incomplete.

The strongest criticisms to date of the probabilistic theory are those of Schroyens & Schaeken (2003). These criticisms are both conceptual and empirical. Conceptually, they point out that in earlier publications of the probabilistic model on the Wason selection task (Oaksford & Chater, 1994; 1998) a rarity assumption was argued for and used (that both A and B had a probability of less that 0.2). However, in more recent work, this assumption is not adhered to, a change in stance that is not explained by Oaksford and Chater.

Empirically, Schroyens & Schaeken have used meta-analyses of conditional reasoning research to show that the pattern of inferences made by reasoners does not match that predicted by the theory as it stands at the moment. For example, when the inferential clause of a conditional argument includes a negation, then there is a greater proportion (versus affirmative clauses with no negation) of AC inferences made compared with MT inferences. This finding should only occur when the probability of B and the probability of not B, given A, is greater than 1. There is also an overall greater proportion of DA inferences made in the case of a negative clause, which should only occur when exactly the same probability is less than 1. The theory also makes problematic claims about affirmative inferences, suggesting that in cases where MP is universally accepted, then MT should also be universally accepted. However, the studies analysed by Schroyens & Schaeken included 23 groups who universally accepted MP but failed to universally accept MT, thus providing strong evidence against the probabilistic theory's hypothesis. These and other empirical findings discussed in Schroyens & Schaeken are a significant blow to the probabilistic account.

Aims of the thesis

The first section in this chapter highlighted the importance of counterfactual thinking in everyday life. Despite its importance, however, very little work has been conducted into how people reason from counterfactual conditionals. The second section provided an introduction to conditional reasoning, why it is important, and the tasks that are used to measure it. The third section reviewed the theories that exist to explain conditional reasoning. However, the majority of theories of conditional reasoning, described in the third section focus exclusively on reasoning from factual conditionals (the mental model theory being the notable exception). Any theory of conditional reasoning, if it is to be

complete, must be able to explain how people reason from counterfactual assertions as well.

The primary aim of this thesis is to investigate reasoning from counterfactual conditionals and to test predictions derived from the mental model account of reasoning from counterfactual conditionals. We aim to extend the theory to account for the role various factors play in reasoning from counterfactual conditionals. Specifically, we consider the role of content, tense and linguistic form in reasoning from counterfactual conditionals. The impact of the results of the eight experiments reported in the thesis will be considered for both counterfactual thinking and conditional reasoning, with the aim of bridging the gap between these two areas. All of the experiments reported in this thesis compare factual and counterfactual conditionals so a secondary aim of the thesis is also to investigate the role of content, tense and linguistic form in reasoning from factual conditionals and consider the implications of these findings for the various theories of reasoning outlined in this chapter.

Chapter 2 investigates the role of content in reasoning from counterfactual conditionals. It is clear that content plays a role in reasoning from factual conditionals as demonstrated by comparing concrete and abstract versions of the Wason selection task. Some recent research shows that content also plays a role in reasoning from counterfactual conditionals (Quelhas & Byrne, 2003; Thompson & Byrne, 2002). The content we have chosen to focus on is inducements (i.e., promises and threats) which has not been considered before in relation to counterfactual conditionals. Using inducements will allow us to investigate questions such as whether good or bad outcomes influence people's mental representations of counterfactual conditionals and how counterfactual conditionals are used in everyday life. We address these questions in a series of three experiments by examining the possibilities that are judged consistent with inducements and the inferences

that are invited by, and drawn from, inducements. We also propose and test a new account of the mental representations of factual promises and threats. We test the prediction that people's reasoning differs for factual promises and threats but not for counterfactual promises and threats.

Chapter 3 considers the role of tense in reasoning from counterfactual conditionals. Most studies of conditional reasoning have ignored the future tense as a factor in reasoning and have focused on reasoning primarily from present and past tense conditionals. Tense has only recently been investigated in relation to factual conditionals (Schaeken, Schroyens & Dieussaert, 2001). This chapter aims to examine the role tense plays in conditionals, in particular, future tense subjunctive conditionals, that is "prefactuals", which have not been considered before (see Byrne & Egan, 2004). We investigate prefactual conditionals in a series of three experiments that examine the possibilities that are implied by and judged consistent with prefactuals and also the inferences that are drawn from them. We test the hypothesis that reasoning from prefactual conditionals is more similar to reasoning from factual conditionals than to reasoning from counterfactual conditionals.

Chapter 4 examines the role of linguistic form in reasoning from counterfactual conditionals. Previous research has shown that different linguistic forms, such as 'only if' and 'unless', affects reasoning from factual conditionals (e.g., Garcia-Madruga, Carriedo, Moreno-Rios & Schaeken, 1998; Evans & Beck, 1981) and this chapter investigates whether or not reasoning from counterfactual conditionals is also affected by linguistic form. Do people keep two possibilities in mind for counterfactual conditionals regardless of linguistic form or can the linguistic form of the conditional modulate the possibilities? We report two experiments that compare reasoning from counterfactual 'if' and 'only if', and we also describe other experiments that we conducted in collaboration with colleagues on reasoning from counterfactual 'unless' assertions (Garcia-Madruga, Byrne, Egan,

Moreno-Rios, Quelhas & Juhos, 2004). A new account of factual 'only if' is also proposed and tested.

In the final chapter, Chapter 5, we consider the implications of our findings for understanding reasoning from counterfactual conditionals. We also consider how our findings, for both factual and counterfactual conditionals, might be accounted for by the mental model theory and by the other theories of conditional reasoning and make recommendations for future research in this area. In summary, the primary aim of this thesis is to advance our understanding of human reasoning by discovering what role is played by content, tense and linguistic form in reasoning from counterfactual conditionals.

Chapter 2: The Role of Content in Reasoning from Counterfactual Conditionals

Our primary aim in this chapter was to investigate how content influences counterfactual reasoning; specifically, reasoning about possible past actions and outcomes, which are often the focus of our counterfactual thinking (e.g., if I had arrived earlier I could have prevented the accident). We attempt to understand this matter using inducements (i.e., promises and threats). Promises and threats both draw attention to an action and the consequence of that action. With promises the speaker tries to persuade the addressee to take the action and therefore the consequence of the action is positive (e.g., if you mow the lawn then I will pay you 10 euro). With threats, the speaker tries to dissuade the addressee from taking the action and therefore the consequence of the action is negative (e.g., if you hit your sister then I will make you wash the dishes). The three experiments reported in this chapter investigate how people reason with these conditionals when they are about past actions and outcomes (e.g., if you *had* hit your sister then I *would have* grounded you) and also whether people reason differently from conditionals with good and bad outcomes. The remainder of this section describes studies of reasoning from counterfactual conditionals that have explored the role of content, and studies that have investigated promises and threats. The next section describes the results of three experiments on the topic.

Content and reasoning from counterfactual conditionals

A number of studies have investigated reasoning from counterfactual conditionals using neutral content such as 'if Aisling had been in Dublin then Gerry would have been in Limerick' (e.g., Byrne & Tasso, 1999). Recall that the subjunctive mood of the

counterfactual seems to convey the presupposition that in fact Aisling was not in Dublin (not A) and Gerry was not in Limerick (not B) (Fillenbaum, 1974; Thompson & Byrne, 2002). As described in Chapter 1, because people keep these presupposed facts in mind from the outset for a counterfactual conditional but not for a factual conditional, they endorse more negative inferences for a counterfactual conditional than a factual one (e.g., Byrne & Tasso, 1999).

Although this pattern is well established for counterfactual 'if then' conditionals with neutral content, people rarely reason about such arbitrary relations between things in everyday situations. Ohm and Thompson (2004, p. 242) state that "...the reasoning people engage in during their everyday lives is not devoid of meaning, and the processes by which people interpret, contextualise, and modify given information are integral to making inferences in most real-world situations. These interpretative processes must be understood before a complete model of reasoning can be achieved". Reasoning from factual conditionals is greatly affected by the content of the conditional (for a review see Evans, *et al.*, 1993). Various factors influence the inferences people endorse such as the believability of the conditional (e.g., Politzer & Bourmaud, 2002; Thompson 1996) and the relation between the antecedent and the consequent (i.e., between A and B) (e.g., Cummins, Lubart, Alksnis & Rist, 1991; Thompson 1994). Recent research (e.g., Thompson & Byrne, 2002; Quelhas & Byrne 2003) shows that content also affects reasoning from counterfactual conditionals.

Thompson and Byrne (2002) investigated reasoning from counterfactual conditionals with causal (e.g. if the butter had been heated then it would have melted) and definitional content (e.g. if the animal had been warm blooded then it would have been a mammal). They examined the inferences people drew, and the possibilities people considered consistent with causal and definitional counterfactual conditionals. They also

gave participants an implications task which presents participants with a conditional assertion and asks what, if anything, they think is implied by the conditional. They found that people are more likely to arrive at a counterfactual interpretation when presented with causal content than with definitional content. That is they are more likely to say that someone uttering a causal counterfactual means to imply that the butter has not been heated, and it did not melt, than they were to interpret someone uttering the definitional counterfactual was meaning to imply the animal was not warm-blooded, and was not a mammal. They suggest the reason may be that counterfactual and causal thinking are related. However, they also found that once people had formed a counterfactual representation there did not appear to be any differences between the causal and definitional conditionals in the inferences that people drew from counterfactual conditionals or in the possibilities they judged to be consistent with counterfactual conditionals.

Quelhas and Byrne (2003) examined deontic counterfactual conditionals. Deontic conditionals are those that refer to permissions or obligations such as 'if the nurse cleaned up blood then she wore rubber gloves'. They proposed that unlike other counterfactual conditionals, deontic counterfactual conditionals do not convey the same presuppositions that their antecedents and consequent are false: 'if the nurse had cleaned up the blood then she would have worn rubber gloves'. They found that rather than keeping in mind the facts and the conjecture that for deontic counterfactual conditionals people keep in mind a possibility that corresponds to what is permissible (e.g., the nurse cleaned up blood and wore rubber gloves) and one corresponding to what is not permissible (e.g., the nurse cleaned up blood and did not wear rubber gloves).

These two studies show that content plays an important role in reasoning from counterfactual conditionals. We wish to examine the role of a central type of content in

counterfactual conditionals: inducements. Inducements are pervasive in everyday language, for example between parents and children (e.g., if you mow the lawn then I will give you 10 euro), school-teachers and pupils (e.g., if you misbehave in class I will give you detention) or between election candidates and voters (e.g., 'I promise that if I am President, we're going to win the fight to make health care affordable and available for you and for all our families', US presidential election candidate John Kerry, 2004). There has been relatively little research devoted to how people reason with them (with some notable exceptions, reviewed later) and the results vary greatly between the existing studies. There has been no research on counterfactual inducements at all. Our study of counterfactual promises (e.g., if you had mown the lawn then I would have given you 10 euro) and threats (e.g., if you had hit your sister then I would have made you wash the dishes) also provides an insight into how counterfactual conditionals are used in daily life. The next section considers inducements in more detail, and highlights some of the similarities and differences between promises and threats.

Inducements

Promises and threats are similar in that they both specify an action and the outcome of that action (i.e., a reward or a punishment). Fillenbaum (1977) investigated the relationship between the value of the action and the value of the reward or punishment. He found that the value of the reward or punishment had to be sufficiently high to elicit the action (e.g., if you mow then lawn then I will give you 10 euro) but not so high as to render the inducement implausible (e.g., if you mow the lawn then I will give you 300 euro).

Verbrugge, Dieussaert, Schaeken & Van Belle (2004) built on this work and investigated how the plausibility of promises and threats affects the inferences people

draw. They showed that reasoners endorse less affirmative inferences (MP and AC) from promises and threats that are low in credibility compared to those that are high in credibility. Reasoners also tend to endorse less inferences when the person uttering the promise or threat does not have a high degree of control over the reward or punishment (Evans & Twyman-Musgrove, 1998). For example, reasoners tended to endorse more inferences from promises where the speaker has direct control over the reward such as 'if you wash the car this afternoon then I will lend it to you this evening' than from promises where the speaker does not have direct control over the reward such as 'if you wash the dishes for me then mum will give you extra pocket money'.

With promises and threats the speaker typically has a high degree of control over the outcome. Evans & Twyman-Musgrove also noted a preference for forward inferences (MP and DA) over backward inferences (MT and AC). They suggested the explanation for this finding was that all of the conditionals used in the study had a "strong (pragmatic) directional link from an antecedent event to a later consequent event which could explain the preference" (p. B15). Other studies of inducements using an inference task have produced very mixed rates of endorsements for the four inferences MP, AC, MT and DA. Table 2.1 below shows the endorsement rates of the four inferences in a number of studies (data from experimental conditions using non-typical inducements is not shown i.e., where the speaker had low control or the inducement was not credible). Newstead, Ellis, Evans & Dennis (1997) found high rates of endorsements for all inferences except MT with promises. Carriedo, Garcia-Madruga, Gutierrez & Moreno (1999) found high rates of all inferences with threats. However, they suggested that this finding was not consistent with a biconditional interpretation because MP was endorsed more frequently than the others. One possible interpretation they suggest is that threats could facilitate the fleshing out of some models (not A not B) more than others, although they do not say why this should be

the case.

Table 2.1: Percentages of inferences endorsed in previous inference tasks using inducements

Study	Inducement	MP	AC	MT	DA	*Mean*
Newstead et al. (1997). Exp 4	Promise	89	78	54	74	*73*
	Threat	93	71	84	84	*83*
Ohm & Thompson (2004)	Promise	60	67	45	60	*58*
	Threat	63	58	52	42	*54*
Evans et al, (1997)	Promise	82	49	42	66	*60*
	Threat	82	34	38	75	*57*
Carriedo et al. (1999)	Threat	92	72	80	72	*79*

Fillenbaum (1976) investigated what people consider natural rephrasings of promises and threats. Although both are readily rephrased using the connective 'and' (e.g., mow the lawn *and* I'll give you 10 euro; hit your sister *and* I'll make you wash the dishes) only threats may be sensibly rephrased using the connective 'or' (e.g., 'don't hit your sister *or* I'll ground you'; 'mow the lawn *or* I'll give you 10 euro').

Another difference between promises and threats is that a promise may be considered a social contract between the speaker and the hearer but a threat cannot because the hearer does not agree to it (e.g., if you are bold then I will ground you). In a threat the situation is forced upon the hearer (e.g., Politzer & Nguyen, 1992). As Searle (1969, pp. 58) puts it "...a promise is a pledge to do something for you, not to you; a threat is a pledge to do something to you, not for you". Legrenzi, Politzer and Girotto (1999) believe that the most fundamental principle of a social contract is that both parties must gain in utility from the exchange. With a promise such as when a parent says to their child 'if you

mow the lawn then I will pay you 10 euro' the parent gains because the lawn is mowed and the child gains because they get 10 euro. Both parties believe they gain from this exchange otherwise they would not enter into the contract (this idea is similar to the idea of subjective expected utilities (SEU), Manktelow & Over, 1991). With a threat such as 'if you stay out late then I will ground you' neither party really gains anything. The child must decide which is worse: not staying out late or being grounded. The parent also does not gain anything by grounding the child.

According to Searle (1969) promises and threats are both a type of speech act. He suggests that in order to understand what a speaker is saying the hearer must understand the speaker's intention and since language is intentional behaviour then it may be considered a form of action. So when someone speaks they are performing an act, in this case the act of promising or threatening. However, the intention of the speaker differs for promises and threats. We suggest that this difference in intention is an important one which leads reasoners to keep different possibilities in mind for promises and threats.

For promises the intention of the speaker is to encourage the action by offering a reward, e.g. 'if you are good then I will buy you ice-cream'. The intention is made explicit: the speaker wants the hearer to be good. We expect that for the hearer to understand a promise, they must keep in mind the action (being good), and the outcome (ice-cream). They may initially keep in mind a single possibility, corresponding to what is mentioned in the conditional, being good and getting ice-cream (A and B), although they can flesh out other possibilities such as not being good and not getting ice-cream (not A and not B), if necessary.

For threats the intention of the speaker is to discourage an action by punishing it, e.g. 'if you are bold then I will ground you'. The intention is implicit: the speaker wants the hearer *not* to be bold. We expect that for the hearer to understand a threat they must

also keep in mind the opposite of what the speaker has said, that is, the negated action (not being bold) and the negated outcome (not being grounded). They may initially keep in mind not only the affirmative possibility but also the negative one, corresponding to the opposite of the elements mentioned in the conditional, not being bold and not being grounded (not A and not B).

Table 2.2. Summary of possibilities people keep in mind from the outset for factual and counterfactual promises and threats

	Promise	Threat
Factual	A and B ...	A and B Not A and not B ...
Counterfactual	Conjecture: A and B Facts: Not A and not B ...	Conjecture: A and B Facts: Not A and not B ...

Promises and threats are generally uttered by a speaker in an attempt to manipulate the future behaviour of the hearer. But counterfactual conditionals about promises and threats are different. A counterfactual promise, such as 'if you had been good I would have given you ice-cream' conveys the presupposed facts that you were not good and I did not give you ice-cream (not A and not B). The counterfactual conditional conveys the presupposition that the behaviour that the speaker wanted to promote has not occurred (you were not good) and the positive outcome did not occur either (no ice-cream). The counterfactual promise refers to a past action and outcome and so it may be at best an

indirect attempt to manipulate future behaviour. For counterfactual promises (e.g., if you had been good then I would have given you ice-cream) we expect that people think about two possibilities from the outset, the conjecture mentioned in the conditional (e.g., be good and get ice-cream) and the presupposed facts (e.g., not being good and not getting ice-cream).

Likewise, a counterfactual threat, 'if you had been bold then I would have grounded you' conveys the presupposed facts that you were not bold and I did not ground you. The behaviour the speaker wanted to prevent has not occurred (you were not bold) and the negative outcome did not occur either (no grounding). Nonetheless counterfactual promises and threats may continue to have illocutionary force with regard to future behaviour. For counterfactual threats (e.g. if you had been bold then I would have grounded you) we expect that people initially think about two possibilities, the conjecture (be bold and get grounded) and the presupposed facts (not being bold and not getting grounded) (see Table 2.2).

The aim of the series of experiments reported in this chapter was to investigate how people reason from factual and counterfactual promises and threats. We expect systematic differences in reasoning to arise between factual and counterfactual promises and factual and counterfactual threats because of the different possibilities we expect people to initially keep in mind. Our first experiment tests the inferences that factual and counterfactual promises and threats invite, the second experiment investigates the inferences that people draw from them and the third experiment investigates the possibilities that people judge to be consistent with them.

Experiment 1: What inferences do promises and threats invite?

The aim of this experiment was to investigate if factual and counterfactual promises and threats invite different inferences. An invited inference (Geis & Zwicky, 1971) is one that can be reached without any additional information. For example, when people are told that 'if Cedric takes up this new job then his life will improve in every respect' and are asked what they think follows the majority say that they think Cedric will take up the new job. The inference is not valid, but many people endorse it. When they are told 'if Cedric takes up this new job then his life will disimprove in every respect' the majority say that Cedric will not take up the new job (Bonnefon & Hilton, 2003). We examined the inferences that factual and counterfactual promises and threats invite using a method similar to Bonnefon and Hilton's method (2003, Experiment 1). Participants were presented with the following task and asked to tick one response option from the five provided (a-e):

Jason's teacher said to him "if you use up the rest of the red paint in your picture then I will give you no homework".

What, if anything, do you think will happen?

(a) Jason will definitely use up the rest of the red paint in his picture

(b) Jason will probably use up the rest of the red paint in his picture

(c) Nothing follows

(d) Jason will probably not use up the rest of the red paint in his picture

(e) Jason will definitely not use up the rest of the red paint in his picture

Based on Bonnefon and Hilton's (2003) study we expected that factual promises and threats would differ in the inferences they invited. We predicted that factual promises would invite an inference to the truth of the antecedent (e.g., Jason will use up the rest of

the red paint in his picture), that is that participants would select options (a) and (b) more often than any of the other options. However, we predicted that factual threats (e.g., if you use up the rest of the red paint in your picture then I will give you detention) would invite an inference to the falsity of the antecedent (e.g., Jason will not use up the rest of the red paint in his picture), that is that participants would select options (d) and (e) more often than any of the other options.

For counterfactual promises and threats we predicted that they would not differ in the inferences that they invite and that both would invite an inference to the falsity of the antecedent as the false antecedent is presupposed by the conditional. For example, for a counterfactual promise (e.g., if you had used up the rest of the red paint in your picture then I would have given you no homework) we predicted that participants would select options (d) and (e) (e.g., Jason did not use up the rest of the red paint in his picture). For counterfactual threats (e.g., if you had used up the rest of the red paint in your picture then I would have given you detention) we also predicted that participants would select options (d) and (e) (e.g., Jason did not use up the rest of the red paint in his picture). We also wished to examine whether counterfactual promises and threats are classified as inducements. Given that the event has already occurred (e.g., Jason used up the rest of the red paint in his picture), and Searle (1969) suggests that promises cannot be about past acts, counterfactual conditionals should not be considered as inducements. But why then do people offer them? We suspect that they may still exert some indirect illocutionary force to influence the future. Accordingly, we asked people to classify the conditionals as promises, threats or neither.

Method

Materials and Design

The materials consisted of 12 problems which were each presented on a separate page and in a random order for each participant. Four of the problems were promises, four were threats and four were neutral outcome conditionals (e.g., if you use up the rest of the red paint in your picture then I will put away the paper. A pilot test was conducted with 8 participants to confirm that the conditionals were interpreted as intended. This was shown to be the case.). Half of the problems (i.e., two promises, two threats and two neutral outcome conditionals) were phrased in the factual mood and the other two were phrased in the counterfactual mood.

We used four different types of content. The four contents involved a parent speaking to a child, a schoolteacher speaking to a pupil, a boss speaking to an employee and a nightclub owner speaking to a customer (see Appendix A). Similar to Bonnefon and Hilton's (2003) study, for each content the antecedent (A) of each conditional was the same. For example, in the parent content the antecedent was always "if you put that package in the bin then I will...". The consequent (B) changed depending on whether the conditional was to be interpreted as a promise ("...double your pocket money this week"), a threat ("...ground you for the week") or neither ("put this box on the shelf"). None of the consequents of the conditionals were extreme (e.g., if you tidy your room then I will pay you 100 euro) as this can affect the credibility of the conditional and the inferences people draw from it (Verbrugge, et al., 2004). After each conditional participants were asked what, if anything they thought would happen (factual) or did happen (counterfactual) and then chose from the five response options as illustrated in the example problem above.

After participants had chosen their conclusion for the problem they were then asked

to classify the conditional assertion as a promise, a threat or neither, before moving on to the next problem. This measure was to check that people were interpreting the factual conditionals appropriately and also to investigate how they were classifying the counterfactual conditionals. Participants were not given a definition of a promise, a threat or a neutral outcome conditional as we wanted them to use their own definition.

Procedure

Before the participants were given the booklet containing the 12 problems they were advised of the nature of the study and were asked to sign a consent form[1] if they wished to participate (all participants who took part in the research reported in this thesis signed a consent form before participating). The 12 problems were each presented on a separate page of the booklet. The participants were tested in groups and the experimenter read the instructions aloud which asked participants to complete the problems in the order they were presented and not to change any answers (full instructions can be found in Appendix A). Participants were advised that they could take as long as they needed to complete the task. Once all participants had completed the booklet they were given a debriefing sheet explaining the main aims of the study and the experimenter answered any questions they had.

Participants

The participants were 77 undergraduate psychology students from Dublin Business School's School of Arts who participated voluntarily. Due to an administrative error in some of the booklets 13 people were excluded prior to any analysis. Of the remaining 64

1 All participants were given a consent form prior to participating in the experiments reported in this thesis. See Appendix A for this consent form.

participants there were 51 women and 13 men and their average age was 27 years, ranging from 18 to 41 years.

Results and discussion

Classifications

Participant's classifications of the factual conditional assertions indicate that they were interpreted as intended and that participants understood what was meant by a promise and a threat. As Table 2.3 shows, positive outcome statements were classified as promises on 95% of trials; negative outcome statements were classified as threats 93% of the time; neutral outcome statements were classified as neither a promise nor threat 76% of the time.

Table 2.3: Percentages of classifications in Experiment 1

		Classification		
		Promise	Neither	Threat
Factual	Promise	95	3	2
	Neutral	16	76	8
	Threat	6	1	93
Counterfactual	Promise	45	52	3
	Neutral	11	83	6
	Threat	12	22	67

The classification pattern for counterfactual conditionals was less clear cut than for factual conditionals. Positive outcome counterfactual conditionals were classified as promises on

45% of trials and as neither a promise nor threat on 52% of the trials. Negative outcome counterfactual conditionals were classified as threats on 67% of the trials and as neither on 22% of the trials. The majority of neutral outcome statements (83%) were classified as neither a promise nor threat.

We expected that factual conditionals would be classified as promises or threats depending whether the outcome was good or bad and the results supported our predictions. We also wish to examine whether counterfactual conditionals would be classified as neither a promise nor a threat because they are in the past tense but the pattern of results did not support our prediction. It is surprising that conditionals in the past tense could still be classified as promises (45%) and threats (67%). Perhaps it is possible that counterfactual promises and threats have implications for future behaviour and we examine this possibility further in Experiments 2 and 3.

Invited Inferences

Table 2.4 shows the percentages of invited inferences for factual and counterfactual promises and threats. As expected, factual promises invited an inference to the truth of the antecedent (definitely A: 71%; probably A: 24%) but counterfactual promises invited an inference to the negation of the antecedent (definitely not A: 61%; probably not A: 23%. In contrast to factual promises, factual threats invited an inference to the falsity of the antecedent as we predicted (definitely not A: 51%; probably not A: 41%). Counterfactual threats also invited an inference to the falsity of the antecedent (definitely not A: 65%; probably not A: 25%).

Table 2.4: Percentages of responses to the invited inference task in Experiment 1

		Definitely A	Probably A	Nothing follows	Probably not A	Definitely not A
Factual	Promise	71	24	1	1	2
	Neutral	5	35	45	10	3
	Threat	2	4	3	41	51
Counter-factual	Promise	10	3	2	23	61
	Neutral	0	5	15	27	53
	Threat	2	4	4	25	65

In order to investigate the differences between promises and threats a series of t-tests was carried out. For ease of statistical analysis the data were recoded to form three response categories instead of five. The 'definitely A' and 'probably A' options were combined as 'A' and the 'definitely not A' and 'probably not A' options were combined as 'not A'. The 'nothing follows' option remained the same (see Table 2.5).

Table 2.5: Percentages of recoded responses in Experiment 1

		A	Nothing follows	not A
Factual	Promise	95	1	3
	Neutral	40	45	13
	Threat	6	3	92
Counterfactual	Promise	13	2	84
	Neutral	5	15	80
	Threat	6	4	90

For factual conditionals participants selected 'A' significantly more often for promises than neutral outcome statements (95% versus 40%, $t = 12.81$, $df = 63$, $p < .01$) or threats (95% versus 6%, $t = 32.46$, $df = 63$, $p < .01$). The 'nothing follows' option was selected

significantly more often for neutral outcome statements than for promises (45% versus 1%, $t = 8.90$, $df = 63$, $p < .01$) or threats (45% versus 3%, $t = 8.63$, $df = 63$, $p < .01$) which suggests that this option was interpreted as intended and not as an alternative for 'I don't know'. Also, no participant reported difficulty understanding the meaning of this option before or after the experiment was carried out. The 'not A' option was selected more after threats than after promises (92% versus 3%, $t = 28.49$, $df = 63$, $p < .01$) or neutral outcome statements (92% versus 13%, $t = 25.00$, $df = 63$, $p < .01$).

For the counterfactual conditionals the majority of participants chose the 'not A' response for promises (84%), threats (90%) and neutral outcome statements (80%). There was no difference in the rate of 'not A' responses between promises and threats (84% versus 90%, $t = 1.15$, $df = 63$, $p = .17$) or between promises and neutral outcome statements (84% versus 80%, $t = 1.04$, $df = 63$, $p = .15$) but there was between threats and neutral outcome statements (90% versus 80%, $t = 2.05$, $df = 63$, $p = .03$). The rates of 'A' and 'nothing follows' responses followed a similar pattern to the factual conditionals though to a much lesser extent. More people selected 'A' following a promise than a threat (13% versus 6%, $t = 1.86$, $df = 63$, $p = .04$) or a neutral outcome statement (13% versus 5%, $t = 2.64$, $df = 63$, $p = .01$). More people selected 'nothing follows' following a neutral outcome statement than a promise (15% versus 2% $t = 3.97$, $df = 63$, $p < .01$) or a threat (15% versus 4%, $t = 2.90$, $df = 63$, $p = .01$).

Summary

These findings support our prediction that factual promises invite an inference to the truth of the antecedent (A) but that counterfactual promises invite an inference to the falsity of it (not A). We suggest, based on the inferences that promises invite, that people keep a single

affirmative possibility (A and B) in mind for factual promises. For counterfactual promises however, we expect that people keep in mind two possibilities from the outset, an affirmative one (A and B) and a negative one (not A and not B).

The results showed that both factual and counterfactual threats invite an inference to the falsity of the antecedent (not A). We therefore suggest that for both factual and counterfactual threats that people initially keep in mind two possibilities, an affirmative one (A and B) and a negative one (not A and not B). For factual threats (e.g., if you are bold then I will ground you) these possibilities correspond to the information mentioned in the conditional (bold and grounded) and the inference that is invited by the conditional (not bold and not grounded). For counterfactual threats (e.g., if you had been bold then I would have grounded you) the two possibilities correspond to the information mentioned in the conditional which is the counterfactual conjecture (bold and grounded) and the other possibility corresponds to the presupposed facts of the situation (not bold and not grounded). The next experiment tests the possibilities people keep in mind for factual and counterfactual promises and threats by examining the inferences that people draw from them.

Experiment 2: Do reasoners draw different inferences from factual and counterfactual promises and threats?

The primary aim of this experiment was to investigate if reasoners draw different inferences from factual and counterfactual promises and threats. We presented reasoners with a task of the following sort:

Laura's mother said to her "If you mow the lawn then I will pay you 10 euro"

Laura mowed the lawn

Therefore:

(a) Laura's mother paid her 10 euro

(b) Laura's mother did not pay her 10 euro

(c) Laura's mother may or may not have paid her 10 euro

Our first set of predictions in this experiment concerned promises and our second set of predictions concerned threats. We proposed that when thinking about factual promises (e.g., if you mow the lawn then I will pay you 10 euro) people initially keep just one affirmative possibility in mind (A and B), the possibility mentioned by the speaker in the conditional (e.g., Laura mows the lawn and her mother pays her 10 euro). This information also corresponds to the invited inference for a factual promise as Experiment 1 demonstrated. We expect, therefore, that reasoners will make more affirmative inferences (MP and AC) than negative inferences (MT and DA) from factual promises.

For counterfactual promises (e.g., if you had mowed the lawn then I would have paid you 10 euro) we proposed that reasoners keep in mind two possibilities: an affirmative possibility (A and B) that corresponds to the information mentioned in the conditional and the counterfactual conjecture (e.g., mowed the lawn and paid 10 euro) and also a negative possibility (not A and not B) that corresponds to the presupposed facts of the situation and also the inference that is invited by a counterfactual promise (e.g., did not mow the lawn and was not paid 10 euro). Accordingly we predict that reasoners will make the same amount of affirmative inferences (MP and AC) and negative inferences (MT and DA) from counterfactual promises.

Comparing factual and counterfactual promises we predicted that reasoners would make the same amount of affirmative inferences from both because reasoners keep in mind the affirmative possibility (A and B) from the outset for factual and counterfactual

promises. We also predicted that reasoners would make more negative inferences from counterfactual than factual promises because reasoners keep in mind the negative possibility (not A and not B) from the outset for the counterfactual promise but not the factual promise.

Our second set of predictions concerned threats. For factual threats (e.g., Mary's father said to her "if you hit your sister then I will make you wash the dishes") we suggested that people keep two possibilities in mind from the outset, an affirmative possibility (A and B) corresponding to the information mentioned in the speaker's conditional (e.g., Mary hits her sister and her father makes her wash the dishes) and a negative possibility (not A and not B) corresponding to the speakers intention and the invited inference (e.g., Mary does not hit her sister and her father does not make her wash the dishes). Accordingly, we predicted that there would be no difference in the rates of affirmative and negative inferences that reasoners would make from factual threats because reasoners keep both an affirmative and a negative possibility in mind from the outset.

We have also suggested that people keep in mind two possibilities for counterfactual threats (e.g., Mary's father said to her "if you had hit your sister then I would have made you wash the dishes"), one affirmative possibility (A and B) that corresponds to the counterfactual conjecture (e.g., Mary hit her sister and her father made her wash the dishes) and one negative possibility (not A and not B) that corresponds to the presupposed facts (e.g., Mary did not hit her sister and her father did not make her wash the dishes). Accordingly, we predicted that there would be no differences between the affirmative and negative inferences for counterfactual threats.

Comparing factual and counterfactual threats we predicted that there would be no differences between the groups in the endorsement rates of any of the inferences (MP, AC, MT or DA) because reasoners keep two possibilities in mind (A and B, not A and not B)

for both factual and counterfactual threats.

We also measured the length of time it took reasoners to endorse the inferences in this experiment. Because reasoners keep both an affirmative and a negative possibility in mind for counterfactual promises, counterfactual threats, and factual threats we predicted that the length of time to endorse inferences would not differ between these three types of conditionals. We suggested that reasoners only keep one possibility in mind for factual promises and we therefore expected that reasoners would make the affirmative inferences (MP and AC) more quickly and the negative inferences more slowly (MT and DA) from factual promises than the other conditionals.

A secondary aim of this experiment was to follow up on the issue that arose in Experiment 1 regarding the function of counterfactual inducements and to investigate if they have implications for future behaviour. In Experiment 1 more participants classified negative outcome counterfactual conditionals as threats (67%) than they classified positive outcome counterfactual conditionals as promises (45%). Accordingly we expected that counterfactual threats may have stronger implications for future behaviour than counterfactual promises do. To test this hypothesis we gave participants a prediction task, for example:

> *Gemma's father said to her "if you had put out the rubbish then I would have bought you a new jigsaw"*
>
> Do you think that if Gemma puts out the rubbish tomorrow then her father will buy her a new jigsaw? Please circle your answer
>
> *Yes* *No* *Can't tell*

We predicted that reasoners would indicate 'yes' more often following a counterfactual threat than a counterfactual promise.

A final aim of this experiment was to control for tense. We used two control groups because by comparing factual and counterfactual inducements we were varying two factors: mood and tense. Factual inducements have a present tense antecedent (if you mow the grass...) and a future tense consequent (...then I will pay you 10 euro) and are phrased in the indicative mood. Counterfactual inducements are in the past tense (if you had mowed the grass then I would have paid you 10 euro) and are phrased in the subjunctive mood. The conditionals in the factual control group were all phrased in the past tense indicative mood (e.g., if you mowed the grass then I paid you 10 euro). We expected that there would be no differences between the factual control group and the factual group, because recent research shows that there is no difference in reasoning from indicative conditionals in past, present and future tenses (Schaeken, Schroyens & Dieussaert, 2001). The conditionals in the counterfactual control group were all formed with a present tense antecedent, future tense consequent and in the subjunctive mood (e.g., if you were to mow the lawn then I would pay you 10 euro). We expected no differences between this group and the counterfactual group because recent research shows that there is no difference between past and present subjunctive conditionals (Byrne & Tasso, 1999).

Method

Materials and Design

Participants were randomly assigned to either the factual group or the counterfactual group or one of the two control groups (the factual control group or the counterfactual control group).

The first task participants completed was the inference task. This task consisted of 24 problems in total, 12 promises and 12 threats, which were presented in blocks to control

for order effects. Half the participants received promises first and half the participants received threats first. Each type of inference (MP, MT, DA, AC) was presented three times for both promises and threats (i.e., 4 inferences x 3 repetitions x 2 inducement types (promises/threats) = 24 problems). Although we did not check speaker control we ensured that as with real life inducements all of the conditional statements involved a level of high control by the speaker in that the speaker could carry out the consequence of the action (e.g., give the child money). We also avoided conditionals that could be interpreted as deontic and therefore did not use phrases that could indicate obligation or permission such as "you may", "I will let you", or "you can" (e.g., we did not use promises such as 'if you mind your sister then I will let you go over to your friend's house later').

Participants were advised that they would be given problems based on typical things a parent might say to their child to get them to help with the housework (see Appendix B). Sometimes the parent might threaten the child with chores if they are misbehaving (e.g. being bold or lazy). Other times they might reward them if they are being good and do the housework (e.g., buy them something or take them somewhere fun). The chores were all things that a child could do (e.g., sweep the garden, do the dishes, set the table). To control for content effects, the contents were assigned to the problems at random twice to make two different sets of problems and participants either received conditionals from set 1 or set 2. Chores that were used as the consequents in threats in one set (e.g., if you do not finish your dinner then I will make you mow the grass) were used as antecedents in promises in the second set (e.g., if you mow the grass then I will pay you 10 euro) and vice versa. Also, contents in the second set were not associated with the same inference as in the first set. For example, in set 1 if "mowing the grass" was followed by a DA categorical premise, in the second set it was followed by either an MP, MT or AC inference selected at random. A different child's name was used for each of the 24

problems in the set. There were equal numbers of male and female names and all were familiar Irish names. Half the conditionals were spoken by the child's mother and half by the child's father.

Once the 24 problems were finished participants were then requested to complete the prediction task. This task consisted of two problems: one counterfactual promise and one counterfactual threat (see Appendix B).

Procedure

Participants were tested individually. The 24 problems for the inference task were presented on Macintosh computers using SuperLab 1.75. The instructions were presented on the computer and included a sample problem and three practice problems (based on conjunctions and disjunctions of shapes) to familiarise participants with the task presentation and keyboard response options (see Appendix B). Participants were advised that they could take as long as they needed to complete the task but that they were being timed. Participants pressed the space bar to view each new piece of information (the conditional, the minor premise, the conclusion set), and each remained on screen to be joined by the additional information. The participants pressed one of the keys labelled 'a' 'b' or 'c' to select a conclusion. These keys were in the centre of the keyboard and corresponded to the T, G, & B keys. Once all 24 problems were completed participants were then presented with the booklet containing the implications task and the prediction task. The aims of the study were explained to the participant and any questions were addressed.

Participants

Seventy-five participants were recruited from the University of Dublin's psychology department's participant panel (members of the general public recruited through newspaper advertisements). They were paid 8 euro for their participation. Seven participants were eliminated prior to any analysis; three because they had received training in logic and four because they said they did not understand the task. Of the remaining 68 participants there were 45 women and 23 men. Their average age was 50 years (ranging from 27 to 74 years). Although this mean age is higher that normal for a typical psychology experiment we suggest that the wide range of ages of the members of the general public who participated in the study increases the ecological validity of the experiment. They were assigned at random to the factual group (n = 16), the counterfactual group (n = 19) or one of the two control groups, factual control (n = 17) or counterfactual control (n = 16).

Results and discussion

Inference Task

Inference Endorsement Order Effects

We controlled for order effects by presenting promises and threats in two separate blocks and which block participants received first was counterbalanced. However, to confirm there was no effect of order we conducted a 5 way ANOVA on the factors order (promises or threats first), tense (past, present/future), mood (factual, counterfactual), inducement type (promise, threat) and inference (MP, AC, MT and DA). The results showed that there was no main effect of order ($F(1, 60) = 1.613$, $Mse = 4.402$, $p = .21$) and that it did not interact with any other factors (see Appendix B for these statistics and other non-reliable

order effect statistics). We originally analysed the data in a 4 way ANOVA collapsing the variables tense and mood into one variable 'group' with four levels (past factual, past counterfactual, present/future factual and present/future counterfactual). However, we later decided that having two variables, tense and mood, would provide a more appropriate and complete analysis of the data.

Inference Endorsements

An ANOVA was carried out on the endorsements of conclusions with tense (past and present/future) and mood (indicative and subjunctive) manipulated as between participant factors and inducement (threat and promise) and inference (MP, AC, MT, DA) manipulated as repeated within participant factors. The ANOVA showed no main effect of inducement ($F(1, 64) = .17$, $Mse = .14$, $p = .34$[2]), no main effect of tense ($F(1,64) = .33$, $Mse = .90$, $p = .28$), no main effect of mood ($F(1,64) = .16$, $Mse = .45$, $p = .34$), and no main effect of inference ($F(3,192) = .59$, $Mse = .34$, $p = .31$). Inducement did not interact with mood ($F(1, 64) = 2.15$, $Mse = 1.79$, $p = .08$), tense ($F(1,64) = .97$, $Mse = .81$, $p = .16$) or inference ($F(3,192) = 1.19$, $Mse = .62$, $p = .16$). Inference did interact with both mood ($F(3,192) = 6.79$, $Mse = 3.87$, $p < .01$) and tense ($F(3,192) = 4.72$, $Mse = 2.69$, $p = .02$). The four-way interaction between these factors was not reliable ($F(3,192) = .88$, $Mse = .44$, $p = .23$). A series of planned comparisons were conducted to investigate any differences between the groups (see Winer, 1971, for the legitimacy of such comparisons).

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2 Note: Throughout the thesis all reported statistics are 1-tailed and the Greenhouse-Geisser correction is used where necessary for ANOVAs. The Greenhouse-Geisser correction is used when assumptions of sphericity are violated in a repeated measures ANOVA. The correction reduces the degrees of freedom to give a more conservative test, appropriate to the amount of violation.

Promises

The first set of predictions concerned promises. We predicted that reasoners would make more affirmative (MP and AC) than negative (MT and DA) inferences from factual promises because reasoners keep only the affirmative possibility in mind from the outset (A and B). Planned comparisons supported this hypothesis, as Table 2.6 shows. Overall, there was a higher rate of affirmative than negative inferences for factual promises (95% versus 69%, $t\ (15) = 4.28$, $p < .01$[3]). Comparisons of the individual inferences also supported this hypothesis with no difference found between the two affirmative inferences MP and AC (94% versus 96%, $t\ (15) = .37$, $p = .36$) or between the two negative inferences MT and DA (69% versus 69%, $t\ (15) = .00$, $p = .5$). As expected, there were differences however between each of the affirmative inferences and each of the negative inferences (MP versus MT: 94% versus 69%, $t\ (15) = 3.87$, $p < .01$; MP versus DA: 94% versus 69%, $t\ (15) = 2.54$, $p = .01$; AC versus MT: 96% versus 69%, $t\ (15) = 2.93$, $p = .01$; AC versus DA: 96% versus 69%, $t\ (15) = 3.57$, $p < .01$).

For counterfactual promises we predicted that reasoners would keep two possibilities in mind from the outset: an affirmative possibility corresponding to the information in the conditional (A and B) and a negative possibility corresponding to the counterfactual conjecture (not A and not B). Accordingly we expected no differences between the affirmative and negative inferences. However, the results did not support this hypothesis, and instead a tendency opposite to the one shown for factual promises was found. Overall, there were higher rates of the negative inferences than the affirmative inferences from counterfactual promises (86% versus 66%, $t\ (18) = 2.96$, $p < .01$). There were no differences between the two affirmative inferences MP and AC (67% versus 65%,

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3 Note: Throughout the thesis power tests for the planned comparisons are reported in the Appendix for each experiment (e.g., Appendix B for Experiment 2). Unless otherwise mentioned in the text each test has 80% power to detect a difference of .2 or less.

t (18) = .17, p = .44) or between the two negative inferences MT and DA (89% versus 82%, t (18) = 94, p = .18). Other comparisons revealed differences between all the inferences except for between MP and DA for promises (MP versus MT: 67% versus 89%, t (18) = 2.23, p = .02; MP versus DA: 67% versus 82%, t (18) = 1.28, p = .11; AC versus MT: 65% versus 89%, t (18) = 3.24, p < .01; AC versus DA: 65% versus 82%, t (18) = 2.73, p = .01). These findings suggest that reasoners keep only the negative possibility (not A and not B) in mind from the outset. A comparison of factual and counterfactual promises supports this suggestion.

Table 2.6: Percentages of endorsements in Experiment 2

		MP	AC	MT	DA	*Affirmative*	*Negative*
Promises	Factual	94	96	69	69	*95*	*69*
	Counterfactual	67	65	89	82	*66*	*86*
	Factual Control	94	86	76	84	*90*	*80*
	Counterfactual Control	85	81	73	79	*83*	*76*
Threats	Factual	88	77	75	79	*83*	*77*
	Counterfactual	65	68	84	88	*67*	*86*
	Factual Control	86	82	82	76	*84*	*79*
	Counterfactual Control	90	90	88	90	*90*	*89*

Factual Promises versus Counterfactual Promises

The results suggest that for factual promises reasoners keep in mind a single affirmative possibility (A and B) from the outset. For counterfactual promises they appear to keep in

mind a single negative possibility from the outset. In keeping with this observation reasoners endorsed more affirmative inferences (MP and AC) and fewer negative inferences (MT and DA) from factual than counterfactual promises. Comparing between groups for promises revealed that participants made more MP and AC inferences in the factual than the counterfactual group (MP: 94% versus 67%, t (25.49) = 2.42, p = .01, equal variances not assumed; AC: 96% versus 65%, t (22.16) = 3.30, p < .01, equal variances not assumed). They made less MT (69% versus 89%, t (20.70) = 2.41, p = .01, equal variances not assumed). Although the differences between the factual and counterfactual group for DA did not reach significance the trend in the data was in the right direction with less DA in the factual than the counterfactual group (69% versus 82%, t (33)= 1.17, p = .13).

Threats

We suggested that reasoners keep two possibilities (A and B, not A and not B) in mind for factual threats and on this account there should be no differences between the affirmative and negative inferences. The results supported this suggestion, as Table 2.6 shows. For factual threats, as expected, no differences were found between affirmative and negative inferences overall (83% versus 77%, t (15) = 1.00, p = .16). There were also no differences between the two affirmative inferences MP and AC (88% versus 77%, t (15) = 1.05, p = .16) or between the two negative inferences MT and DA (75% versus 79%, t (15) = .70, p = .25). There were no differences between any of the other inferences (MP versus DA: 88% versus 79%, t (15) = 1.07, p = .15; AC versus MT: 77% versus 75%, t (15) = .22, p = .41; AC versus DA: 77% versus 79%, t (15) = .27, p = .40) except for MP and MT (88% versus 75%, t (15) = 2.09, p = .02).

For counterfactual threats, like counterfactual promises, we originally predicted

that there would be no differences between the affirmative and negative inferences. Like counterfactual promises, the results did not support this hypothesis. Instead there were higher rates of negative than affirmative inferences from counterfactual threats (86% versus 67%, t (18) = 2.90, p = .01). There were no differences between the two affirmative inferences MP and AC (65% versus 68%, t (18) = .34, p = .38) or between the two negative inferences MT and DA (84% versus 88%, t (18) = .37, p = .36). Other comparisons revealed differences between all the inferences (MP versus MT: 65% versus 84%, t (18) = 2.36, p = .02; MP versus DA: 65% versus 88%, t (18) = 2.31, p = .01; AC versus DA: 68% versus 88%, t (18) = 2.08, p = .03) except AC versus MT (68% versus 84%, t (18) = 1.41, p = .07) which did not reach significance at the alpha = .05 level. However, as five of the six comparisons were as predicted the results very tentatively suggest that for counterfactual threats, like counterfactual promises, reasoners keep just one negative possibility (not A and not B) in mind from the outset. We tested this observation further by comparing factual and counterfactual threats.

Factual Threats versus Counterfactual Threats

Reasoners keep two possibilities in mind for factual threats, an affirmative and a negative one, but for counterfactual threats they appear to only keep in mind a negative possibility. We therefore examined whether reasoners make more affirmative inferences in the factual group than the counterfactual group. For negative inferences however, we do not expect to find a differences between the groups because reasoners keep a negative possibility in mind from the outset for both. The results supported this suggestion. There were no differences between the groups for MT (75% versus 84%, t (33) = .92, p = .18) or DA (79% versus 88%, t (33) = .92, p = .18). For the affirmative inferences there was a difference between the factual and the counterfactual groups for MP as expected (88%

that there would be no differences between the affirmative and negative inferences. Like counterfactual promises, the results did not support this hypothesis. Instead there were higher rates of negative than affirmative inferences from counterfactual threats (86% versus 67%, t (18) = 2.90, p = .01). There were no differences between the two affirmative inferences MP and AC (65% versus 68%, t (18) = .34, p = .38) or between the two negative inferences MT and DA (84% versus 88%, t (18) = .37, p = .36). Other comparisons revealed differences between all the inferences (MP versus MT: 65% versus 84%, t (18) = 2.36, p = .02; MP versus DA: 65% versus 88%, t (18) = 2.31, p = .01; AC versus DA: 68% versus 88%, t (18) = 2.08, p = .03) except AC versus MT (68% versus 84%, t (18) = 1.41, p = .07) which did not reach significance at the alpha = .05 level. However, as five of the six comparisons were as predicted the results very tentatively suggest that for counterfactual threats, like counterfactual promises, reasoners keep just one negative possibility (not A and not B) in mind from the outset. We tested this observation further by comparing factual and counterfactual threats.

Factual Threats versus Counterfactual Threats

Reasoners keep two possibilities in mind for factual threats, an affirmative and a negative one, but for counterfactual threats they appear to only keep in mind a negative possibility. We therefore examined whether reasoners make more affirmative inferences in the factual group than the counterfactual group. For negative inferences however, we do not expect to find a differences between the groups because reasoners keep a negative possibility in mind from the outset for both. The results supported this suggestion. There were no differences between the groups for MT (75% versus 84%, t (33) = .92, p = .18) or DA (79% versus 88%, t (33) = .92, p = .18). For the affirmative inferences there was a difference between the factual and the counterfactual groups for MP as expected (88%

between the factual group (e.g., if you mow the lawn then I will give you 10 euro) and the counterfactual control group (e.g., if you were to mow the lawn then I would give you 10 euro) as those we found between the factual group and the counterfactual group. However, the results showed no differences in any of the inferences between the factual group and the counterfactual control group (see Appendix B for statistics). We then compared the counterfactual group (e.g., if you had mowed the lawn then I would have given you 10 euro) and the counterfactual control group (e.g., if you were to mow the lawn then I would give you 10 euro) and found differences between them. These differences were similar to the pattern of differences found between the counterfactual group and the factual group (e.g., for promises more negative inferences from counterfactual promises than from factual). These findings were unexpected given that previous research has shown that people reason in a similar manner from past and present tense subjunctive conditionals (Byrne & Tasso, 1999). These results show that the tense of counterfactual conditionals may be influential after all: future tense counterfactuals did not exhibit the same pattern of differences compared to factual conditionals. We explore this topic, the role of tense in reasoning from subjunctive conditionals, in the next chapter.

Inference Endorsement Latencies Order Effects

The latencies were measured for reading the minor premise and endorsing a conclusion. Outliers were removed and the data were log transformed to base e in order to achieve normality and reduce the skewedness of the distribution. To determine effects of order we conducted a 5-way ANOVA on the factors order (promises or threats first), tense (past, present/future), mood (indicative, subjunctive), inducement (promise, threat) and inference (MP, MT, AC, DA). No main effect of order was detected ($F(1, 38) = .79$, $Mse = .72$, $p = .38$) and it did not interact with any other factors (see Appendix B for these statistics and

other non-reliable order effect statistics).

Inference Endorsement Latencies

An ANOVA was carried out on the latencies with tense (past and present/future) and mood (indicative and subjunctive) manipulated as between participant factors and inducement (threat and promise) and inference (MP, AC, MT, DA) manipulated as repeated within participant factors. The ANOVA showed no main effect of inducement ($F(1,36) = .21$, $Mse = .15$, $p = .33$), but there was a main effect of tense ($F(1,36) = 3.35$, $Mse = 1.89$, $p = .04$), and of mood ($F(1,36) = 8.13$, $Mse = 4.38$, $p < .015$). No main effect of inference was found ($F(3,192) = 1.15$, $Mse = .18$, $p = .12$). Inducement did not interact with mood ($F(1,36) = 2.02$, $Mse = 1.48$, $p = .08$), tense ($F(1,36) = .76$, $Mse = .54$, $p = .18$) or inference ($F(3,192) = .81$, $Mse = .01$, $p = .25$). Inference did not interact with either mood ($F(3,192) = 2.16$, $Mse = .13$, $p = .09$) or tense ($F(3,192) = 1.44$, $Mse = 1.73$, $p = .13$). The four-way interaction between these factors was not reliable ($F(3,36) = .71$ $Mse = .08$, $p = .27$). A series of planned comparisons were conducted to investigate any differences between the groups (see Winer, 1971, for the legitimacy of such comparisons).

Factual versus Counterfactual

There were no differences between factual and counterfactual promises in the time taken to endorse any of the inferences (MP: 9.19 versus 9.16, $t(27) = .31$, $p = .38$; MT: 9.37 versus 9.08, $t(30) = 1.01$, $p = .16$; DA: 9.07 versus 9.18, $t(28) = .66$, $p = .26$; AC: 9.19 versus 9.02, $t(29) = .89$, $p = .16$) as Table 2.7 shows.

The same pattern of latencies emerged for factual and counterfactual threats with no differences between the groups in any of the inferences (MP: 8.90 versus 9.16, $t(30) = .49$, $p = .31$; MT: 9.21 versus 9.10, $t(29) = .89$, $p = .19$; DA: 9.12 versus 9.35, $t(31) = .34$, $p =$

.31; AC: 9.05 versus 9.14, t (30) = .08, p = .46).

Table 2.7: Latencies (msec) for reading minor premise and endorsing a conclusion (log transformed to base e) in Experiment 2.

		MP	AC	MT	DA
Promises	Factual	9.19	9.19	9.37	9.07
	Counterfactual	9.16	9.02	9.08	9.18
	Factual Control	9.39	9.35	9.39	9.43
	Counterfactual Control	9.07	9.12	9.40	9.29
Threats	Factual	8.90	9.05	9.21	9.12
	Counterfactual	9.16	9.14	9.10	9.35
	Factual Control	9.56	9.60	9.59	9.42
	Counterfactual Control	9.21	9.26	9.26	9.34

Prediction Task

We hypothesised, based on the findings in Experiment 1, that counterfactual threats (e.g., if you had hit your sister then I would have grounded you) would have an implication for future behaviour more so than counterfactual promises (e.g., if you had mowed the grass

then I would have paid you 10 euro) and the results supported this suggestion (as Table 2.8 shows). When asked if they thought that the outcome of a counterfactual inducement (e.g., paid 10 euro) would still occur tomorrow if the action occurred (e.g., mow the grass) more people indicated 'yes' for a counterfactual threat (32%) than a counterfactual promise (15%). This trend in the data was reversed for the 'no' response: more people indicated that the outcome would not occur tomorrow if the action occurred for a counterfactual promise (22%) than for a counterfactual threat (11%). There was no difference in the number of 'can't tell' responses from counterfactual promises and counterfactual threats (57% versus 63%). A Stuart-Maxwell test, which can measure changes in response options, was conducted to determine if participants gave different answers to counterfactual promises and counterfactual threats (e.g., if a person said 'no' to a counterfactual promise but 'yes' to a counterfactual threat). The test showed that reasoners did give different answers to promises and threats (Stuart Maxwell $x\ (2) = 6.62$, $p < .05$).

Table 2.8: Percentages of responses on the prediction task in Experiment 2

	Yes	No	Can't tell
Threat	32	11	57
Promise	15	22	63

Summary

The results of the inference task supported our predictions for factual promises. We expected that for factual promises reasoners would initially keep just one possibility in mind, the affirmative possibility (A and B), and would make more affirmative than negative inferences and the results supported this prediction. The results from the

counterfactual group were somewhat surprising, however. We expected that people would keep two possibilities in mind from the outset for counterfactual promises (A and B, not A and not B), as they do with neutral contents (e.g., Byrne & Tasso, 1999) but the results did not support this hypothesis. Instead reasoners endorsed more negative than affirmative inferences from counterfactual promises. This finding suggests that they keep one possibility, the *negative* possibility (not A and not B), in mind initially. One explanation for this finding is that the realistic content of inducements used in this study encouraged people to focus on the real or factual event implied by the conditional (not A and not B) rather than on the conjecture mentioned in it (A and B).

For factual threats we hypothesised that people would keep two possibilities in mind from the outset, both an affirmative and a negative one, and in line with this hypothesis we found no differences in the rates of affirmative and negative inferences. However, the inferences reasoners endorsed from counterfactual threats followed a similar pattern to counterfactual promises, that is, reasoners endorsed more negative than affirmative inferences. This finding suggests that reasoners keep just the negative possibility in mind from the outset (not A and not B), again perhaps because they focus on the factual event implied by the conditional.

One final point to note from this experiment is that overall the endorsement rates of all inferences, in all groups, were quite high. The lowest endorsement rate was 65% (MP from counterfactual threats and AC from counterfactual promises). This finding suggests that people may interpret inducements as biconditionals when they fully flesh out the possibilities, that is, people consider only the affirmative (A and B) and negative (not A and not B) possibility to be true; they do not consider the conditional possibility (not A and B) to be true. Given a conditional such as 'if you mow the grass then I will give you 10 euro' reasoners only think about the possibility that the grass is mowed and the child is

paid 10 euro, and the possibility that the grass is not mowed and the child is not paid 10 euro. They do not think about the possibility that the grass is not mowed and the child still gets 10 euro. This suggestion may also explain why there were no differences between the factual and counterfactual groups in the time taken to endorse the inferences from promises or threats. It may be that because inducements are biconditional it is easy to flesh out the implicit possibility if necessary. For example, although reasoners keep the 'A and B' possibility in mind for factual promises initially, it may be easy to flesh out the implicit possibility 'not A and not B' because it is the only implicit possibility. In the next section we consider some studies that have investigated whether or not factual promises and threats are biconditional and we also test how people interpret counterfactual promises and threats.

Experiment 3: What possibilities do reasoners judge to be consistent with promises and threats?

Previous work exploring factual inducements suggests that they are interpreted as biconditional. In a truth table task Newstead, et al. (1997) found that only the 'A and B' and 'not A and not B' situations were selected as true; the 'not A and B' and 'A and not B' situations were judged to be false. This finding supported earlier work by Fillenbaum (1976) who asked participants if the obverse of a proposition follows from it (e.g., does "if you are not bold then you will not be grounded" follow from "if you are bold then you will be grounded"). Participants said it did over 80% of the time. Even when Newstead et al presented scenarios where the likelihood of the outcome occurring without the antecedent was high the participants did not rate the 'not A and B' situation as true. For example, some participants were given a conditional such as 'if you turn up the radio then I will

smack you' and additional information about the parent such as they would punish the child for the slightest thing. Even with this additional information participants did not rate the situation where the child did not turn up the radio and was smacked as true. As Fillenbaum states, "Consider that the inducement q is being offered to get the addressee to do or refrain from doing p. Now precisely insofar as the obtaining or avoiding of q is contingent upon some action with regard to p, the inducement would lose all point or force if that contingency were eliminated." (1976, p. 246). Based on these findings and on the high rates of all inferences in Experiment 2 we suggest that factual inducements may be interpreted as biconditional (i.e., only the 'A and B' and 'not A and not B' possibilities are considered true).

Are counterfactual promises and threats also interpreted as biconditionals? The aim of the third experiment was to investigate this matter. Participants were given the following task and had to decide for each possibility whether it was consistent, inconsistent or irrelevant, with regard to the conditional premise. The participants placed a tick corresponding to their answer in the boxes provided:

The boss said to the employee "if you are late for work then I will fire you"

	Consistent	*Inconsistent*	*Irrelevant*
The employee was late for work and the boss fired him	❑	❑	❑
The employee was late for work and the boss did not fire him	❑	❑	❑
The employee was not late for work and the boss fired him	❑	❑	❑
The employee was not late for work and the boss did not fire him	❑	❑	❑

We predicted that reasoners would not judge the 'A and not B' and 'not A and B'

possibilities as consistent because they are not part of a biconditional representation.

Method

Materials and Design

The materials and design of this experiment were similar to Experiment 2. As in Experiment 2 we constructed four sets of problems, two of which were the experimental conditionals (factual and counterfactual), and the other two were control conditionals (factual control and counterfactual control). Each set of problems contained 6 problems, 3 promises and 3 threats (see Appendix C). Participants were advised they would receive problems based on typical promises or threats that might be said by a parent to a child (e.g. if you are rude then I will give you chores to do), by a schoolteacher to a pupil (e.g., if you are good then I will give you no homework) or by a boss to an employee (e.g., if you forget your uniform then I will dock your pay). The conditionals were designed with similar constraints and controls to those in the previous experiment

Each problem consisted of a conditional premise and four possibilities (A and B, not A and not B, not A and B, A and not B). The possibilities were listed in a different random order for each problem. Once the consistency judgement task was completed the participants were then asked to complete a prediction task for one promise and one threat in order to attempt to replicate the results of Experiment 2.

Procedure

The 8 problems were presented in a booklet. The participants were tested in groups and were told that they would be presented with promises and threats and they would then be

given four sentences about four possible situations that could arise from the statement. They were given an example problem based on an exclusive disjunction (e.g., either there is an A on the board or there is a B on the board but not both), and told that two of the options (corresponding to 'A and not B' and 'not A and B') were consistent and two were not (corresponding to 'A and B' and 'not A and not B'). They were reminded that they could also use the 'irrelevant' option. The experimenter read the instructions aloud which asked participants to complete the problems in the order they were presented in the booklet and not to change any answers or go back to previous problems (see Appendix C). The experimenter answered any questions the participants had and advised participants that they could take as long as they needed to complete the task. Once participants had completed the task they were given a debriefing sheet explaining the aims of the study and any issues were discussed with the experimenter.

Participants

The participants consisted of 63 undergraduate psychology students from Dublin Business School's School of Arts who participated voluntarily. There were 41 women and 22 men. They had no formal training in logic and had not participated in a similar study before. Their average age was 22 years (range from 18 to 32 years). They were assigned at random to the factual (n = 16) or the counterfactual (n = 15) group, or one of the two control groups (factual control (n = 16), counterfactual control (n = 16)).

Results and discussion

Order Effects

We controlled for order effects by presenting promises and threats in two separate blocks

and which block participants received first was counterbalanced. However, to confirm there was no effect of order we conducted a 5 way ANOVA on the factors order (promises or threats first), tense (past, present/future), mood (factual, counterfactual), inducement type (promise, threat) and inference (MP, AC, MT and DA). The results showed that there was no main effect of order ($F(1, 55) = .16$, $Mse = .10$, $p = .69$) and that it did not interact with any other factors (see Appendix C for these statistics).

Consistent Responses

As Table 2.9 shows, participants rarely, if at all, considered the 'not A and B' or 'A and not B' possibilities to be consistent with the conditional statement in all groups, both experimental and control, as we predicted. We conducted an ANOVA on the consistent responses (see Appendix C for inconsistent and irrelevant responses) on the factors tense (past, present/future), mood (indicative, subjunctive), inducement (promise, threat) and possibility (A and B, not A and not B; the other two possibilities were not included in the ANOVA because they were rarely if at all selected as consistent). The ANOVA showed no main effect of inducement ($F(1, 59) = .35$, $Mse = .03$, $p = .28$), a main effect of tense ($F(1, 59) = 2.84$, $Mse = 2.08$, $p = .05$), a main effect of mood ($F(1, 59) = 3.34$, $Mse = 2.45$, $p = .04$), and a main effect of possibility ($F(1,59) = 2.78$, $Mse = 2.80$, $p = .05$). Inducement did not interact with mood ($F(1,59) = .04$, $Mse = .03$, $p = .43$), tense ($F(1,59) = .51$, $Mse = .19$, $p = .09$) or possibility ($F(1, 59) = .02$, $Mse = .03$, $p = .45$). Possibility did not interact with either mood ($F(1, 59) = .31$, $Mse = .311$, $p = .29$) or tense ($F(1, 59) = .46$, $Mse = .46$, $p = .25$). The four-way interaction between these factors was marginally reliable ($F(1, 59) = 2.14$, $Mse = .32$, $p = .08$). A series of planned comparisons were conducted to investigate any differences between the groups (see Winer, 1971, for the legitimacy of such comparisons).

Promises

Participants rarely chose the 'A and not B' and 'not A and B' options which suggests that people did not interpret the promises as conditional but as biconditional, as Table 2.9 shows. Moreover, planned comparisons between the factual and the counterfactual group revealed that reasoners judged the 'A and B' possibility to be consistent more often for a factual than a counterfactual promise (100% versus 80%, t (29) = 1.93, p = .03) but there was no difference between the groups for the 'not A and not B' possibility (92% versus 82%, t (29) = .98, p = .17).

Table 2.9: Percentages of consistent responses in Experiment 3.

		A & B	Not A & not B	Not A & B	A & not B
Promises	Factual	100	92	2	0
	Counterfactual	80	82	0	0
	Factual Control	100	88	2	2
	Counterfactual Control	100	90	0	0
Threats	Factual	98	85	0	0
	Counterfactual	82	80	0	2
	Factual Control	98	94	2	0
	Counterfactual Control	98	90	0	2

Threats

Similar to promises, the 'not A and B' and 'A and not B' possibilities were rarely, if at all, selected as consistent in any of the groups. This result suggests that threats were not

interpreted as conditional, but as biconditional. Planned comparison showed that participants judged the 'A and B' possibility to be consistent more often for a factual than a counterfactual threat (98% versus 82%, t (29) = 1.63; p = .05). There was no difference between the groups for the 'not A and not B' possibility (85% versus 80%, t (29) = .5; p = .31).

Interpretation Patterns

We recoded the data according to the pattern of consistent responses, in order to investigate the combinations of possibilities participants judged as consistent. Participants were considered to have reached a conjunction interpretation if they selected as consistent either the 'A and B' possibility (affirmative conjunction) or the 'not A and not B' possibility (negative conjunction) and no other options. The response was considered a biconditional, two possibility interpretation, if they ticked both 'A and B' and 'not A and not B' and no other options (see Table 2.10).

We conducted an ANOVA on the interpretation patterns on the factors tense (past, present/future), mood (indicative, subjunctive), inducement (promise, threats) and interpretation pattern (total conjunction, biconditional). The ANOVA showed a main effect of inducement (F (1, 59) = 75.00, Mse = 227.88, p < .01), no main effect of tense (F (1, 59) = .47, Mse = .02, p = .25), no main effect of mood (F (1,59) = .53, Mse = .02, p = .24), and no main effect of interpretation pattern (F (1,59) = .00, Mse = .00, p = .5). Inducement interacted with mood (F (1, 59) = 2.97, Mse = 9.03, p = .05), and marginally with tense (F (1,59) = 2.5, Mse = 7.59, p = .06) but not interpretation pattern (F (1,59) = .33, Mse = .14, p = .27). Interpretation pattern did not interact with either mood (F (1, 59) = .00, Mse = .00, p = .5) or tense (F (1, 59) = .00, Mse = .00, p = .5). The four-way interaction between these factors was not reliable (F (1, 59) = .33, Mse = .14, p = .28). A series of planned

comparisons was conducted to investigate any differences between the groups (see Winer, 1971, for the legitimacy of such comparisons).

Promises

In the factual group there were significantly more biconditional responses than total conjunctions for promises (90% versus 8%, $t = 10.93$, $df = 15$, $p < .01$). There were also significantly more affirmative conjunctions than negative conjunctions (8% versus 0%, $t = 2.24$, $df = 15$, $p = .02$). The majority of participants in the counterfactual group also gave a biconditional response to promises (62%). Unlike factual promises however, there was no significant difference between the number of biconditional responses and total conjunction responses (62% versus 37%, $t = 1.01$, $df = 14$, $p = .17$) or between affirmative conjunctions and negative conjunctions (24% versus 13%, $t = 1.82$, $df = 14$, $p = .24$).

Comparing between the factual and the counterfactual groups revealed that there were fewer biconditional responses from counterfactual promises than factual promises (62% versus 90%, $t = 2.15$, $df = 17.02$, $p = .02$, equal variances not assumed) and more total conjunction responses (37% versus 8%, $t = 2.32$, $df = 16.64$, $p = .02$, equal variances not assumed).

Threats

A similar pattern emerged for threats as for promises. There were more biconditional responses than total conjunction interpretation patterns for factual threats (83% versus 17%, $t = 4.47$, $df = 15$, $p < .01$) and also more affirmative conjunctions than negative conjunctions (15% versus 2%, $t = 1.86$, $df = 15$, $p = .04$). Counterfactual threats followed the same pattern as counterfactual promises with no significant difference in the

amount of biconditional and total conjunction responses (62% versus 35%, t = 1.23, df = 14, p=.12) and affirmative conjunctions and negative conjunctions (22% versus 13%, t = .62, df = 14, p = .27).

Comparing the factual threats and the counterfactual threats showed that there were fewer biconditional responses from the counterfactual group (83% versus 62%, t = 1.62, df = 25.29, p = .06, equal variances not assumed) and more total conjunction responses (17% versus 35%, t = .1.42, df = 24.89, p = .08, equal variances not assumed).

Table 2.10: Interpretation patterns of consistent responses in Experiment 3.

		Affirmative Conjunction	Negative Conjunction	*Total Conjunction*	Biconditional
Promises	Factual	8	0	*8*	90
	Counterfactual	24	13	*37*	62
	Factual Control	10	0	*10*	85
	Counterfactual Control	10	0	*10*	90
Threats	Factual	15	2	*17*	83
	Counterfactual	22	13	*35*	62
	Factual Control	6	2	*8*	90
	Counterfactual Control	10	2	*13*	85

Comparisons with Control Groups

Tables 2.9 and 2.10 show that the possibilities judged as consistent and the interpretation patterns were similar for the factual group, the factual control group, and the counterfactual control group. All of these groups differed in similar ways from the counterfactual group

(see Appendix C for statistics). As in Experiment 2, possibilities selected in the counterfactual control group were more similar to the factual groups than the counterfactual groups, once again raising a question about whether tense plays a role in reasoning from subjunctive conditionals, to which we will return to in the next chapter.

Prediction Task

The results of the prediction task replicated those in Experiment 2. Reasoners gave different answers to counterfactual promises and counterfactual threats (Stuart-Maxwell $x = 14.28$, $df = 2$, $p < .00$). Table 2.11 shows that participants thought that a threat was more likely to be carried out tomorrow than a promise ("yes": 48% versus 21%) while a promise was more likely not to be carried out than a threat ("no": 25% versus 6%).

Table 2.11: Percentages of responses in the prediction task in Experiment 3

	Yes	No	Can't tell
Threat	48	6	46
Promise	21	25	54

Summary

The results of this experiment provide evidence that factual inducements are interpreted as biconditional, that is, people consider only the 'A and B' and 'not A and not B' possibilities to be true. The majority of participants selected these possibilities as consistent for both a promise (90%) and a threat (83%). This finding is consistent with previous studies (e.g., Newstead et al, 1997; Fillenbaum, 1976). Most of the remaining

participants interpreted the factual inducements as a conjunction, that is, they considered only the 'A and B' possibility to be true.

It seems that when the possibilities are laid out in front of people, as in this task, there is no difference between factual promises and factual threats. People indicate that the same possibilities are consistent for both promises and threats, the affirmative possibility (A and B) and the negative possibility (not A and not B). We predicted that when reasoning people keep both of these possibilities in mind from the outset for factual threats but just the affirmative possibility in mind from the outset for factual promises. The inferences people drew in Experiment 2 supported this prediction.

Why were there no differences between factual promises and threats in this experiment? We suggest the reason may be because it is easy to flesh out the implicit negative possibility for factual promises because there is only one implicit possibility to flesh out (because people interpret factual promises as a biconditionals as opposed to conditionals, for example). Also, when the possibility is presented to the participants, as in this task, rather than the participants having to construct it themselves, as in the inference task, participants may find it easy to judge the 'not A and not B' possibility as consistent with a factual promise.

The results of this experiment also showed that the majority of people interpret counterfactual inducements as biconditionals, and again there was no difference between promises (62%) and threats (62%). However, the case does not seem to be as clear-cut as with factual inducements. In the counterfactual group, for both promises and threats, a significant minority of reasoners arrived at a conjunction interpretation, either keeping in mind just the affirmative possibility (A and B) or the negative possibility (not A and not B). For example, given a counterfactual promise such as 'if you had mowed the lawn then I would have paid you 10 euro' a significant minority of people only kept in mind the

situation where the lawn was mowed and the child was paid 10 euro, or the situation where the lawn was not mowed and the child was not paid 10 euro. They did not keep both of these possibilities in mind. However, the majority of people interpreted counterfactual inducements as a biconditional.

Previous research, using neutral, causal and definitional content (e.g., Byrne & Tasso, 1999; Thompson & Byrne, 2002), has found that there are differences in how people interpret counterfactual conditionals, with some people focusing on the affirmative situation (the conjecture mentioned in the conditional) and others focusing the negative situation (the presupposed facts implied by the conditional). The results of this experiment are consistent with the findings that a minority of individuals interpret counterfactual conditionals as consistent with a single possibility.

General Discussion

The aim of the three experiments reported in this chapter was to investigate the role of content, specifically inducement content, in reasoning from counterfactual conditionals. The remainder of this section summarises the findings of the experiments, first for promises and then for threats. Finally, it considers the implications of these results for other theories of conditional reasoning.

Summary

Experiment 1 examined the inferences that factual and counterfactual promises and threats invite. Considering promises first, the results showed that *factual promises* (e.g. if you mow the lawn then I will pay you 10 euro) invite an inference to the truth of the antecedent (e.g., you will mow the lawn) (95%) as we expected. We suggested this invited inference

encourages reasoners to keep in mind a single affirmative possibility (e.g., mow the lawn and paid 10 euro) from the outset for a factual promise. The results of experiment 2 supported this suggestion: reasoners endorsed more affirmative than negative inferences from factual promises (95% versus 69%). Experiment 3 demonstrated that the majority of people interpret factual promises as biconditionals (90%), that is, they judge only the possibilities 'Laura mowed the lawn and received 10 euro' and 'Laura did not mow the lawn and did not received 10 euro' to be consistent with the conditional. Because reasoners interpret factual promises as biconditional the negative possibility (not A and not B) is easily fleshed out.

We expected that *counterfactual promises* (e.g., if you had mowed the lawn then I would have paid you 10 euro) would invite an inference to the falsity of the antecedent (e.g., you did not mow the lawn) and the results of Experiment 1 supported this hypothesis (84%). We then suggested that reasoners would keep both the affirmative possibility (mow the lawn and paid 10 euro) and the negative possibility (do not mow the lawn and not paid 10 euro) in mind when thinking about counterfactual promises. The results of experiment 2, however, suggested that reasoners just keep the negative possibility in mind from the outset for counterfactual promises: reasoners endorsed more negative than affirmative inferences from counterfactual promises (86% versus 66%). Also, the comparison of counterfactual and factual promises revealed that reasoners endorsed less affirmative (66% versus 95%) and more negative (86% versus 69%) inferences from counterfactual than factual promises. Finally, experiment 3 showed that although the majority of reasoners interpret counterfactual promises as biconditionals (62%) a significant minority only considered a single possibility (35%) to be consistent with a counterfactual promise, more so than in the factual group.

Turning to threats, Experiment 1 revealed that *factual threats* (e.g., if you hit your

sister then I will ground you) invite an inference to the falsity of the antecedent (92%), as we predicted. We suggested that this invited inference would encourage reasoners to keep two possibilities in mind from the outset when thinking about factual threats: an affirmative possibility corresponding to the information in the threat (e.g., hit sister and grounded) and a negative possibility corresponding to the invited inference (e.g., do not hit sister and not grounded). We tested this hypothesis in Experiment 2 using an inference task. The results supported our hypothesis: there were no differences in the rates of affirmative (83%) and negative (77%) inferences from factual threats. This finding is in contrast to the finding that reasoners endorse more affirmative than negative inferences from factual promises. In Experiment 3, the consistency judgment task, the results showed that factual threats are interpreted as biconditionals by the majority of participants (83%).

Experiment 1 showed that *counterfactual threats* (e.g., if you had hit your sister then I would have grounded you) invite an inference to the falsity of the antecedent (90%), as expected. Like counterfactual promises, we expected that reasoners would keep two possibilities in mind from the outset for counterfactual threats (e.g., hit sister and be grounded, do not hit sister and not grounded) but the inferences that reasoners drew in Experiment 2 did not support this suggestion. Reasoners endorsed more negative (86%) than affirmative (67%) inferences from counterfactual threats, suggesting that reasoners just keep a single negative possibility in mind from the outset for counterfactual threats, similar to counterfactual promises. Experiment 3 showed that, like counterfactual promises, counterfactual threats are interpreted as biconditionals by the majority of participants (62%) but that a significant minority only consider a single possibility to be consistent with the conditional (33%).

Overall, the results of the experiments tend to support the idea that people understand and reason differently from factual promises and threats. Our findings support

the suggestion that reasoners initially keep a single affirmative possibility in mind (A and B) from the outset for factual promises but two possibilities in mind (A and B, not A and not B) from the outset for factual threats. This idea has not been explored before and previous research has often focused more on comparing reasoning from promises and threats to other types of contents (e.g., advice) rather than to each other (e.g., Newstead *et al.*, 1997; Evans & Twyman-Musgrove, 1998; Ohm & Thompson, 2004). The results presented here demonstrate the importance of conversational pragmatics and the inferences that conditional assertions invite (for example threats invite an inference to the falsity of the antecedent: not A) rather than just the information mentioned in the conditional (A and B).

For counterfactual promises and threats, overall, the results show that reasoners initially keep in mind a single negative possibility (e.g., not A and not B) from the outset for both types of conditional. One suggestion is that reasoners focus on the negative possibility because it refers to the presupposed factual situation that is implied by the counterfactual conditional to have actually happened (e.g., Thompson & Byrne, 2002). Perhaps the use of a realistic content such as inducements encourages people to focus more on what actually happened (not A and not B) rather than on the counterfactual conjecture (A and B).

The experiments reported in this chapter also explored the function of counterfactual inducements and the role they may play in conversation. Promises and threats are typically phrased with a present tense antecedent and a future tense consequent and their function is to manipulate the future behaviour of the hearer by rewarding or punishing an action or non action (e.g., if you are bold then I will ground you). However, counterfactual promises and threats cannot directly manipulate future behaviour because they are in the past tense and the action or non-action is presupposed to have already taken

place (e.g. if you had been bold...). Although counterfactual inducements are in the past tense, it appears that they may still play a role in influencing the future actions of the hearer, and this effect seems to be slightly stronger for counterfactual threats than promises.

Experiment 1 showed that even though the inducements were phrased in the past tense participants still classified them as promises (45%) or threats (67%) rather than as neither. In Experiment 2 we asked participants directly if they thought the consequence of the action would still occur if the hearer took the action tomorrow. For example, participants were given a conditional such 'if you had been bold then I would have grounded you' and were then asked if they thought that the child would still be punished if they were bold tomorrow. The majority of people said they could not tell whether or not the child would still be punished tomorrow and there was no difference in the rates between promises (63%) and threats (57%). However, for a threat a sizeable minority (32%) thought that the child would be punished if they were bold tomorrow, twice as many as thought that the child would still be given a reward tomorrow in the case of a counterfactual promise (15%, e.g., if you had mowed the lawn then I would have paid you 10 euro). Experiment 3 replicated these findings with again twice as many participants believing that the consequence (e.g., being grounded in the case of a threat and paid 10 euro in the case of a promise) would occur tomorrow if the antecedent occurred for a threat (48%) rather than for a promise (21%). Based on these findings it seems that counterfactual inducements, especially threats, do have some role to play in influencing future behaviour.

It may be that in uttering a counterfactual threat (e.g., if you had been bold then I would have grounded you) a parent wants to draw a child's attention to what nearly happened (e.g., being grounded) in case the child does not realise the potential outcome of

being bold. The uttering of a counterfactual threat suggests that there was some situation in which the child could have been good or bold, and in the end was good (i.e., not bold), otherwise the parent would not mention the conditional 'if you had been bold then I would have grounded you'. The parent, however, may be uncertain about whether or not the child will be good in another situation and therefore utters the counterfactual threat to draw the child's attention to being grounded if they are bold. The aim of this utterance may be to serve as a warning to the child in a future situation.

A similar account may be provided for counterfactual promises (e.g., if you had mowed the lawn then I would have paid you 10 euro) although our experiments suggest that their influence on future behaviour is not as strong as counterfactual threats. It may be that counterfactual promises serve as a general guide to future behaviour (e.g., be good and you will be rewarded) rather than as a specific instruction (e.g., if you mow the grass tomorrow then I will pay you 10 euro). The utterance of a counterfactual promise also suggests that the desirable behaviour has already not occurred and that there was no reward (e.g., the child did not mow the grass and was not paid 10 euro). It may be that a parent's aim when uttering a counterfactual promise is to draw the child's attention to the missed opportunity, or perhaps to make them feel guilty about not helping out with chores for example. The negative feelings of regret and guilt might make the child more likely to help out in future.

The finding that counterfactual threats have stronger implications for future behaviour than counterfactual threats is somewhat in contrast to the findings of Verbrugge et al. (2004). They found that people are more likely to accept a promise than a threat with an excessive consequent. The discrepancy between these results may be explained by the possibility that in real life when a counterfactual threat is uttered it is the second time that the person has heard the content of the threat (e.g., bold and grounded) and it reinforces the

first threat. The counterfactual promises may carry less weight however because both the speaker and the hearer know that a mistake has already been made.

Implications of findings for other theories of conditional reasoning

The experiments in this chapter were guided by the mental model theory and the findings are consistent with this perspective. In this section we consider the implications of the findings for other theories of conditional reasoning.

The formal inference rules theories of reasoning (e.g., Braine & O'Brien, 1991; 1998; Rips, 1994) suggest that people reason by constructing proofs using an internal set of abstract general-purpose rules as we saw in Chapter 1. These logic-like rules can be applied to any area of knowledge because all that is important for reasoning is the form of the problem. The form of promises and threats is the same (i.e., if A then B) and therefore formal inference rule theories should predict that there would be no difference between them in reasoning. Our results do not support this prediction. For example, reasoners endorsed more affirmative inferences than negative inferences from factual promises but the same amount of affirmative inferences and negative inferences for factual threats. The formal inference rule theory cannot account for these effects of content on reasoning.

Another difficulty formal rule theories may have with our results is in relation to our findings with counterfactual promises and counterfactual threats. Reasoners endorsed more negative than affirmative inferences from both counterfactual promises and counterfactual threats. For example, reasoners endorsed more MT than MP. This finding is particularly problematic for formal inference rule theories such as Braine and O'Brien's (1991) theory. Their theory suggests that reasoners usually endorse more MP than MT inferences (e.g., for a review see Schroyens et al 2000; Evans et al, 1993) because reasoners are said to have a rule for MP but not to have a rule for MT. In order to make the

MT inference reasoners have to take an indirect route involving a number of steps, as described in Chapter 1. Accordingly, the formal rule theory cannot explain why reasoners make more MT than MP inferences given a conditional of the form 'if A then B'.

Domain specific rule theories (e.g., Holyoak & Cheng, 1995; Fiddick, et al, 200) have been applied to promises because promises may be considered a type of social contract in that both the hearer and the speaker gain from the exchange and they both agree to it. For example, given a conditional such as 'if you mow the lawn then I will pay you 10 euro' the speaker gains by having someone else mow the lawn and the speaker gains because they get 10 euro. As such, a promise can activate a permission or obligation schema (Cheng & Holyoak, 1985) depending on whether the perspective of the reasoner is as hearer or speaker (Politzer & Nguyen-Xuan, 1992). For example, the hearer of the promise would feel that if they have mowed the lawn then the speaker is obliged to pay the 10 euro. The speaker of the promise similarly might think that if the hearer has mowed the lawn then they are permitted to claim the 10 euro. Perspective effects have been demonstrated using the Wason selection task (e.g., Politzer & Nguyen-Xuan, 1992). However, participants were not cued to take the perspective of the speaker or the hearer in the experiments reported in this chapter. If reasoners had taken the perspective of the speaker or the hearer then one hypothesis, derived from the domain-specific view, is that they should have kept in mind the possibility of the hearer not mowing the lawn and still getting the 10 euro. Keeping this possibility in mind reduces the number of invalid inferences, DA and AC, as described in Chapter 1, but we found that the rates of DA and AC were high.

Domain specific rule theories do not make any predictions regarding the role of mood in conditional reasoning even though previous research shows it to be an important factor in reasoning (e.g., Byrne & Tasso, 1999). Our experiments showed that systematic

differences in reasoning arose because of the mood of the conditional even though the content was the same. For example, factual promises invited an inference to the truth of the antecedent and reasoners made more affirmative than negative inferences. Counterfactual promises on the other hand invited an inference to the falsity of the antecedent and reasoners made more negative than affirmative inferences. The only difference between the factual and counterfactual conditionals was the mood: indicative or subjunctive. Domain-specific theories cannot explain this result.

Domain-specific theories may also have a problem explaining counterfactual promises. For example, although they are uttered in the present situation (e.g., a parent speaking to a child) counterfactual promises refer to past behaviour (e.g., if you had mowed the lawn then I would have paid you 10 euro). Can they still be considered a social contract in this situation? We suggest that the answer is no. As the events have already taken place neither party can agree to, or benefit from, the situation mentioned in the conditional. Furthermore, even if the action takes place in the future, for example the child mows the lawn next week, is the parent still *obliged* to give them 10 euro? We suggest that they are not.

Probabilistic theories of reasoning suggest that people make choices that maximise the information available to them while trying to reduce uncertainty about situations (e.g., Oaksford & Chater, 1994, 2003). Inducements have not been investigated by probabilistic theorists. However, Ohm and Thompson (2004) asked participants to rate the probability of B occurring given A, on a 7-point scale. For example, participants were given a conditional such as 'if you attract new clients, you will get promoted' and asked how likely it is that you will be promoted if you attract new clients. Higher ratings on the 7-point scale indicated higher perceived probability. The results showed that participants thought it was very likely that you will be promoted if you attract new clients (mean = 5.55), that is B will

occur given A. Participants also indicated for threats that there was a high probability of the punishment occurring if the action occurred (mean = 5.26). Despite these high ratings of probability however, this factor was not an important predictor of the inferences reasoners drew in a later task. This finding may pose a problem for probabilistic theories because a key factor for their explanation of inference patterns is the probability of B given A. Furthermore, although Ohm and Thompson (2004) do not report statistics comparing between the probability ratings of promises and threats, it appears the difference between them, if there is one, is small (5.55 versus 5.26). It is unlikely that such a small difference in probability would be sufficient to produce the very distinct patterns of inferences that we observed for factual promises and threats in Experiment 2.

Conclusion

Our exploration of inducements in this chapter has provided the first account of counterfactual promises and threats and shows that people keep similar possibilities in mind for both, based on what is presupposed by the conditional (i.e., not A and not B). We have also provided an account of factual promises and threats and have shown that the value of the outcome of the conditional leads to different invited inferences which can influence the possibilities reasoners keep in mind. For factual promises reasoners seem to initially keep just an affirmative possibility in mind (A and B) but for factual threats they keep both an affirmative and a negative possibility in mind (A and B, not A and not B) from the outset. The experiments were designed to test predictions derived from the mental model theory and the results were consistent with it. We also considered how alternative theories of conditional reasoning might interpret some of our findings and found these other theories could not explain the results.

As so many of our judgements and decisions to act in everyday life are based on

whether or not the outcome will be beneficial or detrimental to us these findings may have important implications for how people reason on a daily basis. In the next chapter we pursue the issue of tense that arose in experiments 2 and 3. We explore the role of tense in reasoning from subjunctive conditionals next.

Chapter 3: The Role of Tense in Reasoning from Subjunctive Conditionals

In the previous chapter we examined how content influences reasoning from counterfactual conditionals and the results of experiments 2 and 3 raised a question regarding the role of tense in reasoning from subjunctive conditionals. The aim in this chapter is to investigate if tense modulates the possibilities people keep in mind for subjunctive conditionals. We focus on future tense subjunctive mood conditionals, which are called prefactual conditionals, which have not been considered before (e.g., if it were to rain tomorrow then Jonathan would bring an umbrella).

The role of tense in conditional reasoning has been relatively neglected until recently. Much conditional reasoning research has focused on conditionals in the present tense indicative mood (e.g., Evans, 1977; Thompson, 1994). Some studies have considered conditionals in the past tense, in both the indicative and subjunctive moods (e.g., Byrne & Tasso, 1999), but very few have considered how people reason from future tense conditionals (e.g., if it rains tomorrow then Jonathan will bring an umbrella). The study of future tense conditionals is important because hypothetical thought is a key characteristic of human endeavour. The ability to plan and speculate is essential for political and social advancement (e.g., if we vote for good candidates in the next election then the country will be better off) as well as scientific discovery (Johnson-Laird & Byrne, 1991).

Recent work shows that there is no difference in how people reason from conditionals in the indicative mood in the past tense (e.g., if it rained then Jonathan brought an umbrella), the present tense (e.g., if it rains then Jonathan brings an umbrella) and the future tense (e.g., if it rains tomorrow then Jonathan will bring an umbrella) (Schaeken, Schroyens & Dieussaert, 2001). Schaeken et al found no differences in the rates of inferences drawn from conditionals in the different tenses. Their findings suggest that

regardless of tense people initially keep just one possibility in mind for indicative conditionals. They keep in mind the possibility that corresponds to the information mentioned in the conditional (e.g., rain and Jonathan bringing an umbrella).

But what about conditionals in the subjunctive mood? Do people initially keep two possibilities in mind for subjunctive conditionals regardless of whether they are in the past, present or future tense? We suggest that the answer to this question is no. Previous research has shown that there is no difference in reasoning from past (e.g., if it had rained then Jonathan would have brought an umbrella) and present subjunctive conditionals (e.g., if it were to rain then Jonathan would bring an umbrella). For both, reasoners seem to keep two possibilities in mind, the conjecture and the presupposed facts. Accordingly, they make more negative inferences (MT and DA), but the same amount of affirmative inferences (MP and AC), from past and present subjunctive conditionals when compared to indicative ones (Byrne & Tasso, 1999).

Although two possibilities are kept in mind initially for past and present subjunctive conditionals we propose that people will at first only keep one possibility in mind for future subjunctive conditionals (e.g., rain and Jonathan bringing an umbrella). We predict that reasoning from future subjunctive conditionals will be similar to reasoning from future indicative conditionals. Unlike past and present subjunctive conditionals, future subjunctive conditionals do not convey any presupposed facts (e.g., that it will not rain tomorrow and that Jonathan will not bring an umbrella) and people will therefore not keep this possibility in mind from the outset (see Table 3.1 for a summary of the initial possibilities kept in mind for past, present and future tense conditionals in the indicative and subjunctive moods).

Table 3.1: The initial possibilities kept in mind for past, present and future tense conditionals in the indicative and subjunctive moods.

		Tense		
		Past	Present	Future
Mood	Indicative	A B ...	A B ...	A B ...
	Subjunctive	A B not A not B ...	A B not A not B ...	A B ...

The experiments in the last chapter provided some tentative support for the hypothesis that people only keep one possibility in mind for future subjunctive conditionals. The results of experiments 2 and 3 showed that people reasoned from present tense antecedent/future tense consequent subjunctive promises and threats (e.g., if you were to hit your sister then I would ground you) in a manner more similar to present tense antecedent/future tense consequent indicative promises and threats (e.g., if you hit your sister then I will ground you) than to past subjunctive promises and threats (e.g., if you had hit your sister then I would have grounded you). However, it is difficult to draw any definite conclusions from these findings because promises and threats are not pure future tense conditionals. Although they refer to future actions and the consequent is clearly in the future tense (e.g., I will ground you) the antecedent is in the present tense (e.g., if you hit your sister). However, the phrase 'if you hit your sister' could be followed by the word 'now', placing it in the present tense, or by the word 'tomorrow', placing it in the future tense. These

linguistic markers are needed to clarify whether the phrase is in the present or future tense. They are required in languages such as English which do not have markers built into the verb, unlike other languages such as Spanish. To avoid this problem all of the conditionals used in the experiments in this chapter contain the linguistic marker "tomorrow" to clarify that the conditional is in the future tense (e.g., if it were to rain tomorrow then Jonathan would bring an umbrella).

In summary, the aim in this chapter is to investigate future subjunctive conditionals, which have not been examined before. They are important to our understanding of hypothetical thought and conditional reasoning because when people generate hypotheses or predictions about the future often they are in the 'uncertain' subjunctive mood (e.g., if it were to rain tomorrow then Jonathan would bring an umbrella). We expect that reasoning from future subjunctive conditionals will be similar to reasoning from future indicative conditionals because people should keep in mind just one possibility for both. We also predict that reasoning will differ for future and past subjunctive conditionals because people keep in mind just one possibility for the former but two possibilities for the latter. We test these predictions in three experiments which use tasks that have previously differentiated reasoning from indicative and subjunctive conditionals in the past and present tenses (e.g., Byrne & Tasso, 1999; Thompson & Byrne, 2002). The first type of task we turn to is a consistency judgment task.

Experiment 4: What situations do people judge to be consistent with prefactual conditionals?

The aim of this experiment was to examine the possibilities that reasoners judge to be consistent with future subjunctive conditionals and to measure the response latencies for

these consistent judgements. Each problem consisted of a conditional premise, e.g., 'if Linda were in Cork tomorrow then Cathy would be in Galway', followed by one of four possibilities and participants had to judge for each one if it was consistent, inconsistent or irrelevant with regard to the conditional:

Linda was in Cork and Cathy was in Galway.

Linda was not in Cork and Cathy was not in Galway.

Linda was not in Cork and Cathy was in Galway.

Linda was in Cork and Cathy was not in Galway.

Our first set of predictions concerned past versus future tense conditionals. In this experiment we examined future and past tense subjunctive conditionals and we compared them to future and past tense indicative conditionals. We have suggested that reasoners keep in mind a single possibility to understand future subjunctive conditionals but two possibilities for past subjunctive conditionals. Accordingly we predicted that reasoners would rate the 'not A and not B' possibility (e.g., Linda was not in Cork and Cathy was not in Galway) as consistent more often with the past subjunctive than the future subjunctive conditional because this possibility is explicitly represented in the initial set of possibilities for the past but not the future subjunctive conditional. We did not expect to find a difference between the past and future subjunctive conditionals for the affirmative 'A and B' possibility (e.g., Linda was in Cork and Cathy was in Galway) because it should be explicitly represented for both tenses from the outset. Previous research (including Experiment 3 in Chapter 2) has shown that people rarely select the 'not A and B' and 'A and not B' possibilities as consistent (e.g., Thompson & Byrne, 2002) and we expected the same pattern in this study. For indicative conditionals, unlike subjunctive conditionals, we expected no differences between the past and future tenses in consistent ratings of any of

the possibilities because reasoners should keep a single possibility in mind for both (Schaeken *et al.*, 2001).

Our second set of predictions concerned indicative versus subjunctive mood. We did not expect to find a difference between future indicative and future subjunctive conditionals because we expected that reasoners would initially keep a single possibility (A and B) in mind for both. We did, however, predict that we would find a difference in the number of consistent ratings of the negative possibility 'not A and not B' comparing past indicative and past subjunctive conditionals. Past subjunctive conditionals convey presupposed facts which correspond to the information in the negative possibility (not A and not B) but past indicative conditionals do not convey this information. We therefore expected no difference for the affirmative possibility but more consistent ratings for the negative possibility following past subjunctive than past indicative conditionals.

This experiment also measured latencies for possibilities selected as consistent. Based on the possibilities people keep in mind we expected no differences in response latencies for any of the possibilities for future subjunctive, future indicative and past indicative conditionals because people should keep in mind just one possibility, an affirmative one, for each of them. We predicted that there would be a difference between past subjunctive conditionals and the other conditionals because people keep two possibilities in mind from the outset, an affirmative and a negative one, for past subjunctive conditionals. People should be able to judge the "not A and B" possibility to be consistent more quickly for past subjunctive conditionals.

Method

Materials and design

All of the future tense conditionals we used contained the linguistic marker 'tomorrow' and were of neutral content. We used three sorts of neutral content which involved people using certain ingredients (e.g., if Evan uses fennel tomorrow, then Martin will use lettuce), being in certain locations (e.g., if Rosanna is in Dublin tomorrow, then Anthony will be in Wicklow) and doing certain actions (e.g., if David jumps tomorrow then Gary will run) (see Appendix D).

We gave one group of participants a set of problems based on indicative conditionals, and the other group received subjunctive conditionals. Each set contained 24 problems, 12 in the past tense and 12 in the future tense, which were presented to the participants in blocks. The order of presentation was counterbalanced to control for order effects and half the participants received the block of past tense conditionals first and the other half received the future tense conditionals first. Each possibility (A and B, not A and not B, not A and B, A and not B) was presented once for each content (i.e. 4 possibilities x 3 contents = 12 problems). To control for content effects, the contents were assigned to the problems at random twice to make two different sets of problems.

Participants

The participants were 46 undergraduate psychology students from the University of Dublin, Trinity College, who took part voluntarily in return for course credits. They had not received any prior training in logic or taken part in a reasoning study before. There were 33 women and 13 men and their average age was 20 years (range 18-27 years).

Procedure

The participants were tested individually or in groups of two or three participants. The 24

problems were presented on Macintosh computers using SuperLab 1.75. The instructions were presented on the computer and included an example problem and three practice problems (based on conjunctions and disjunctions of shapes) to familiarise them with the task presentation and keyboard response options (see Appendix D). Participants were advised they could take as long as they needed but that they were being timed. Participants pressed the space bar to view each new piece of information (the conditional, the possible situation, and the consistency judgement), and each remained on screen to be joined by the additional information. They pressed one of the keys labelled 'a' 'b' or 'c' to indicate their judgement. These keys were in the centre of the keyboard and corresponded to the T, G, and B keys.

Results and discussion

Consistent Responses

Order Effects

Tense was manipulated within-participants so that participants received both past and future tense conditionals. To control for order effects in the experiment we counterbalanced the tense that participants received first. Before analysing the data to test our predictions we checked that there was no effect of order by conducting an ANOVA on the factors order (past or future tense conditionals first), mood (indicative, subjunctive), tense (past, future) and possibility (A and B, not A and not B, not A and B, A and not B). The results showed that there was no main effect of order ($F(1,42) = .05$, $Mse = .05$, $p = .82$) but that there was a three way interaction between order, tense and mood ($F(1,42) = 4.95$, $Mse = .86$, $p = .03$). None of the other interactions were reliable (see Appendix D for

these statistics and other non-reliable order effect statistics for this experiment).

The data file was split to compare the conditionals that were received in the first block ('first block data set') with those conditionals received in the second block ('second block data set'). A series of comparisons were carried out between the first block data set and the second block data set to determine where the order effects had occurred. However, despite the significant interaction between order, tense and mood none of the comparisons were statistically significant for any of the individual possibilities (e.g., A and B). As the pattern of first block data set did not differ from the pattern of the overall data set the overall data set was used to test our predictions.

Consistent Responses

We analysed the overall data set in an ANOVA on the possibilities that participants selected as 'consistent' (see Appendix D for the inconsistent and irrelevant responses). The factors were group (indicative, subjunctive), tense (future, past) and possibility (A and B, not A and not B, not A and B, A and not B), with repeated measures on the last two factors. The ANOVA showed a main effect of possibility ($F(1.38,60.78) = 213.42$, Mse = 175.15, $p < .01$ but none of tense ($F(1,44) = 1.36$, Mse = .27, $p = .13$), or group ($F(1,44) = .53$, Mse = .53, $p = .24$). Tense interacted with group ($F(1,44) = 3.49$, Mse = .70, $p = .03$) but not with possibility ($F(1.77,77.78) = 1.01$, Mse = .31, $p = .18$). Group and possibility also did not interact ($F(3,132) = .40$, Mse = .33, $p = .38$). To test our predictions we carried out a series of planned comparisons on the non-significant three-way interaction ($F(3,132) = 1.03$, Mse = .19, $p = .19$).

Table 3.2: Percentages of judgements of possibilities as 'consistent' in Experiment 4

		A and B	not A & not B	A & not B	not A & B
Future	Indicative	99	57	1	3
	Subjunctive	94	55	3	6
Past	Indicative	99	55	0	1
	Subjunctive	99	67	0	12

Tense: Future versus Past

Planned comparisons of the past and future subjunctive conditionals revealed that participants judged the 'not A and not B' possibility to be consistent more often for the past tense than for the future tense as we predicted, although the 12% difference failed to reach significance (67% versus 55%, t (22) = 1.62, p = .06). This marginal result provides only weak support for our hypothesis that reasoners initially keep just one possibility in mind for future subjunctive conditionals, but two possibilities in mind for past subjunctive conditionals. Further studies will be required to investigate the difference between past and future subjunctive conditionals for the 'not A and not B' possibility. As we predicted, there were no other differences between past and future subjunctive conditionals for 'A and B' (99% versus 94%, t (22) = 1.41, p = .13), 'not A and B' (12% versus 6%, t (22) = 1.16, p = .13), and 'A and not B' (0% versus 3%, t (22) = 1.45, p = .08).

As expected, there was no difference in participants' consistent responses for 'not A and not B' for past and future indicative conditionals (55% versus 57%, t (22) = .23, p = .41), unlike the subjunctive conditionals. There were also no reliable differences between past and future indicative conditionals for the comparisons of 'A and B' (99% versus 99%, t (22) = .00, p = .5), 'not A and B' (1% versus 3%, t (22) = 1.00, p = .16), and 'A and not B' (0% versus 1%, t (22) = 1.00, p = .16). These findings support the idea that people

initially keep in mind just one possibility, an affirmative one, for indicative conditionals regardless of tense. This comparison also extends Schaeken *et al.*'s finding, that there is no difference in reasoning from indicative conditionals, from an inference task to a consistency judgement task.

Mood: Subjunctive versus Indicative

We predicted that reasoners would keep the same possibility (A and B) in mind for future subjunctive conditionals as future indicative conditionals and the results supported this hypothesis. Participants judged the 'not A and not B' option to be consistent as often for the future subjunctive as for the future indicative conditional (55% versus 57%, t (44) = .12, p = .45) and there were also no differences for 'A and B' (99% versus 94%, t (29.68) = 1.17, p = .18, equal variances not assumed), 'not A and B' (1% versus 3%, t (44) = .23, p = .26), and 'A and not B' (3% versus 6%, t (44) = .59, p = .28). These results corroborate our suggestion that a single affirmative possibility is kept in mind initially for future conditionals regardless of whether they are phrased in the subjunctive or indicative mood.

Our final comparisons examined the differences between past subjunctive and past indicative conditionals. We expected that participants would judge the 'not A and not B' option to be consistent more often for the subjunctive than the indicative past conditional. The trend in the data supported this prediction (67% versus 55%) but the difference between the groups was not statistically significant (t (42.27) = .90, p = .19, equal variances not assumed). There was no difference between the indicative and subjunctive groups for the 'A and B' (99% versus 99%, t (44) = .00, p = .5) and 'A and not B' options (0% versus 0%) and a marginal difference for 'not A and B' (12% versus 1%, t (44) = 1.61, p = .06, equal variances not assumed).

Latencies for Consistent Responses

Order Effects

Although we counterbalanced the presentation of the past tense and future tense conditionals we checked that there was no effect of order on the latencies for consistent judgements by conducting an ANOVA on the factors order (past or future tense conditionals first), mood (indicative, subjunctive), tense (past, future) and possibility (A & B, not A & not B, not A & B, A & not B). The results showed that there was no main effect of order ($F(1,21) = .18$, $Mse = .23$, $p = .68$) and it did not interact with any other factors (see Appendix D).

Latencies

We conducted an ANOVA on the latencies for the possibilities that participants considered consistent with regard to the conditional premise. The time to judge whether a possibility was consistent was measured as the time to read the possibility and make the judgement. As we only examined the possibilities people judged as consistent we were able to analyse only the log transformed latencies of the 'A and B' and 'not A and not B' possibilities because so few participants considered the 'not A and B' and 'A and not B' possibilities to be consistent. The ANOVA showed that there was no main effect of mood ($F(1,23) = .02$, $Mse = .02$, $p = .44$), tense ($F(1,23) = .01$, $Mse = .01$, $p = .46$) or possibility ($F(1,23) = .41$, $Mse = .26$, $p = .27$). Mood did not interact with tense ($F(1,23) = .36$, $Mse = .32$, $p = .28$) or possibility ($F(1,23) = .11$, $Mse = .07$, $p = .37$) and tense and possibility did not interact ($F(1,23) = 1.16$, $Mse = .74$, $p = .15$). The three-way interaction between tense, mood and possibility was not significant ($F(1,23) = .72$, $Mse = .45$, $p = .20$).

Table 3.3: Latencies in msec (log transformed to the base e) of possibilities selected as consistent in Experiment 4

		A & B	not A & not B	A and not B	not A & B
Past	Indicative	8.21	8.49	-	10.12
	Subjunctive	8.28	8.58	-	9.10
Future	Indicative	8.31	8.50	-	9.95
	Subjunctive	8.47	8.34	8.74	8.73

Tense: Past versus Future

For the subjunctive group, participants made the consistency judgement more quickly for the past than the future conditionals for the 'A and B' possibility (8.28 msec versus 8.47 msec, $t(23) = 1.92$, $p = .03$). This finding is somewhat surprising because we predicted, and our prediction was corroborated, that reasoners keep in mind two possibilities for past subjunctive conditionals but one for future subjunctive conditionals. Reasoners should have therefore been quicker for future than past subjunctive conditionals but they were not. There was no difference between the past and future subjunctive conditional for 'not A and not B' (8.58 msec versus 8.34 msec, $t(14) = .75$, $p = .23$).

For the indicative conditionals, there was no difference in the time taken to make consistency judgements for past and future conditionals, for 'A and B' (8.21 msec versus 8.31 msec, $t(20) = 1.16$, $p = .13$) and 'not A and not B' (8.49 msec versus 8.50 msec, $t(9) = .52$, $p = .31$). These findings are consistent with Schaeken et al's findings and support the hypothesis that reasoners keep in mind one possibility for indicative conditionals regardless of tense.

Mood: Indicative versus Subjunctive

For the future conditionals, we expected that there would be no difference between the indicative and subjunctive groups in the time to judge possibilities as consistent. This prediction was supported for both 'A and B' (8.31 msec versus 8.47 msec, $t(43) = 1.03$, $p = .15$) and 'not A and not B' (8.50 msec versus 8.34 msec, $t(31) = .75$, $p = .35$).

For the past tense conditionals there were also no differences between the indicative and subjunctive groups for 'A and B' (8.21 msec versus 8.28 msec, $t(43) = .60$, $p = .28$), and 'not A and not B' (8.49 msec versus 8.58 msec, $t(30) = 47$, $p = .32$). Given that reasoners keep two possibilities in mind for past subjunctive conditionals but only one possibility for past indicative conditionals the finding that there is no difference in latencies is unexpected. It is, however, in keeping with the results of the consistent responses. We expected that reasoners would judge the 'not A and not B' possibility as consistent more often following a past subjunctive than a past indicative conditional. Although the trend was in the right direction the difference failed to reach significance.

Summary

This experiment provides two main results. Firstly, the results of this experiment extend Schaeken et al's findings that there is no difference in reasoning from past and future indicative conditionals. Our results showed that there was no difference between the tenses for indicative conditionals in the number of consistent ratings or the time taken to make these judgements for any of the possibilities. Secondly, the results support our suggestion that people keep just one possibility in mind initially for future tense conditionals, regardless of whether they are phrased in the indicative or subjunctive mood. There was no difference between future subjunctive and future indicative conditionals in the number of

consistent judgements for any of the possibilities or in the time taken to make these consistent judgements. The evidence supports our suggestion that people keep the same possibility in mind (A and B) for past indicative, future indicative and future subjunctive conditionals.

We also hypothesised that reasoners would keep two possibilities in mind (A and B, not A and not B) for past subjunctive conditionals. We predicted that the negative possibility would be rated as consistent more often following a past subjunctive conditional than a past indicative or a future subjunctive conditional. Although neither of the comparisons reached statistical significance at the .05 level the trends in the data supported this suggestion. One possible explanation is that the content of the conditional did not encourage a counterfactual interpretation. Previous research has shown that reasoners are more likely to make a counterfactual interpretation of a causal or a definitional content conditional than of a neutral content conditional (Thompson & Byrne, 2002). Also, in Experiment 3 in the last chapter, consistent ratings of the negative possibility for counterfactual promises and threats were at least 80% whereas they only reached 67% in this experiment.

The next experiment investigated if greater differences arise between past and future subjunctive conditionals using an inference task, than were demonstrated using a consistency judgement task in this experiment.

Experiment 5: Do reasoners draw difference inferences from past and future subjunctive conditionals?

The aim of this experiment was to examine the inferences reasoners draw from future subjunctive conditionals. Once again we examined past and future subjunctive

conditionals, and compared them to past and future indicative conditionals. We gave participants a task of the following sort:

If Linda were in Cork tomorrow then Cathy would be in Galway.

Cathy was not in Galway.

What, if anything, follows?

Therefore

(a) Linda was in Cork

(b) Linda was not in Cork

(c) Linda may or may not have been in Cork.

Our first set of predictions concerned past and future tense conditionals. Because reasoners initially keep in mind a single affirmative possibility (A and B) to understand a future subjunctive conditional but two possibilities for a past subjunctive conditional, an affirmative and a negative one (A and B, not A and not B), we predicted that reasoners would make more negative inferences (MT and DA) from the past subjunctive conditional than from the future subjunctive conditional but the same amount of affirmative inferences for both (MP and AC). We did not expect any differences in any of the inferences comparing past and future indicative conditionals because reasoners keep a single affirmative possibility in mind for both (A and B).

Our second set of predictions concerned indicative and subjunctive conditionals. We did not expect to find any differences between the indicative and subjunctive groups for future conditionals because again we hypothesised that reasoners would initially keep one possibility in mind for both (A and B). In contrast, we did expect a difference in negative inferences (MT and DA), but not in affirmative inferences (MP and AC) for past indicative conditionals versus past subjunctive conditionals. We expected that reasoners

would make more negative inferences from the past subjunctive than indicative conditionals because they keep the negative possibility in mind from the outset for the past subjunctive.

We expected no differences in latencies to endorse any of the inferences from future subjunctive, future indicative and past indicative conditionals because reasoners keep one possibility in mind initially for all of the conditionals. We expected the past subjunctive conditional latencies to differ from the other conditionals because reasoners have to keep an extra possibility in mind (not A and not B).

Method

Materials and design

The materials and design were similar to the previous experiment, but the task was different. Each problem consisted of a conditional and a categorical premise corresponding to MP (Linda was in Cork), AC (Cathy was in Galway), DA (Linda was not in Cork), or MT (Cathy was not in Galway). We gave one group subjunctive conditionals and the other indicative conditionals. Each set contained 24 problems, 12 in the past tense and 12 in the future tense (see Appendix E). The same sorts of contents were used as in the previous experiment, and similar controls for content assignment and order were employed.

Procedure

The procedure was also similar to the previous experiment. Once again, the problems were presented on a Macintosh computer using SuperLab 1.75. Participants pressed the space bar to view each new piece of information (the conditional, the minor premise, the

conclusion set), and each remained on screen to be joined by the additional information. The instructions advised participants that they were being timed but to work at their own pace (see Appendix E).

Participants

The participants were 40 members of the University of Dublin's psychology department's participant panel (members of the general public recruited through newspaper advertisements). They were paid 8 euro for their participation. There were 29 women and 11 men and their average age was 54 years (range from 27 to 74 years). Age details were not available for 2 participants. None of the participants had previously taken part in a reasoning study or had prior training in logic.

Results and discussion

Inference Endorsements

Order Effects

As in Experiment 4 to control for order effects we counterbalanced the presentation of the within participant factor tense so that half the participants received past tense conditionals first and half received future tense conditionals first. We conducted an ANOVA on the factors order (past or future tense conditionals first), mood (indicative, subjunctive), tense (past, future) and inference (MP, MT, DA and AC). The ANOVA showed that there was no main effect of order ($F(1,36) = .59$, $Mse = .43$, $p = .73$) and it did not interact with any of the other factors (see Appendix E for the non-significant order effect statistics).

Inference Endorsements

We analysed the results in an ANOVA on the endorsements with the between-participant factor of mood (indicative, subjunctive) and the within-participant factors of tense (future, past) and inference (MP, MT, DA and AC). It showed a main effect of inference ($F(3,114) = 17.81$, $Mse = 20.35$, $p < .01$) but none of tense ($F(1,38) = .01$, $Mse = .01$, $p = .46$), or mood ($F(1,38) = .37$, $Mse = 1.25$, $p = .27$). Tense did not interact with mood ($F(1,38) = .79$, $Mse = .80$, $p = .19$) or inference ($F(2.20,83.75) = .33$, $Mse = .20$, $p = .37$). Mood and inference did not interact ($F(3,114) = .66$, $Mse = .75$, $p = .29$). To test our predictions we carried out planned comparisons on the non-significant three-way interaction ($F(3,114) = .30$, $Mse = .13$, $p = .41$).

Tense: Past versus Future

The past and future subjunctive conditionals showed no differences in the endorsement rates of the affirmative inferences as expected: MP (98% versus 95%, $t(19) = 1.00$, $p = .17$), and AC (73% versus 75%, $t(19) = .21$, $p = .42$). We predicted that there would be more negative inferences from the past than future subjunctive conditionals, and although the 10% difference between the groups for MT was in the predicted direction, it was not statistically significant, for MT (73% versus 63%, $t(19) = 1.06$, $p = .15$), or DA (57% versus 57%, $t(19) = .00$, $p = .5$).

We expected no differences between past and future indicative conditionals because people keep one possibility in mind for both. This prediction was corroborated: past and future indicative conditionals showed no differences in the endorsement rates for any of the inferences, MP (92% versus 95%, $t(19) = .70$, $p = .25$), AC (72% versus 73%, $t(19) = .25$, $p = .40$), MT (53% versus 57%, $t(19) = .36$, $p = .36$), and DA (55% versus 62%, $t(19) = .66$, $p = .26$). This result replicates earlier findings (Schaeken *et al.*, 2001)

and is consistent with the results of the previous experiment.

Mood: Subjunctive versus Indicative

As we expected, participants did not make more negative inferences from future subjunctive than future indicative conditionals: MT (57% versus 63%, t (38) = .51, p = .31) and DA (62% versus 57%, t (38) = .39, p = .35). There were also no differences for MP (95% in both cases, t (38) = .00, p = .50), and AC (73% and 75%, t (38) = .14, p = .44). This finding is consistent with the results of the consistency judgement task and supports our suggestion that reasoners keep the same possibility in mind (A and B) for future conditionals whether they indicative or subjunctive.

Table 3.4: Percentages of conclusions endorsed in Experiment 5

		MP	AC	MT	DA
Past	Indicative	92	72	53	55
	Subjunctive	98	73	73	57
Future	Indicative	95	73	57	62
	Subjunctive	95	75	63	57

In contrast, participants tended to make somewhat more of the negative inferences from past subjunctive than past indicative conditionals at least for MT, as Table 3.4 shows. However, the result for MT was only marginally reliable (73% versus 53%, t (38) = 1.51, p = .07), and there was no difference for DA (57% versus 55%, t (38) = .12, p = .45). Again, this finding is consistent with the results of experiment 4. The trend in the data supported the hypothesis that reasoners keep two possibilities in mind for past subjunctive but only one possibility for past indicative, but the difference between the groups did not reach

significance. Unexpectedly, participants made less MP from past indicative conditionals than past subjunctive conditionals and this difference was reliable (98% versus 92%, t (28.05) = 1.80, p = .04). There was no difference for AC (72% versus 73%, t (38) = .14, p = .46).

Latencies of Inference Endorsements

Order effects

We checked that there was no effect of order on the latencies for inference endorsements by conducting an ANOVA on the factors order (past or future tense conditionals first), mood (indicative, subjunctive), tense (past, future) and inference (MP, MT, DA, AC). The results showed that there was no main effect of order (F (1, 36) = 2.18, Mse = 3.63, p = .15) and that it did not interact with any other factors (see Appendix E for statistics).

Latencies

The data were analysed in an ANOVA on the latencies log-transformed to the base e, on the factors of mood (indicative, subjunctive), tense (future, past) and inference (MP, AC, MT, DA), with repeated measures on the last two factors. There was no main effect of mood (F (1, 16) = .00, Mse = .00, p = .48) but there was of tense (F (1, 16) = 5.20, Mse = .91, p = .02) and inference (F (3, 48) = 10.03, Mse = 1.45, p < .01). Mood did not interact with tense (F (1, 16) = .10, Mse = .01, p = .38) or inference (F (3, 48) = 1.74, Mse = .25, p = .09) and tense and inference did not interact (F (3, 48) = 2.12, Mse = .14, p = .06). The three-way interaction between mood, tense and inference was not significant (F (3, 48) = .83, Mse = .05, p = .24).

Tense: past and future

For the subjunctive conditionals, participants took longer to make to make the MP inference from the future tense than the past tense (9.15 msec versus 8.98 msec, t (19) = 2.38, p = .01). This is consistent with the finding in Experiment 4 that reasoners took longer to judge the 'A and B' possibility as consistent following a future than a past subjunctive conditional. Reasoners also took longer to make the DA inference from future than past conditionals (9.32 msec versus 9.02 msec, t (11) = 2.32, p = .02). It may be that because the future conditional does not convey any presupposed facts it is more difficult to keep possibilities in mind for future tense conditionals and therefore reasoners take longer to endorse some inferences. There was no difference in the response times for AC (9.40 msec versus 9.31 msec, t (14) = 1.44, p = .09) or MT (9.43 msec versus 9.45 msec, t (13) = .66, p = .26).

Table 3.5: Latencies in msec (log transformed to the base e) for conclusions endorsed by participants in Experiment 5 (followed by the standard error of the mean in brackets)

		MP	AC	MT	DA
Indicative	Past	8.99 (.14)	9.16 (.20)	9.44 (.19)	9.33 (.17)
	Future	8.95 (.09)	9.44 (.14)	9.56 (.17)	9.52 (.15)
Subjunctive	Past	8.98 (.13)	9.31 (.15)	9.45 (.15)	9.02 (.16)
	Future	9.15 (.11)	9.40 (.13)	9.43 (.17)	9.32 (.16)

The results of the indicative group support this suggestion. Participants took longer to make three of the four inferences from the future than the past conditionals, for DA (9.52 msec versus 9.33 msec, t (11) = 2.37, p = .02), MT (9.56 msec versus 9.44 msec, t (11) = 1.59, p = .07), and AC (9.44 msec versus 9.16 msec, t (16) = 1.46, p = .08) but not MP

(8.95 msec versus 8.99 msec, t (19) = .28, p = .39).

Mood: Indicative versus Subjunctive

The pattern of latencies for future conditionals was broadly consistent with the pattern of inference endorsements which found no differences between the indicative and subjunctive groups. Although participants took slightly longer to make MP from the subjunctive than indicative conditional (9.15 msec versus 8.95 msec, t (38) = 1.50 p = .07), this finding was marginal, and there were no other differences between the groups: DA (9.32 msec versus 9.52 msec, t (29) = .95, p = .18), MT (9.43 msec versus 9.56 msec, t (28) = .55, p = .29), and AC (9.40 msec versus 9.44 msec, t (32) = .21, p = .42).

For the past conditionals there were no differences between the groups for MT (9.45 msec versus 9.44 msec, t (28) = .03, p = .49), AC (9.31 msec versus 9.16 msec, t (31) = .58, p = .28) and MP (8.98 msec versus 8.99 msec, t (38) = .06, p = .48). Although there was no difference in the endorsement rates of DA, participants endorsed DA marginally more quickly from past subjunctive than indicative conditionals (9.02 msec versus 9.33 msec, t (26) = 1.39, p = .09).

Summary

This experiment provides two main results. First, with regard to the comparison of past and future indicative conditionals, the results indicate there are few differences between them in the inferences reasoners endorse, although there are differences in the length of time it takes to make the inferences. There were no differences between the past and future indicative conditionals in the inferences participants made, replicating Schaeken et al's findings. But participants took longer to make most of the inferences from future indicative

and subjunctive conditionals perhaps because they do not imply anything. We return to this point in the next experiment.

The second main result of this experiment is with regard to the comparison of future indicative and subjunctive conditionals. There were no differences in the inferences participants endorsed, and only a small difference in the length of time it took them to make the inferences (they took longer to make MP from a future subjunctive). This finding supports our suggestion that reasoners keep the same possibility (A and B) in mind for future indicative and subjunctive conditionals.

The experiment also replicated previous findings for past subjunctive conditionals (e.g., Byrne & Tasso, 1999). Participants made somewhat more negative inferences, at least for MT (and perhaps surprisingly more MP inferences), and they made the DA inference slightly more quickly from the past subjunctive conditional than the past indicative conditional. Although these results are only marginally significant previous studies have found the difference to be somewhat labile (Byrne & Tasso, 1999) perhaps because neutral content does not evoke a counterfactual interpretation as often as causal or definitional content (Thompson & Byrne, 2002). Nonetheless the results are broadly consistent with earlier findings that participants make more negative inferences from past subjunctive conditionals compared to past indicative conditionals (Byrne & Tasso, 1999; Thompson & Byrne, 2002). More importantly, the results show that reasoners do not make more negative inferences from future subjunctive conditionals compared to future indicative conditionals.

Overall, the results of the experiment are broadly consistent with our suggestion that reasoners keep two possibilities in mind for past subjunctive conditionals but only a single possibility in mind to understand future subjunctive, future indicative and past indicative conditionals. The results also showed that people take longer to reason from

future than past conditionals. We suggest this result may arise because future conditionals do not convey presupposed facts and we test this hypothesis in the next experiment using an implications task.

Experiment 6: What, if anything, do future conditionals imply?

Experiments 4 and 5 showed that people do not reason differently from future indicative and future subjunctive conditionals and we suggest they initially keep a single possibility in mind for both. However, these studies only used conditionals with neutral content about people in locations, using ingredients and doing actions. People may sometimes think about these kinds of relations in everyday reasoning, but they may also think about other sorts of relations. In this experiment we investigated what future conditionals imply, if anything, and we examined fantasy-type realistic contents, e.g., 'if I were to win the lottery tomorrow I would buy a yacht', as well as more neutral contents, e.g., 'if Ciara were in Athlone tomorrow then Maria would be in Limerick'. We gave participants a task of the following sort:

If I were to win the lottery tomorrow then I would buy a yacht.

What if anything do you think is implied by this sentence?

Please tick as many options as you think appropriate.

We provided them with a range of options:

(a) I will win the lottery tomorrow

(b) I will not win the lottery tomorrow

(c) I will buy a yacht

(d) I will not buy a yacht

(e) Nothing is implied

Participants were allowed tick as many options as they wished. As in Experiments 4 and 5 we did not expect to find any difference between the future indicative and subjunctive groups. We predicted that the majority of participants would indicate that nothing was implied by future conditionals because we suggest that future conditionals do not convey any presupposed facts in the way past subjunctive conditionals do. This experiment is the first experiment to investigate what future conditionals imply. However, previous studies that have used an implications task (Thompson & Byrne, 2002) have found that the majority of people indicate that nothing is implied for present indicative conditionals. We also hypothesised that participants would indicate that nothing was implied by the future conditionals regardless of whether the conditional was about neutral content or more realistic content.

Method

Materials and design

Participants were given 6 problems, 3 based on neutral contents about actions, ingredients and locations, and 3 based on realistic contents: 'if I were to win the lottery tomorrow then I would buy a yacht', 'if I were to die tomorrow, then my family would have enough life insurance ', and 'if I were to become a film star tomorrow then I would move to Hollywood' (see Appendix F). The two kinds of contents were presented in blocks with half of the participants receiving on form of content first and the rest of the participants the other kind first. The problems within each block were presented in a different random order to each participant. The options were presented in a random order for each problem

with the exception that 'nothing is implied' was always last.

We gave one group of participants an indicative set, based on future indicative conditionals (e.g., 'if I win the lottery tomorrow then I will buy a yacht'), and the second group received a subjunctive set based on future subjunctive conditionals)e.g., 'if I were to win the lottery tomorrow then I would buy a yacht').

Procedure

The problems were presented in a booklet. The participants were tested in groups and the experimenter read the instructions aloud (see Appendix F) and answered any questions the participants had. Participants were advised they could take as long as they needed to complete the task but that they should complete the problems in the order they were presented and not to change their answers. Once all of the booklets were collected a debriefing sheet was given to each participant and any issues were discussed.

Participants

The participants were 79 undergraduate psychology students from Dublin Business School's School of Arts who participated voluntarily. There were 63 women and 16 men and their average age was 26 years, ranging from 18 to 41 years. They were assigned at random to the indicative group (n = 43) or the subjunctive group (n = 36). They had no prior training in logic and had not participated in a reasoning study before.

Results and discussion

Order effects

Participants received both neutral and realistic content and to control for order effects in the experiment we counterbalanced the type of content that participants received first. However, to confirm there was no effect of order we conducted an ANOVA on the factors order (neutral or realistic content first), mood (indicative, subjunctive), content (neutral, realistic) and possibility (A, B, not A, not B, nothing implied). The results revealed that there was a main effect of order ($F(1, 75) = 4.18$, $Mse = 4.53$, $p = .04$) and that there was a three way interaction between order, content and possibility ($F(4, 300) = 9.16$, $Mse = 4.083$, $p < .01$). None of the other interactions were reliable (see Appendix F for these statistics and other non-reliable order effect statistics).

We investigated these order effects further by comparing the possibilities selected in the first block data set with those possibilities selected in the second block data set. As the order effects were minimal (only 3 out of a possible 20 cells differed significantly) and the pattern of the first block data set did not differ to the pattern of the overall data set we used the overall data to test our predictions as it consisted of the full sample of participants (see Appendix F for further details).

Implications

We examined the results in an ANOVA with the between-participant factor of mood (indicative, subjunctive) and the within-participant factors of content (neutral, realistic) and possibility (A, B, not A, not B, nothing implied). The ANOVA showed main effects of both content ($F(1, 77) = 8.50$, $Mse = 2.72$, $p = .01$) and possibility ($F(1.56, 119.98) = 62.44$, $Mse = 206.688$, $p < .01$), but not of group ($F(1,77) = 1.61$, $Mse = 1.79$, $p = .10$). There was a reliable interaction of content and possibility ($F(1.65, 127.36) = 3.93$, $Mse = 4.72$, $p = .01$), but group did not interact with content ($F(1, 77) = .09$, $Mse = .03$, $p = .38$) or possibility ($F(4, 308) = .64$, $Mse = .82$, $p = .32$). To test our predictions we carried out

planned comparisons on the non-significant three way interaction ($F(4, 308) = .05$, $Mse = .02$, $p = .50$, see Winer, 1971 for the legitimacy of such comparisons).

Content: Neutral versus Realistic

We predicted that there would be no difference between realistic and neutral contents because we expected that the majority of participants would indicate 'nothing is implied' for the future conditionals. The majority of participants did indicate that nothing was implied by the future subjunctive conditionals and there was no difference between the contents as we expected (68% versus 59%, $t(35) = 1.18$, $p = .12$). However, a difference arose between the contents for the 'A' option as Table 3.6 shows. For the future subjunctive conditionals participants indicated that 'A' was implied more often for neutral content (e.g., Ciara will be in Athlone tomorrow) than realistic content (e.g., I will win the lottery tomorrow) (26% versus 13%, $t(35) = 2.17$, $p = .02$) although there were no other differences between the contents for the other options (not A, 16% versus 12%, $t(35) = .94$, $p = .18$; B, 33% versus 31%, $t(35) = .26$, $p = .40$; not B, 8% versus 10%, $t(35) = .53$, $p = .30$)

A similar pattern emerged for the indicative group. The only difference found between the realistic and neutral contents was that participants tended to judge that 'A' was implied more often for neutral than for realistic content (22% versus 5%, $t(42) = 3.52$, $p < .01$) and there were no differences between the contents in the selection rates of the other options (not A, 9% versus 6%, $t(42) = .77$, $p = .22$; B, 28% versus 26%, $t(42) = .27$, $p = .39$; not B, 5% versus 6%, $t(42) = .27$, $p = .39$; nothing implied, 73% versus 64%, $t(42) = 1.48$, $p = .07$). Again, the 'nothing is implied' option was selected most often for both contents (69%) as we predicted.

The results show that for both indicative and subjunctive future tense conditionals

reasoners judge that a neutral content such as 'if Ciara were in Athlone tomorrow then Maria would be in Limerick' implies 'Ciara will be in Athlone tomorrow' more often than they judge a realistic content such as 'if I were to win the lottery tomorrow then I would buy a yacht' implies 'I will win the lottery tomorrow'. Perhaps participants found it easier to imagine someone being in a particular location tomorrow than someone winning the lottery, the odds of which are small.

Mood: Subjunctive versus Indicative

As we predicted, the judgements of what the conditional implies were very similar for the indicative and subjunctive groups. For the realistic content conditionals there were no differences between the indicative and subjunctive groups in the selection rates of the options (A, 5% versus 13%, t (54.42) = 1.32, p = .10, equal variances not assumed; not A, 9% versus 16%, t (55.03) = 1.17, p = .12, equal variances not assumed; B, 28% versus 33%, t (77) = .83, p = .20; not B, 5% versus 8%, t (77) = .71, p = .24; nothing implied, 73% versus 68%, t (77) = .64, p = .26).

Table 3.6: Percentages of options selected as implied in Experiment 6

		A	B	Not A	Not B	Nothing Implied
Indicative	Realistic	5	28	9	5	73
	Neutral	22	26	6	6	64
	Total	*14*	*27*	*7*	*6*	*69*
Subjunctive	Realistic	13	33	16	8	68
	Neutral	26	31	12	10	59
	Total	*19*	*32*	*14*	*9*	*63*

The same pattern was found comparing between the groups for neutral content. There were no differences in the selection rates between indicative and subjunctive conditionals for any of the options: (A, 22% versus 26%, t (77) = .49, p = .31; not A, 6% versus 12%, t (51.62) = 1.13, p = .13, equal variances not assumed; B, 26% versus 31%, t (77) = .55, p = .29; not B, 6% versus 10%, t (77) = .77, p = .22; nothing implied, 64% versus 59%, t (77) = .57, p = .29).

We also classified participants' responses as indicating an 'affirmative-possibility' interpretation when they chose the options corresponding to 'A' or 'B' or both (and no other option), and we classified them as having a 'negative-possibility' interpretation when they chose the options corresponding to 'not A' or 'not B' or both (and no other option) (see Thompson & Byrne, 2002). They were classified as having correctly answered 'nothing is implied' if they selected only that option and the majority of participants' judgements corresponded to this option (64%), as we predicted. Most of the remainder were 'affirmative-possibility' interpretations (22%). As we expected there were very few interpretations in the 'negative-possibility' category (6%) providing support for our suggestion that future subjunctive conditionals do not convey any presupposed facts (not A and not B) unlike past subjunctive conditionals.

Table 3.7 shows that the interpretations were similar for indicative and subjunctive conditionals and for neutral and realistic contents. The high percentage of judgements that 'nothing is implied' for future indicative conditionals (66%) is similar to the high percentage of such judgements for past indicative conditionals in other studies (54% in Experiment 1, Thompson & Byrne, 2002). The equally high percentage of judgements that 'nothing is implied' for future subjunctive conditionals (63%) is quite different from the percentage of such judgements for past subjunctive conditionals (30% in Experiment 1,

Thompson & Byrne, 2002).

Table 3.7: Percentages of affirmative, negative and nothing implied interpretations in Experiment 6

		Affirmative Possibility	Negative Possibility	Nothing Implied
Indicative	Realistic	23	9	62
	Neutral	22	3	69
	Overall	*22*	*6*	*66*
Subjunctive	Realistic	24	9	58
	Neutral	20	2	67
	Overall	*22*	*5*	*62*

Summary

The main finding of this experiment is that judgements of what future subjunctive conditionals imply are similar to judgements about what indicative conditionals imply, therefore more similar to judgements about what indicatives imply than as found in previous studies. The results of this experiment corroborate our view that people initially keep in mind one possibility to understand future conditionals regardless of whether the conditionals are phrased in the indicative (e.g., 'if I win the lottery tomorrow then I will buy a yacht') or subjunctive mood (e.g., 'if I were to win the lottery tomorrow then I would buy a yacht'). For both moods in the future tense people keep in mind the possibility of winning the lottery and buying a yacht. This finding for future subjunctive conditionals is different to findings with past subjunctive conditionals which convey the presupposed negated antecedent and consequent (Thompson & Byrne, 2002). Unlike a past subjunctive

conditional (e.g., if I had won the lottery then I would have bought a yacht) reasoners do not keep in mind the negative possibility, 'I do not win the lottery and I do not buy a yacht'.

General discussion

It is surprising that future tense conditionals have been relatively neglected by researchers of conditional reasoning and that prefactual (future subjunctive) conditionals have not been studied before. Thinking about the future and considering future possibilities is important for cognitive processes such as planning and decision making. The remainder of this section summarises the findings of the three experiments reported in this chapter and considers the implications of the findings for other theories of conditional reasoning.

Summary of findings

The first experiment in this series showed that reasoners judge the same sorts of possibilities to be consistent with a prefactual and future indicative conditional. For both types of conditional the participants typically selected the 'A and B' and 'not A and not B' possibilities as consistent, and they considered the 'not A and B' and 'A and not B' possibilities as not consistent or irrelevant. A similar pattern of consistent judgements occurred for the counterfactual conditionals but with the important exception that the negative possibility (not A and not B) tended to be judged as consistent with a counterfactual more often than a prefactual or a past indicative conditional. We predicted this result given that the counterfactual conditional presupposes the 'not A and not B' possibility and that people keep it in mind from the outset.

The second experiment in this series showed that reasoners make the same

frequency of inferences from a prefactual as from a future indicative and they do not make more of the negative inferences from prefactual conditionals, whereas they showed some tendency to do so for counterfactual conditionals. The third experiment showed that reasoners judged that someone uttering a prefactual means to imply the same thing as someone uttering a future indicative conditional. For both types of conditional the majority of people indicated that nothing was implied. This finding is consistent with the idea that the prefactual conditional does not convey any presupposed facts unlike a counterfactual conditional.

The three experiments presented in the chapter provide three main results. Firstly, they replicate Schaeken *et al.*'s (2001) finding that people do not reason differently for past and future indicative conditionals. Secondly, the findings of the experiments support our suggestion that people keep in mind the same possibility initially (A and B) to understand a prefactual as they do to understand the corresponding future indicative conditional. Thirdly, they provide some support for the suggestion that reasoners keep in mind the negative possibility (not A and not B) for counterfactual conditionals more so than prefactual or indicative conditionals.

One possible criticism of the experiments is that the hypothesis we tested was in fact the null hypothesis. For example, we predicted that there would be no difference between future indicative and future subjunctive conditionals. This hypothesis was supported, in that we found no difference between the two groups on a variety of tasks. However, could these results have arisen, not because there is no difference between the two groups, but rather because we failed to detect a difference? We suggest that the answer is no: that is, we did not detect a difference between the groups because there was none to be found. We base this claim on the power tests that we conducted on each comparison. The power tests conducted for the comparisons in the experiments reported in this chapter

showed that there was sufficient power (i.e. 80% to detect a difference of .2 or less) in our studies to detect differences between groups if they were there.

We derived these predictions from the mental model theory of conditional reasoning. We suggested that reasoners initially keep in mind one possibility for future tense conditionals (e.g., if Rosanna is in Dublin tomorrow then Anthony will be in Wicklow) regardless of whether they are phrased in the indicative or subjunctive mood. They initially keep in mind just the information mentioned in the conditional (Rosanna in Dublin and Anthony in Wicklow) although they can think about other possibilities if necessary (e.g., Rosanna not in Dublin and Anthony not in Wicklow). Prefactual conditionals do not convey any presupposed facts unlike counterfactual conditionals (Thompson & Byrne, 2002). Counterfactual conditionals such as 'if Rosanna had been in Dublin then Anthony would have been in Wicklow' convey the presupposition that in fact 'Rosanna was not in Dublin and Anthony was not in Wicklow' and reasoners keep this possibility in mind from the outset, as well as the conjecture mentioned in the conditional (e.g., Rosanna was in Dublin and Anthony was in Wicklow).

Implications of findings for other theories of conditional reasoning

The finding that people understand, interpret and reason from prefactual conditionals somewhat differently to counterfactual conditionals and in a manner similar to future indicative conditionals is not easily explained by other accounts of deductive reasoning. For example, the domain-specific rule theories of reasoning (e.g., Holyoak & Cheng, 1995; Fiddick, Cosmides & Tooby, 2000) make no predictions regarding the role of tense or mood in reasoning. These accounts of deductive reasoning predict that differences in reasoning arise because the content of the conditional invokes a schema for reasoning in that situation (e.g., in situations involving permissions). We found two pieces of evidence

in this series of experiments to suggest that people did not use a type of content-based schema to reason. Firstly, in experiment 6 we gave participants two different types of content (neutral and realistic) yet we found very few differences between them in the options participants indicated as implied by the conditional. Secondly, in experiments 4 and 5 we used only neutral content yet we found some differences in reasoning from prefactual and counterfactual conditionals, and in reasoning from factual and counterfactual conditionals. As there could have been no effect of content in these experiments it is difficult to see how domain-specific rule theories might account for our results.

The formal inference rule theories of deductive reasoning (Braine & O'Brien, 1991; 1998; Rips, 1994) suggest that people reason by constructing an internal set of abstract general-purpose rules. These logic-like rules can be applied to any area of knowledge because all that is important for reasoning is the form of the problem. These theories are able to explain some of the findings presented in this chapter. They make no predictions about the role tense plays in reasoning so we must therefore assume that the same rates inferences will be made. This prediction has been corroborated for indicative conditionals as there is no difference in reasoning from the past, present and future tenses (Schaeken *et al.*, 2001). However, there appears to be a difference in reasoning from conditionals in different tenses in the subjunctive mood, as this set of experiments suggests. The formal inference rule theory suggests that the form of counterfactual conditionals is the same as the form of indicative conditionals (i.e., if A then B) and therefore there should be no difference between the two moods (Braine & O'Brien, 1991) and therefore cannot account for some of our findings. For example, it cannot account for the finding that people judge 'not A and not B' to be consistent somewhat more often for counterfactual than prefactual conditionals, or that they tend to endorse more negative

inferences from counterfactual than prefactual conditionals. Any theory of reasoning, if it is to be complete, should be able to provide an account of these differences in reasoning that arise as a result of the tense and the mood of the conditional assertion.

The probabilistic theory claims that the inferences people make depend on the perceived probability of the different factors involved in an event (e.g., the probability that I will buy a yacht given that I will win the lottery) (Oaksford & Chater, 1994). Because it is unclear how people form these subjective probabilities about an event the theory makes no clear predictions about the role of tense. However, given the lack of certainty in making predictions or planning for the future, it might predict an increase in the likelihood of an exception to any given conditional (e.g., winning the lottery and not buying a yacht). An increase in the subjective probability of an exception should lead a reasoner to show a decrease in MT inferences. Our results do not provide any support for this hypothesis. Also, if the probability of *B given not A* (buying a yacht without winning the lottery) decreases (as the probability of alternative causes increases e.g., inheriting money and buying a yacht) the theory predicts an increase in DA inferences, but our results suggest that DA does not increase. Our results, rather, suggest that the subjective probabilities produced by a past indicative conditional are unaltered by a transformation into either future indicative or future subjunctive conditional. This means that the probabilities model should make the claim that the subjective probabilities of winning the lottery, and of buying a yacht, are identical in the following three cases: 1) if I won the lottery then I bought a yacht; 2) if I win the lottery tomorrow they I will buy a yacht; 3) if I were to win the lottery tomorrow, then I would buy a yacht. The statistical models used by the probabilities theorists are complex, but it seems counter-intuitive that people would be as sure about their inferences about something that will or may happen in the future, as they are about something that has happened in the past. Future research might examine this

prediction of the probabilities model by having people estimate probabilities of unknown past and future events. More recently some probabilistic theorists (Oaksford & Chater, 2003) have suggested that perceived probability is affected by the subjective expected utility (Manktelow & Over, 1991, 1995) of different possibilities. Although subjective expected utility may suggest why different probabilities might be perceived for situations where the perceiver has control or intent concerning one or more of the possibilities, it does not explain why these probabilities would remain the same across the tenses and moods found in the experiments reported in this chapter.

Conclusion

Prefactual conditionals are curious. The results of the experiments reported in this chapter support our suggestion that people reason from prefactual and future indicative conditionals in a similar manner. We suggest they keep in mind initially a single possibility for both (A and B). Yet there must be some reason why we have two different linguistic moods to talk about future events. The difference is not apparent in the possibilities people keep in mind when reasoning; perhaps the difference relates to how people use factual and prefactual conditionals in everyday language. It may be that factual conditionals are more suitable for talking about future plans while prefactual conditionals are used more in speculation and daydreaming. Future work should investigate this matter further.

Reasoning from prefactual conditionals appears to be somewhat different to reasoning from counterfactual conditionals because people tend to initially keep two possibilities in mind (A and B, not A and not B) for the counterfactual. These results are consistent with the mental model theory of reasoning and they are incompatible with other accounts of conditional reasoning. The findings provide some support for our suggestion that tense plays a role in reasoning from subjunctive conditionals. The experiments

reported in the next chapter investigate the role of another important variable, that of linguistic form in reasoning from subjunctive conditionals.

Chapter 4: The Role of Linguistic Form in Reasoning from Counterfactual Conditionals

The six experiments reported in the previous two chapters all investigated how people reason from counterfactual conditionals of the form 'if A had been then B would have been' (e.g., if Colette had been in Dublin then Martin would have been in Wexford'). Previous research has also only investigated reasoning from counterfactual conditionals of this form (e.g., Byrne & Tasso; Thompson & Byrne, 2002). However, the counterfactual thoughts that people generate are not expressed just in 'if then' conditionals. For example, people can just as easily express their thoughts with other connectives such as 'Colette would have been in Dublin only if Martin had been in Wexford' or 'Colette would not have been in Dublin unless Martin had been in Wexford'. Our primary aim in this chapter, therefore, was to examine the role of linguistic form (e.g., 'if then', 'only if') in reasoning from counterfactual conditionals, which had not been investigated before.

Linguistic form has long been identified as an important factor in conditional reasoning (e.g., Evans, 1977) and many studies have considered the influence of different linguistic forms on reasoning from factual conditionals such as "only if" (e.g., Evans & Beck, 1981; Johnson-Laird & Byrne, 1989; Evans, Clibben & Rood, 1995; Thompson & Mann, 1995) and "unless" (Garcia-Madruga, Carriedo, Moreno & Schaeken, 1998; Carriedo, Garcia-Madruga, Gutierrez & Moreno, 1999). But what about reasoning from counterfactual conditionals phrased in these different linguistic forms? Research has shown that people tend to keep two possibilities in mind (A and B, not A and not B) when reasoning from counterfactual 'if then' (e.g., Byrne & Tasso). But do people also keep the same two possibilities in mind for other linguistic forms and if so what effect does linguistic form have on reasoning from counterfactual conditionals?

The linguistic forms we chose to compare directly were 'if then' and 'only if' because logicians have long identified that 'if A then B' is logically equivalent to 'A only if B'. For example, 'if Colette went to the meeting then she received the documentation' is logically equivalent to 'Colette went to the meeting only if she received the documentation' (e.g., Copi & Cohen, 1994; Jeffrey, 1981) because both are false in the same situation: Colette went to the meeting and she did not receive the documentation (A and not B).

Although 'if then' and 'only if' are logically equivalent, people do not tend to view them as equivalent psychologically. Their interpretations have been debated by linguists (e.g., Keenan, 1971) and psychologists (e.g., Evans, 1977) and have been investigated in a number of studies (e.g., Cheng & Holyoak, 1985; Evans & Beck, 1981; Ormerod, Manktelow & Jones, 1993; Thompson & Mann, 1995). Some studies have found that reasoners understand 'only if' more rapidly when the content refers to a situation in which the consequent (B) precedes in time the antecedent (A) (Evans & Beck, 1981; Evans & Newstead, 1977). It seems that a sentence such as 'the second letter is an R only if the first letter is a K' is a more natural phrasing of 'only if' than a sentence such as 'the first letter is a T only if the second letter is an F'. The opposite is true for 'if then' conditionals: they are understood more rapidly when the content refers to situations in which the antecedent precedes in time the consequent, rather than the other way around. For example, 'if the first letter is a Q then the second letter is an X' is more natural for 'if then' conditionals than 'if the second letter is an S then the first letter is an E'. Similarly, when people are asked to construct 'if then' and 'only if' conditionals they do so in accordance with their temporal order (Evans, 1977). For example, people constructed sentences such as 'the match will be played only if the weather improves' but not sentences such as 'the weather will improve only if the match is played'. It seems that 'only if' often contains a precondition in its

consequent (Girotto, Mazzocco, & Cherubini, 1992; Evans, 1977) which emphasizes the necessity of the consequent for the antecendent (i.e., A cannot occur without B). For example, 'I will go to the theatre only if I have enough money' seems to convey the information that if I do not have enough money then I will not go to the theatre.

Reasoners typically make more MP than MT from 'if then', but this difference disappears with 'only if'. Previous studies investigating 'only if' have found that reasoners typically make similar rates of MP and MT (e.g., Evans, 1977; Evans & Beck, 1981; Roberge, 1978). This finding led Johnson-Laird and Byrne (1989) to originally propose that reasoners keep two possibilities in mind for 'A only if B': 'A and B' and 'not A and not B' (e.g., Colette goes to the meeting and receives the documentation, Colette does not go to the meeting and does not receive the documentation). As a result, they can readily make both MP and MT. But on this account, they should make more DA (not A therefore not B) from 'only if', and the same frequency of AC (B therefore A) from 'only if' and 'if then', and they do not.

Another typical finding is that reasoners tend to make more of the backwards MT and AC inferences from 'only if' than 'if then' (e.g., Evans, 1993; Evans, Clibbens & Rood, 1995; 1996). This finding lead some authors to suggest that reasoners keep a single possibility in mind for 'A only if B' but in the direction 'B and A' (e.g., Colette receives the documentation and she goes to the meeting), and they have a processing preference for making inferences in accordance with this direction, from B to A (Evans, 1993; Santamaría & Espino, 2002). For 'if A then B' they keep a single possibility in mind in the direction, 'A and B', and they have a processing preference for making inferences in this direction, that is, from A to B. As a result, the backward inferences AC (B therefore A) and MT (not B therefore not A) are made more often from 'A only if B' (e.g., Evans, 1993; Evans, Clibbens & Rood, 1995; 1996). However, the evidence that 'if then' favours the forward

inferences, MP (A therefore B) and DA (not A therefore not B) is less clear-cut. Moreover, on this account because reasoners have only a single possibility in mind they should make fewer MT (not B therefore not A) than AC (B therefore A) inferences from 'only if' but they do not.

We combined aspects of these two proposals to suggest instead that reasoners understand 'A only if B' by thinking about two possibilities, in a directional manner: 'B and A' and 'not B and not A' (Garcia-Madruga, Byrne, Egan, Moreno-Rios, Quelhas & Juhos, 2004; Byrne, Egan & Garcia-Madruga, 2003). Hence they make more AC (B therefore A) and MT (not B therefore not A) from 'only if' than from 'if then' (see also Carriedo, García-Madruga, Moreno & Gutiérrez, 1999; García-Madruga, Gutiérrez, Carriedo, Moreno, & Johnson-Laird, 2002). In fact, recent evidence shows that when reasoners read 'A only if B', they are primed to understand quickly both 'B and A', and also 'not B and not A' (Santamaría & Espino, 2002, Experiment 3). Participants in the study also read 'not B and not A' reliably faster when primed by 'A only if B' than when primed by 'if A then B'.

We tested this new hypothesis about the mental representation and processing of 'only if' by comparing factual and counterfactual 'if then' and 'only if' conditionals (e.g., Colette would have gone to the meeting only if she had received the documentation; if Colette had gone to the meeting then she would have received the documentation). On our account factual and counterfactual 'only if' are both understood by keeping in mind two possibilities (see Table 4.1 for a summary of the possibilities people keep in mind for factual and counterfactual 'only if' and 'if'). For factual 'only if' the two possibilities are true possibilities, whereas for counterfactual 'only if' one of these possibilities is understood as the facts (not B and not A) and the other is understood as the counterfactual conjecture (B and A). Nonetheless, because two possibilities are kept in mind for both

factual and counterfactual 'only if', our account makes novel predictions about the possibilities people will judge to be consistent with the conditionals and about the inferences they will draw from them. We test this account in two experiments to which we now turn.

Table 4.1: A summary of the possibilties people keep in mind for factual and counterfactual 'only if' and 'if then'

	Factual	Counterfactual
If A then B	A and B ...	Facts: not A and not B Conjecture: A and B ...
A only if B	B and A not B and not A ...	Facts: not B and not A Conjecture: B and A ...

In summary, the two experiments reported in this chapter had three main aims. First, to investigate the role of linguistic form in reasoning from counterfactual conditionals, second to test our new account of the representation of 'only if' and third to replicate previous findings comparing factual and counterfactual 'if then'.

Experiment 7: What possibilities are judged to be consistent with 'only if'?

The aim of the first experiment in this series was to examine the possibilities that reasoners judge to be consistent with 'only if'. Each problem consisted of a conditional premise, e.g., 'David was in Kildare only if Evan was in Limerick', followed by four possibilities:

David was in Kildare and Evan was in Limerick.

David was not in Kildare and Evan was not in Limerick.

David was not in Kildare and Evan was in Limerick.

David was in Kildare and Evan was not in Limerick.

We asked participants to judge whether each possibility was consistent, inconsistent, or irrelevant with regard to the conditional. We examined factual and counterfactual 'only if' conditionals and compared them with factual and counterfactual 'if then' conditionals.

Our first set of predictions concerned the comparison of counterfactual 'only if' and 'if then'. We proposed that reasoners initially keep in mind two possibilities, an affirmative one and a negative one, for counterfactual 'only if' (B and A, not B and not A) and previous research has found that reasoners also initially keep two possibilties in mind for counterfactual 'if then' (A and B, not A and not B) (e.g., Byrne & Tasso, 1999). Accordingly we predicted that there would be no difference between the two linguistic forms for counterfactual conditionals in the rates of consistent judgements for the affirmative and negative possibilities.

Our second set of predictions concerned factual 'only if' and 'if'. We expected to find a difference between the two linguistic forms for factual conditionals because on our account reasoners initially keep just one affirmative possibility in mind for factual 'if then', but they initially keep in mind two possibilities, an affirmative and a negative one, for

factual 'only if'. We hypothesised that reasoners would consider the 'not A and not B' possibility as consistent more often following factual 'only if' than factual 'if then', but that there would be no difference for the affirmative 'A and B' possibility because people keep the possibility in mind from the outset for both linguistic forms. We did not expect to find any differences between the linguistic forms for the 'not A and B' and 'A and not B' possibilties because previous research, including experiments reported earlier in this thesis, shows that these possibilities are rarely selected as consistent (e.g., Thompson & Byrne, 2002).

Our final prediction concerned the comparison of the factual and counterfactual conditionals. We predicted for 'only if' there would be no difference in the pattern of consistent responses between the factual and counterfactual conditionals because reasoners would keep two possibilities in mind for both factual and counterfactual 'only if'. For 'if then' conditionals, however, we expected that there would be more consistent responses for the the negative possibility (not A and not B) following the counterfactual than factual conditional because people keep this possibilitiy in mind from the outset for the counterfactual but not for the factual. We did not expect a difference in the affirmative possibility comparing factual and counterfactual 'if then'.

Method

Materials and design

The design and materials were similar to previous experiments, and we gave one group of participants a set of problems based on indicative conditionals, and the other group received subjunctive conditionals. There were six problems in total, three 'if then' and three 'only if' problems which were presented in blocks. Each problem consisted of a

conditional statement followed by four possibilities which were presented in random order ('A and B', 'not A and B', 'A and not B' and 'not A and not B'). We used three sorts of neutral content: ingredients, locations, and actions. To control for content effects, the contents were assigned to the problems at random twice to make two different sets of problems (see Appendix G).

Procedure

The participants were tested in groups and the experimenter read the instructions aloud which asked participants to complete the problems in the order they were presented and not to change any responses once they had made them (see Appendix G). The experimenter answered any questions the participants had and participants were advised that they could take as long as they needed to complete the task.

Participants

The participants were 44 undergraduate psychology students from Dublin Business School's School of Arts, who took part voluntarily. They had not received any prior training in logic or taken part in a reasoning study before. There were 31 women and 13 men and their average age was 25 years (range 19 - 40 years). They were assigned at random to the factual (n = 23) or counterfactual (n = 21) group.

Results and discussion

Order Effects

We checked that there was no influence of order in the possibilities participants rated as

consistent by conducting an ANOVA on the factors order ('if then' or 'only if' conditionals first), mood (indicative, subjunctive), linguistic form ('if then', 'only if') and possibility (A and B, not A and B, A and not B, not A and not B). The ANOVA confirmed that there was no main effect of order ($F(1, 40) = .84$, $Mse = .42$, $p = .37$) and that order did not interact with any other factors (see Appendix G for the non-significant order effect statistics).

Consistent Responses

We analysed the results in an ANOVA on the possibilities that participants selected as 'consistent'. The factors were group (indicative, subjunctive), linguistic form (if then, only if) and possibility (A and B, not A and not B, not A and B, A and not B), with repeated measures on the last two factors. There was a main effect of linguistic form ($F(1,42) = 4.72$, $Mse = .90$, $p = .02$), possibility ($F(1.57,65.85) = 325.67$, $Mse = 366.09$, $p < .01$) and mood ($F(1,42) = 5.67$, $Mse = 2.92$, $p = .01$). Form interacted with possibility ($F(2.04, 85.85) = 2.71$, $Mse = .77$, $p = .04$) but not with mood ($F(1,42) = .15$, $Mse = .29$, $p = .35$), and mood and possibility interacted ($F(3,126) = 6.08$, $Mse = 3.57$, $p < .01$). The three way interaction was marginally reliable ($F(3,126) = 1.72$, $Mse = .33$, $p = .08$).

Linguistic Form: 'Only if' versus 'If then'

To test our predictions we conducted a series of planned comparisons. The planned comparisons showed that, consistent with our first set of predictions, there were no differences between 'if then' and 'only if' counterfactual conditionals in the rates of 'consistent' judgements for the options 'not A and not B' (90% versus 89%, $t(20) = .25$, $p = .40$) and 'A and B' (100% versus 100%, $t(22) = .00$, $p = .5$) as Table 4.2 shows. This finding supports our suggestion that people keep two possibilities in mind for both sorts of

counterfactual conditional. The other possibilities were rarely selected as consistent (see Appendix G for the percentages of inconsistent and irrelevant judgements).

Table 4.2: Percentages of possibilities judged as 'consistent' in Experiment 7

		A & B	not A & not B	not A & B	A & not B
If then	Factual	99	58	3	4
	Counterfactual	100	90	0	0
Only if	Factual	97	70	10	3
	Counterfactual	100	89	13	0

There was no difference between the two linguistic forms for the 'A and not B' possibility (0% for both, $t(22) = .00$, $p = .5$) but there was for the 'not A and B' possibility (0% versus 13%, $t(20) = 1.90$, $p = .04$) perhaps suggesting that a minority of reasoners found it easier to form a conditional interpretation of counterfactual 'only if' than of counterfactual 'if then'. This suggestion is supported by the data in Table 4.3. This finding is somewhat strange given that reasoners typically find it easier to form a conditional interpretation with 'if then' than 'only if'. However, previous research has not investigated *counterfactual* 'only if' so it may be that the counterfactual mood makes it easier for a small number of reasoners (13% in this experiment) to keep the 'not A and B' possibility in mind from the outset. Further research on counterfactual 'only if' is required to investigate this effect.

The pattern of consistent responses in Table 4.3 also indicates that there are individual differences in the possibilities reasoners keep in mind. Although the majority of reasoners consider both the 'A and B' and 'not A and not B' possibilities as consistent, that is they have a biconditional interpretation of both factual and counterfactual 'if then' and 'only if' conditionals, a substantial minority just keep the 'A and B' possibility in mind;

they have a conjunctive interpretation.

Table 4.3: Interpretation patterns of consistent responses in Experiment 7

		Conjunction	Biconditional	Conditional	Negative conjunction	Inconsistent
If then	Factual	38	54	1	1	6
	Counterfactual	10	90	0	0	0
Only if	Factual	23	62	6	1	7
	Counterfactual	11	76	13	0	0

Comparing the factual 'if then' and 'only if' conditionals to test our second set of predictions revealed that participants judged the 'not A and not B' possibility to be consistent more often for 'only if' than for 'if then' as expected (70% versus 58%, t (22) = 2.01, p = .03), in contrast to the findings of Evan & Newstead (1977). There were no other differences between 'only if' and 'if then' conditionals for 'A and B' (97% versus 99%, t (22) = 1.00, p = .17), 'not A and B' (10% versus 3%, t (22) = 1.31, p = .10), and 'A and not B' (3% versus 4%, t (22) = .57, p = .28). This result supports our hypothesis that reasoners initially keep just one possibility in mind for factual 'if then' conditionals, but two for factual 'only if' conditionals. The finding that participants judged the 'not A and not B' possibility to be consistent more often for 'only if' than for 'if then' has not been shown before and in it is inconsistent with alternative explanations of 'only if', such as the explanation that people only keep one possibility in mind (B and A) for 'only if' (Santamaria & Espino, 2002).

Mood: Indicative versus Subjunctive

Comparing the factual and counterfactual 'if then' conditionals to our third set of predictions, as expected the results showed no difference for 'A and B' (99% versus 100%, t (42) = .96, p = .17) but there was a difference between the two groups for the 'not A and not B' option (58% versus 90%, t (39.01) = 2.88, p = .01, equal variances not assumed). This finding supports the idea that people keep the negative possibility 'not A and not B' in mind more for a counterfactual than factual conditional and is consistent with previous findings (e.g., Byrne & Tasso, Thompson & Byrne 2002). The 'A and not B' (4% versus 0%, t (22) = 1.37, p = .10, equal variances not assumed) and 'not A and B' (3% versus 0%, t (22) = 1.45, p = .09) options were rarely selected as consistent with the conditional in the factual or counterfactual groups for 'if then'.

For the 'only if' conditionals we expected no differences between the factual and counterfactual groups and we found no differences between the groups for 'A and B' (97% versus 100%, t (42) = .96, p = .17), 'A and not B' (3% versus 0%, t (22) = 1.45, p = .09, equal variances not assumed) and 'not A and B' possibilities (10% versus 13%, t (42) = .30, p = .38). Unexpectedly, however, participants considered the 'not A and not B' possibility to be consistent more often with counterfactual than factual 'only if' (89% versus 70%, t (42) = 2.25, p = .01). One suggestion for this finding is that the counterfactual phrasing of the 'only if' conditionals further increased the likelihood that people would keep the negative possibility in mind more than they do for the factual conditional. We test this possibility in the next experiment which examines inferences from 'only if'. If this explanation is true then reasoners should endorse more negative inferences from counterfactual than factual 'only if' in the next experiment. Another possibility, and one that we consider more likely, is that rather than the negative possibility rate being elevated in the counterfactual group (89%) the negative possibility rate was somewhat suppressed in the factual group (70%). This effect may have occurred for factual

'only if' because all of the response options were in the direction of A to B to maintain consistency in the experiment, rather than B to A, which we suggest is the direction people keep in mind the possibilities for 'only if'. The negative possibility may not have been suppressed for counterfactual 'only if' by the "A to B" direction of judgements because reasoners had the additional cue of the presupposed facts to help them keep the negative possibility in mind. We suggest that there was not a similar effect on the affirmative 'A and B' possibility in this experiment because the conditional was phrased in an affirmative manner (e.g., A only if B) for both groups. As a result participants would have less of a working memory load to consider the affirmative than the negative possibility regardless of whether the conditional was factual or counterfactual. If this explanation is true then reasoners should endorse the same rates of both affirmative and negative inferences from factual and counterfactual 'only if' conditionals in the next experiment.

Summary

This experiment provided three main results. Firstly, we found that participants considered the 'not A and not B' possibility to be consistent more often following counterfactual than factual 'if then' conditionals (90% versus 58%). This finding is consistent with previous work (e.g., Byrne & Tasso, 1999; Thompson & Byrne 2002) and supports the hypothesis that reasoners keep two possibilities in mind for counterfactual 'if then' but only one for factual 'if then'. Secondly, participants also considered the 'not A and not B' possibility to be consistent more often following factual 'only if' than 'if then' conditionals (70% versus 58%). This finding supports our suggestion that reasoners initially keep two possibilities in mind for factual 'only if' but just one possibility for factual 'if then'. Thirdly, as we expected in relation to the role of linguistic form in reasoning from counterfactual conditionals, we found no difference in the pattern of consistent responses between

counterfactual 'only if' and 'if then' because reasoners keep an affirmative possibility (100% for both) and a negative possibility (89% and 90%) in mind for both.

A final point to mention concerns the comparison of factual 'only if' with counterfactual 'only if'. We predicted that reasoners would keep two possibilities in mind for both and that therefore there would be no differences between the groups in the consistent judgements for any of the possibilities. Although the results showed that there was no difference in the rates of consistent responses for the affirmative possibility (97% versus 100%) a difference was found in the rates of consistent responses for the negative possibility (70% versus 89%). We have suggested this difference may be a result of the response options participants were presented with in this experiment (i.e., not A and not B rather than not B and not A) and we test this hypothesis in the next experiment.

The results of this experiment show that reasoners keep two possibilities in mind for both 'only if' and 'if then' counterfactual conditionals as we predicted. We also proposed, however, a difference in these representations. We proposed that for counterfactual 'if then' reasoners keep the two possibilities in mind in the direction of A to B but for counterfactual 'only if' they keep the two possibilities in mind in the direction of B to A. Our next experiment tests if this difference in the direction of the possibilities for counterfactual 'if then' and 'only if' influences the inferences reasoners draw from these conditionals.

Experiment 8: Do reasoners make more backwards inferences from counterfactual 'only if' than 'if then'?

The primary aim of this experiment was to examine how the linguistic form of a counterfactual conditional influences the inferences people draw. We compared the

inferences drawn from factual and counterfactual 'only if' and 'if then' conditionals using a task of the following sort:

David would have been in Kildare only if Evan had been in Limerick

Evan was in Limerick

Therefore,

(a) David was in Kildare

(b) David was not in Kildare

(c) David may or may not have been in Kildare

We proposed that for counterfactual 'only if' conditionals people initially keep two possibilities in mind from the direction B to A. For counterfactual 'if then' people also keep two possibilities in mind but in the direction A to B. Our first set of predictions, therefore, were that the direction of the possibilities would affect the inferences people make and that reasoners would endorse more of the backward inferences (MT and AC) and less of the forward inferences (MP and DA) from counterfactual 'only if' compared with counterfactual 'if then'.

A secondary aim of the experiment was to test our new account of the mental representation of factual 'only if', that is that people keep two possibilities in mind to understand it in the direction of B to A (B and A, not B and not A). Previous research (Byrne & Tasso, 1999) has found that people keep just the affirmative possibility (A and B) in mind in the direction of A to B for factual 'if then' conditionals, and Experiment 7 supports this suggestion. Our second set of predictions were that for factual conditionals reasoners should make both more backwards inferences (AC and MT) and more negative inference (MT and DA) from 'only if' than 'if then'.

On our account of 'only if' reasoners keep two possibilities in mind in the direction

of B to A for both factual and counterfactual 'only if'. However, in Experiment 7 we found that the negative possibility was judged as consistent more often following counterfactual than factual 'only if'. We have suggested that the direction of A to B in the response options (not A and not B) may have suppressed somewhat the consistent judgements of the negative possibility for factual 'only if'. We do not expect the negative possibility to be suppressed for factual 'only if' in this experiment because reasoners receive both forwards (MP and DA) and backwards inferences (MT and AC). Accordingly we expect that reasoners will make the same frequency of inferences from both factual and counterfactual 'only if'. A third aim of this experiment was to replicate typical findings with factual and counterfactual 'if then' and our third set of predictions are that reasoners will make more negative inferences (MT and DA) from the counterfactual than factual 'if then' conditionals.

We also measured how long it took people to endorse the inferences in this experiment. First, we predicted that reasoners would endorse the backwards inferences more quickly, but the forwards inferences more slowly from counterfactual 'only if' compared to counterfactual 'if then'. Second, we expected to see the same pattern of backwards and forwards inferences to emerge for factual 'only if' compared to factual 'if then', with reasoners endorsing backwards inferences more quickly and forwards inferences more slowly. We did not expect a difference in latencies comparing factual 'only if' to counterfactual 'only if' because we predicted that reasoners keep the same possibilities in mind for both. Finally, comparing factual and counterfactual 'if then' we expected that reasoners would make the negative inferences more quickly but the affirmative inferences more slowly from the counterfactual than the factual because reasoners keep an affirmative and negative possibility in mind for the former but just an affirmative possibility in mind for the latter.

Method

Materials and Design

We constructed two sets of problems, a factual set based on conditionals in the indicative mood and a counterfactual set based on conditionals in the subjunctive mood, and all the assertions were in the past tense. Each set contained 24 problems, 12 for the linguistic form 'if then' and 12 for 'only if'. We used three sorts of neutral content as in the previous experiment: locations, action and ingredients (e.g., David would have been in Kildare only if Evan had been in Limerick) (see Appendix G). Each problem consisted of a conditional premise and a categorical premise corresponding to MP (David was in Kildare), MT (Evan was not in Limerick), DA (David was not in Kildare) and AC (Evan was in Limerick). And participants had a choice of three conclusions to select from as described in the previous section. Each type of inference was presented once for each content and for each linguistic form (i.e., 4 inferences x 3 contents x 2 linguistic forms = 24 problems). To control for content effects, the contents were assigned to the problems at random twice to make two different sets of problems. To control for linguistic form order effects, half the participants received the 'if then' problems first and the other half received the 'only if' problems first. The 12 problems within each block were presented in a different random order for each participant.

Procedure

Participants were tested individually or in groups of two or three participants. The 24 problems were presented on Macintosh computers using SuperLab 1.75. The instructions were presented on the computer and included an example problem and three practice problems (based on conjunctions and disjunctions of shapes) to familiarise participants

with the task presentation and keyboard response options (see Appendix G). Participants were advised that they could take as long as they needed to complete the task. They pressed the space bar to view each new piece of information (the conditional, the minor premise, the conclusion set), and each remained on screen to be joined by the subsequent information. The participants pressed one of the keys labelled 'a' 'b' or 'c' to select a conclusion, these keys were in the centre of the keyboard and corresponded to the T, G, & B keys.

Participants

The participants were 40 undergraduate psychology students from Trinity College, University of Dublin, who participated for course credits. There were 28 women and 12 men and their average age was 22 years, ranging from 18 to 45 years. They had not been trained in logic nor had they participated in any previous reasoning study. They were assigned at random to the factual group (n = 19) or the counterfactual group (n = 21).

Results and discussion

Inference Endorsements

Order Effects

To control for order effects we counterbalanced the presentation of the within participant factor linguistic form so that half the participants received 'if then' conditionals first and half received 'only if' conditionals first. We conducted an ANOVA on the factors order ('if then' or 'only if' conditionals first), mood (indicative, subjunctive), linguistic form ('if then', 'only if') and inference (MP, MT, DA and AC). The ANOVA showed that there was

no main effect of order (F (1,36) = .03, Mse = .04, p = .88) and it did not interact with any of the other factors (see Appendix G for the non-significant order effect statistics).

Inference Endorsements

We analysed the results in an ANOVA on the endorsements of conclusions with the factors of mood (factual, counterfactual), form (if then, only if), and inference (MP, AC, MT, DA), with repeated measures on the second two factors. It showed a main effect of form (F (1,38) = 3.98, Mse = 3.41, p = 0.03) and inference (F(2.36,89.72) = 12.62, Mse = 13.09, p < .01), but not of mood (F(1,38) = .05, Mse = .09, p = 0.41). Form interacted with inference (F (2.49,94.42) = 4.16, Mse = 2.38, p = 0.01) but not mood (F(1,38) = 1.70, Mse = 1.46,p = 0.10), and mood and inference did not interact (F(3,114)= .67, Mse = .55, p = 0.29). The three way interaction was reliable (F (3,114) = 2.61, Mse = 1.24, p = 0.03).

Linguistic Form: 'Only if' versus 'If then'

We tested our predictions in a series of planned comparisons. Firstly, we predicted that we would find more backwards inferences (MT and AC) and less forwards inferences (MP and DA) from counterfactual 'only if' than 'if then' because reasoners keep possibilities in mind in the direction of B to A for 'only if', rather than A to B. The results showed that, as predicted, participants made more of the backwards MT inference from counterfactual 'only if' than counterfactual 'if then' (92% versus 71%, t (20) = 2.44, p = .01) although the difference for AC did not reach significance (73% versus 67%, t (20) = .68, p = .25) (see Table 4.3). The results also showed that, as we predicted, reasoners made fewer of the forwards DA inference from 'only if' (68% versus 84%, t (20) = 2.35, p = .02), contrary to the predictions of Evans (1993), although there was no difference for MP (98% versus 100%, t (20) = 1.00, p = .17). These results provide some tentative support for our

suggestion that people keep in mind possibilities in the direction of B to A for counterfactual 'only if' (B and A, not B and not A), compared to A to B for 'if then' (A and B, not A and not B).

Table 4.4: Percentages of conclusions endorsed by participants in Experiment 8

		MP	AC	MT	DA
If A then B	Factual	100	67	79	63
	Counterfactual	100	67	71	84
A only if B	Factual	95	84	96	79
	Counterfactual	98	73	92	68

Our second prediction concerned factual 'only if'. We suggested that people keep two possibilities in mind for 'only if' in the direction of B to A, but only one possibility in mind for 'if then' in the direction of A to B. Accordingly, we predicted that reasoners would endorse more negative and more backwards inferences from 'only if' than 'if then'. The results tended to support this idea. Participants made more MT from factual 'only if' (96% versus 79%, $t(18) = 2.04$, $p = .03$), and marginally more DA (79% versus 63%, $t(18) = 1.63$, $p = .06$). This finding supports our suggestion that people keep the negative as well as the affirmative possibility in mind for 'only if' but not for 'if then'. Participants also made somewhat more AC (84% versus 67%, $t(18) = 1.56$, $p = .07$) from 'only if' than 'if then' lending support to the idea that the possibilities are in the direction of B to A rather than A to B for 'only if'. They also made slightly fewer MP (95% versus 100%, $t(18) = 1.37$, $p = .09$) which is consistent with them keeping in mind the possibility 'not B

and not A', as well as 'B and A' to understand 'only if'.

Mood: Subjunctive versus Indicative

We found further support for our hypothesis that reasoners keep two possibilities in mind for factual 'only if' by comparing it with counterfactual 'only if'. As expected, there were no differences in the frequency of negative inferences from counterfactual and factual 'only if', for DA (68% versus 79%, t (38) = 1.00, p = .17), and MT (92% versus 96%, t (38) = 1.09, p = .14). Likewise, there were no differences in the affirmative inferences from counterfactual and factual 'only if', for MP (98% and 95%, t (38) = .92, p = .18) and AC (73% and 84%, t (38) = 1.03, p = .15). The results show that reasoners make the same frequency of inferences from counterfactual 'only if' as they do from factual 'only if', supporting the idea that people keep two possibilities in mind for both: 'B and A' and 'not B and not A'. The results also support our suggestion that the negative possibility was judged to be consistent more often with counterfactual than factual 'only if' in Experiment 7 because the possibility presented in the experimental task was in the direction of A to B, rather than B to A, thereby suppressing somewhat the rate of consistent judgements.

Finally, as expected participants endorsed more negative inferences from counterfactual than factual 'if then', and the difference was reliable for DA (84% versus 63%, t (38) = 1.79, p = .04), although there was no difference for MT (71% versus 79%, t (38) = .66, p = 0.26) perhaps because we found a particularly high rate of MT with factual conditionals in this study (79%). If MT was already close to ceiling level for factual 'if then' it would be difficult to find an increase with counterfactual 'if then' conditionals. As expected there were no differences in the affirmative inferences from counterfactual and factual 'if then', for MP (100% in each case, t (38) = .00, p = .5) and AC (67% in each case t (38) = .00, p = .5), as Table 4.3 shows. The results for 'if then' are consistent with earlier

findings that participants make more of the negative inferences from counterfactual 'if then' compared to factual 'if then', at least in this case for DA (Byrne & Tasso, 1999; Thompson & Byrne, 2002). Like earlier findings however, the result suggests the differences are somewhat labile. These findings are also consistent with the results of Experiment 7 which showed that the negative possibility is judged to be consistent more often for counterfactual than factual 'if then' and there is no difference for the affirmative possibility.

Latencies of Inference Endorsement

Order Effects

We checked that there was no influence of order in response latencies for endorsements by conducting an ANOVA on the factors order ('if then' or 'only if' conditionals first), mood (indicative, subjunctive), linguistic form ('if then', 'only if') and inference (MP, MT, DA and AC). The ANOVA showed that there was a main effect of order ($F(1,22) = 13.74$, $Mse = 7.45$, $p < .01$) and that it interacted with linguistic form ($F(1,22) = 6.47$, $Mse = .38$, $p = .02$). It did not interact with any other factors (see Appendix G for the non-significant order effect statistics).

A series of comparisons were carried out between the first block data set and the second block data set to determine where the order effects had occurred. The only significant differences in response latencies between the first block and second block data were in the counterfactual group for 'only if'. Only two out of sixteen comparisons differed and the pattern of latencies in the first block data set did not differ from the pattern in the overall data set so we used the overall data set to test our predictions.

Latencies

The latencies for endorsements were analysed for reading the minor premise and endorsing a conclusion, in a 2 (factual versus counterfactual) by 2 ('if then' versus 'only if') by 4 (MP, AC, MT, DA) ANOVA carried out on the latencies, log-transformed to base e, with repeated measures on the second two factors. We analysed the results in an ANOVA on the latencies for endorsements of conclusions with the factors of mood (factual, counterfactual), form (if then, only if), and inference (MP, AC, MT, DA), with repeated measures on the second two factors. There was no main effect of mood ($F(1, 24) = .19$, $Mse = .17$, $p = .33$) or linguistic form ($F(1,24) = 1.26$, $Mse = .20$, $p = .14$), but there was of inference ($F(3,72) = 13.58$, $Mse = 1.25$, $p < .01$). Inference interacted with mood ($F(3, 72) = 4.59$, $Mse = .42$, $p < .01$) and linguistic form ($F(3,72) = 4.24$, $Mse = .49$, $p = .01$), and mood and linguistic form also interacted ($F(1,24) = 5.47$, $Mse = .88$, $p = .01$). The three way interaction was not reliable however ($F(3, 72) = 1.39$, $Mse = .16$, $p = .13$).

Linguistic Form: 'Only if' versus 'If then'

Firstly, as we predicted, reasoners endorsed the forwards DA and MP inferences more slowly from counterfactual 'only if' than 'if then' (9.00 versus 8.72, $t(17) = 1.88$, $p = .04$, and 8.85 versus 8.57, $t(20) = 2.85$, $p = .01$ respectively) as Table 4.4 shows. This finding is consistent with our suggestion that for 'only if' reasoners keep possibilities in mind in the direction of B to A, but for 'if then' the possibilities are in the direction of A to B. There were no differences for MT and AC (8.78 versus 8.92, $t(18) = 1.03$, $p = .16$, and 8.92 versus 8.79, $t(14) = .57$, $p = .29$ respectively).

Secondly, for factual conditionals participants made the backwards MT and AC inferences more quickly from 'only if' than from 'if then' (8.77 versus 9.13, $t(16) = 2.74$, $p = .01$, and 8.57 versus 8.91, $t(13) = 2.79$, $p = .01$, respectively). They made the MP

inference more slowly (8.56 versus 8.24, t (18) = 3.76, p < .01) and the difference for DA from 'only if' and from 'if then' factual conditionals (9.00 versus 8.88, t (18) = .96, p = .16). These findings are broadly consistent with the hypothesis that people keep in mind two possibilities for factual 'only if' but only one possibility for factual 'if then'.

Mood: Indicative versus Subjunctive

Comparing factual and counterfactual 'only if' revealed no differences between the groups for DA (9.00 in each case t (35) = .02, p = .49), and MT (8.77 versus 8.78, t (38) = .10, p = .46). Unexpectedly, participants took longer to make the affirmative inferences from counterfactual than factual 'only if' conditionals, for MP (8.85 versus 8.56, t (38) = 2.03, p = .02) and AC (8.92 versus 8.57, t (34) = 2.37, p = .01) perhaps because of the extra working memory load of keeping track of the epistemic status of the possibilities (facts and conjecture).

Table 4.5: Mean latencies in msec (log transformed to base e) of conclusions endorsed by participants in Experiment 8

		MP	AC	MT	DA
If A then B	Factual	8.24	8.91	9.13	8.88
	Counterfactual	8.57	8.79	8.92	8.72
A only if B	Factual	8.56	8.57	8.77	9.00
	Counterfactual	8.85	8.92	8.78	9.00

There was no difference in the latencies for inferences from counterfactual and factual 'if then' conditionals for DA (8.72 versus 8.88, t (36) = .98, p = .17) and MT (8.92 versus 9.13, t (34) = 1.09, p = .14), as Table 4.4 shows. Reasoners took longer to make MP from

counterfactual than factual 'if then' conditionals (8.57 versus 8.24, t (38) = 2.72, p = .01) and there was no difference for AC (8.79 versus 8.91, t (29) = .54, p = .29).

Summary

This experiment provides three main results. First, the results showed that when asked to draw inferences, there is some effect of linguistic form on reasoning from counterfactual conditionals. Participants made more of the backwards MT inference from counterfactual 'only if' than 'if then' as we predicted although there was no difference for AC. They also made less of the forwards DA inference and they also made the forwards inferences, DA and MP, more slowly from counterfactual 'only if' than 'if then'. These findings support our suggestion that reasoners keep both an affirmative and a negative possibility in mind for 'only if' in the direction of B to A, but in the direction of A to B for 'if then'.

Secondly, the results also support our new account of factual 'only if', that people keep two possibilities in mind in the direction of B to A (B and A, not B and not A). The results showed that there is no advantage for the negative MT and DA inferences from counterfactual 'only if' versus factual 'only if'. There is also no difference between the groups in the endorsement of the affirmative inferences MP and AC, although participants did take longer to endorse these inferences in the counterfactual group, perhaps because the participants must also keep track of the epistemic status of the possibilities. These findings are consistent with our suggestion that both the 'B and A' and 'not B and not A' possibilities are available for both factual and counterfactual versions of 'only if'.

Some further support for our account of factual 'only if' is available from the comparison of factual 'only if' and 'if then'. Reasoners tended to make more backwards inferences, MT and AC, and make them more quickly, from factual 'only if' than 'if then'

as we expected. We suggest the result arises because the possibilities people keep in mind are in the direction of B to A, rather than A to B as is the case with 'if then'. We also found that reasoners made somewhat more of the negative inference DA from 'only if' than 'if then' and this finding is consistent with the idea that reasoners keep the negative possibility in mind from the outset for 'only if' but not for 'if then'. Reasoners also made slightly less MP from 'only if' than 'if then' and this finding is consistent with the suggestion that reasoners keep 'B and A' in mind for 'only if' but 'A and B' in mind for 'if then'.

The third main result of this experiment is the replication of previous findings for factual and counterfactual 'if then'. We found that reasoners endorsed more negative inferences from counterfactual than factual 'if then', at least for DA in this experiment. The results are consistent with previous findings that reasoners make more of the negative inferences from counterfactual 'if then' compared to factual 'if then' (Byrne & Tasso, 1999). However, we did not find an increase in the endorsement rate of MT for counterfactual 'if then' conditionals compared to factual 'if then' conditionals. Previous studies have found that differences are labile but there is always an increase in at least one of the negative inferences for the counterfactual conditional compared to the factual conditional for 'if then'. For example, in Experiment 5 we found that reasoners endorsed more MT but not more DA from counterfactual than factual 'if then' conditionals. The 'if then' conditionals used in this experiment were exactly the same as the past tense conditionals used in Experiment 5. Our results for the affirmative inferences, MP and AC, are also consistent with previous findings and showed no differences between factual and counterfactual conditionals for 'if then', although participants did take longer to endorse the MP inference from the counterfactual than factual, perhaps because they keep two possibilities in mind for the counterfactual but only one for the factual. These results provide further support for the idea that reasoners keep a single possibility in mind to

understand factual 'if then' but two possibilities in mind to understand counterfactual 'if then'.

Overall, the results of this experiment replicate previous studies of factual and counterfactual 'if then' and provide some support for our new account of factual 'only if'. They also provide some support for our suggestion that linguistic form plays a role in the inferences people draw from counterfactual conditionals.

General Discussion

The aim of this chapter was primarily to investigate the role of linguistic form in reasoning from counterfactual conditionals because when people generate counterfactual thoughts or utterances they are not limited to expressing them only in counterfactuals of the form 'if A had been then B would have been' (e.g., if Colette had gone to the meeting then she would have received the documentation). For example, they may also generate counterfactuals of the form 'A would have been only if B had been' (e.g., Colette would have gone to the meeting only if she had received the documentation). A secondary aim of these two experiments was to test a new account of 'only if' and a third aim was to replicate previous findings comparing factual and counterfactual 'if then' (e.g., Byrne & Tasso, 1999; Thompson & Byrne, 2002). We compared factual and counterfactual 'only if' with 'if then' on a consistency judgement task and on an inference task. In the remainder of this section we summarise the main findings of the two experiments in relation to the aims of the chapter we consider other possible accounts of our results and we discuss counterfactual conditionals and other possible linguistic forms such as "unless".

Summary of findings

Firstly, Experiments 7 and 8 provided some support for our hypothesis that linguistic form plays a role in reasoning from counterfactual conditionals. Experiment 7 established that reasoners initially keep two possibilities in mind for counterfactual 'only if' as well as for counterfactual 'if then'. They keep an affirmative and negative possibility in mind for both. Experiment 8 then showed that even though reasoners keep an affirmative and a negative possibility in mind for counterfactual 'only if' and 'if then' some differences exist in the inferences people endorsed, and in the time taken to endorse them, because the two possibilities are in the direction of B to A for 'only if', but A to B for 'if then'. We predicted that reasoners would endorse more backwards inferences (MT and AC) and less forwards inferences (MP and DA) from counterfactual 'only if' than counterfactual 'if then'. We also predicted that they would endorse the backwards inferences more quickly and the forwards inferences more slowly from counterfactual 'only if' than 'if then'. We found that reasoners made more of the backwards MT inference, less of the forwards DA inference and made DA and MP more slowly from 'only if' than 'if then'. Although there was no difference between the linguistic forms for AC, the other three inferences showed some effect of the direction of the possibilities people keep in mind, either in the endorsement rate, the time to make the endorsement, or both.

The second aim of this chapter concerned our new account of factual 'only if', that reasoners keep both an affirmative and a negative possibility in mind in the direction of B to A (B and A, not B and not A). As people keep the same possibilities in mind for counterfactual 'only if' we did not expect to find differences between factual and counterfactual 'only if' in the possibilities people judged as consistent, the inferences they endorsed or in the time taken to endorse them. However, in Experiment 7 we found that reasoners judged the negative possibility to be consistent more often with the

counterfactual than the factual conditional. We suggested that this finding was due to the response options being presented in the direction A to B which suppressed the rate of consistent judgements in the factual group but not in the counterfactual group because the counterfactual presupposes the negative situation. It may be interesting to conduct a future experiment in which the response options are presented in the direction of B to A to further test this idea. In support of this suggestion in Experiment 8 we found that there were no differences between the groups in the endorsement of any of the inferences, forwards or backwards. Reasoners did take longer to make the MP and AC inferences from counterfactual than factual 'only if' however, and we suggested this finding was due to reasoners also having to keep track of the epistemic status of the possibilities (the facts and the conjecture) for the counterfactual.

We derived some further support for our account of factual 'only if'' by comparing factual 'only if' and factual 'if then'. Because reasoners keep both an affirmative and a negative possibility in mind for 'only if', but only one affirmative possibility in mind for 'if then', in Experiment 7 we found that the negative possibility was judged as consistent more often with factual 'only if' than 'if then' and there was no difference for the affirmative possibility as we predicted. In Experiment 8 we predicted that reasoners would make more backwards (MT and AC) and more negative inferences (MT and DA) from factual 'only if' compared to 'if then' because people keep in mind the possibilities for 'only if' in the direction of B to A, but in the direction of A to B for 'if then'. The results tended to support this prediction with reasoners endorsing more MT and somewhat more AC and DA and slightly less MP. They also endorsed the backwards inferences more quickly for 'only if' and MP more slowly. The comparison of factual 'only if' with both factual 'if then' and counterfactual 'only if' provides some support for our new account of the possibilities people keep in mind for factual 'only if'.

The third and final aim of the experiments presented in this chapter was to replicate previous findings comparing factual and counterfactual 'if then'. Previous studies (e.g., Byrne & Tasso, 1999; Thompson & Byrne, 2002) have shown that reasoners endorse more negative inferences from counterfactual than factual 'if then', but the same amount of affirmative inferences because they keep in mind the negative and the affirmative possibility for the counterfactual but just the affirmative possibility for the factual. Our results tended to be consistent with this trend. In Experiment 7 reasoners judged the negative possibility to be consistent more often following counterfactual than factual 'if then' but there was no difference for the affirmative possibility. In Experiment 8 reasoners endorsed more of the negative DA inference from the counterfactual than the factual and the same amount of AC and MP. There was no difference for MT which we suggested was because the rate of endorsement of MT in the factual group was close to ceiling level and therefore could not be increased by the counterfactual phrasing of the conditional. The findings for the MP, AC and DA supported our predictions and are broadly consistent with previous findings using an inference task (Byrne & Tasso, 1999; Thompson & Byrne 2002).

Implications of findings for other theories of conditional reasoning

The predictions in this chapter were derived from the mental model theory of conditional reasoning and the results that were found using a consistency judgement task and an inference task were explained by the possibilities people initially keep in mind for factual and counterfactual 'only if' and 'if then'. The remainder of the chapter considers the implications of our results for other theories of conditional reasoning and also other linguistic forms and reasoning from counterfactual conditionals.

First we consider the domain-specific rule theories (e.g., Cheng & Holyoak, 1985;

Holyoak & Cheng, 1995, Cosmides, 1989; Fiddick, Cosmides & Tooby, 2000). These theories suggest that people reason using a schema appropriate to the situation they are in (e.g., a situation involving a permission) and most of the predictions derived from these theories have concerned performance on the Wason selection task as outlined in Chapter 1. One experiment by Cheng and Holyoak (1985, Experiment 3) examined performance on the Wason selection task using 'if then' and 'only if' conditionals with arbitrary content. Previous research shows that 'only if' often contains a precondition in its consequent (Girotto, Mazzocco, & Cherubini, 1992) and that conditionals of the form 'A only if B' carry the connotation that B is necessary for A and also precedes it in time (Evans, 1977; Evans & Newstead, 1977). Cheng and Holyoak (1985) suggest that permission statements such as 'if the action is to be taken then the precondition must be satisfied' may be readily rephrased as 'the action is to be taken only if the precondition is satisfied'. They compared performance on the Wason selection task using permission rules and arbitrary rules phrased using the linguistic forms 'if then' and 'only if'. We will focus only on the results from the arbitrary rules (e.g., if a bird has a purple spot underneath each wing then it must build nests on the ground) as these rules are more similar to the type of content we used (e.g., if Rosanna was in Dublin then Anthony was in Wicklow) than the permission contents are (e.g., if a customer is to drink an alcoholic beverage then she must be at least eighteen).

Unfortunately, Cheng and Holyoak (1985) only report the percentages of people who selected the correct combination of cards on the selection task (i.e., the cards that correspond to 'A' and 'not B' given a conditional 'if A then B') rather than the selection rates for the four individual cards, which makes it difficult to consider their findings in light of our predictions and results. However, their results showed that more people tended to select the correct cards for 'if then' rules (17%) than 'only if' rules (4%). Whether this

difference is significant is unclear because Cheng and Holyoak (1985) only report statistics for the arbitrary content combined with the permission content (for the combined contents performance is significantly more accurate for 'if then' than 'only if' rules). Extrapolating from their finding that performance is more accurate for 'if then' than 'only if', and that the selection of the correct cards ('A' and 'not B') corresponds to making the MP (A therefore B) and MT (not B therefore not A) inferences, we derive the prediction for their account that reasoners should endorse more MP and MT, and less DA and AC, from 'if then' than 'only if'. However, this predicted pattern is not consistent with previous findings (e.g., Evans, 1977; Johnson-Laird & Byrne, 1989) or the results in this chapter. Although, reasoners endorsed somewhat less DA and AC, they did not endorse more MT from 'if then' than 'only if'. In fact, we found the opposite: reasoners endorsed less MT from 'if then' than 'only if'. In support of this is the trend in Evans et al's (1999) selection task data, which goes against the findings of Cheng and Holyoak (1985). Their data (in Table 5) shows that reasoners selected the 'not B' card somewhat more often from 'only if' than 'if then' (21% versus 18%), although they do not report statistics for this finding. Our findings in this experiment are consistent with previous studies (e.g., Evans, 1977; Johnson-Laird & Byrne, 1989) and it supports our suggestion that reasoners keep two possibilities in mind for 'only if' in the direction of B to A (B and A, not B and not A), but just one possibility for 'if then' in the direction of A to B (A and B). The domain specific theories cannot explain this result.

The domain-specific theories of reasoning also cannot account for our findings regarding counterfactual conditionals, for example that reasoners judge the negative possibility to be consistent more often with counterfactual than factual 'if then' conditionals, and they make more negative inferences from counterfactual than factual 'if then'. They make no predictions regarding the role of mood in conditional reasoning and

cannot explain the result that there are differences.

The probabilistic theory of reasoning (e.g., Oaksford & Chater, 1994; Oaksford, Chater & Larkin, 2000) also makes no predictions regarding the role of mood in conditional reasoning and like the domain-specific theories cannot account for our findings with counterfactual conditionals. However, 'only if' conditionals have been modelled within the theory (Oaksford & Chater, 2003). The theory attempted to model the results of a previous study of 'only if', (Evans, 1977). However, the attempt was not completely successful and the model 'clearly does not address the psycholinguistic findings on paraphrasing' (Oaksford & Chater, 2003, p.119).

The formal inference rule theories of deductive reasoning (Braine & O'Brien, 1991; 1998; Rips, 1994) suggest that people reason by constructing an internal set of abstract general-purpose rules. These logic-like rules can be applied to any area of knowledge because all that is important for reasoning is the form of the problem. Formal rule theorists have proposed an account of 'only if' that provides an explanation for why reasoners endorse more MT from 'only if' than 'if then' (Braine, 1978).

Braine (1978) suggests that 'A only if B' (e.g., Colette goes to the meeting only if she receives the documentation) conveys a double negative similar to 'if not B then not A' (e.g., if Colette does not receive the documentation then she does not go to the meeting). MT is endorsed more from 'only if' than 'if then' because it is in effect MP (not B therefore not A) from 'if not B then not A'. However, on this account MP should be more difficult because it is in effect MT (A therefore B) from 'if not B then not A', but it is not (e.g., Johnson-Laird & Byrne, 1989). Our results showed that MP is endorsed as much as MT from 'only if' (95% and 96% respectively). Braine's (1978) account is inconsistent with our findings and with previous findings (e.g., Evans 1977; Johnson-Laird & Byrne, 1989). Also, Garcia-Madruga et al (2004, Experiment 3), which is discussed in more detail

below, showed that reasoners make more negative inferences from counterfactual than factual 'if not B then not A'. This difference is not present between counterfactual and factual 'only if' suggesting that reasoners do not understand and represent 'A only if B' and 'if not B then not A' in the same way.

Another explanation for 'only if' is that it is interpreted as a biconditional. But, on this account DA (not A therefore not B) and AC (B therefore A) should be made more often from factual 'only if' than from 'if then'. AC is made more readily and more quickly from 'only if' (Evans, 1977; Evans & Beck, 1981; Johnson-Laird & Byrne, 1989; Santamaría & Espino, 2002). But, DA is unstable. Most studies of 'only if' have been based on truth table tasks (e.g., Evans, Clibbens & Rood, 1996) or the selection task (e.g., Evans, Legrenzi & Girotto, 1999), but the few inference studies show DA is sometimes made more often (e.g., Johnson-Laird & Byrne, 1989), sometimes less often (Evans & Beck, 1981), and sometimes the same (Evans, 1977). These results rule out the explanation that counterfactual 'only if' is interpreted as a biconditional. A third explanation is that 'A only if B' is interpreted as 'A, if B', in other words, 'if B, A'. But 'if B, A' is false in the situation 'B and not A'. It is true in the situations 'A and B', 'not A and not B', and 'A and not B'. Hence reasoners should not make MP (from 'A only if B', and 'A' to 'B'). Nor should they make MT. Yet they make these inferences readily. The explanation that 'A only if B' is 'A if B' cannot explain these results.

The suppositional theory of conditional reasoning (Evans, Over & Handley, 2003; Evans, Handley & Over, 2003; Evans & Over, in press) also cannot account for our findings on 'only if', or any of the other findings in this thesis. This theory is an extension of, and has developed from, dual process accounts of reasoning (Evans & Over, 1996). Dual process accounts suggest that there are two systems underlying reasoning. System 1, or the implicit system, consists of sets of domain-specific knowledge that operate relatively

independently, and includes things like instinctive behaviours (Stanovich, 1999). These sets of knowledge are acquired by a domain-general learning mechanism. Evans and his colleagues suggest that this system is old in evolutionary terms and is shared with other animals. System 2, they suggest, has evolved much more recently and is uniquely human. It is a slow system, by comparison with system 1, and operates in a sequential manner. It makes use of the central working memory system and it is therefore limited in processing capacity. This system is also called the explicit system and is linked to language, hypothetical thinking, reflective consciousness and reasoning.

The suppositional theory of reasoning is an account of reasoning using system 2. Evans et al (2003) suggest that people form representations of hypothetical possibilities or a 'mental model'. On the surface, this suggestion would seem to be very similar to the mental model theory. However, the suppositional theory is guided by three principles of hypothetical thinking which are not consistent with the mental model theory.

The first principle is the singularity principle. This states that people only consider one hypothetical possibility or mental model at a time. The second principle is the relevance principle which states that people consider the model that is most relevant in the current context. The third principle is the satisficing principle which states that models are evaluated with reference to the current goal and accepted if satisfactory. These principles are not supported by our findings however. For example, our data show that reasoners keep two possibilities in mind for both 'only if' conditionals and counterfactual conditionals. This is clearly not compatible with the singularity principle.

In summary, although there may be individual differences in the representation of 'only if' with some reasoners keeping the possibilities in mind in the direction of A to B, the evidence is broadly consistent with our account of 'only if', that is that people keep both an affirmative and negative possibility in mind from the direction of B to A ('B and

A' and 'not B and not A'). We have provided some support for this account using two different types of tasks. The data from our experiments, and previous research, are not readily explained by alternative accounts of 'only if'.

Other Linguistic Forms and Counterfactual Conditionals

The two experiments reported in this chapter were carried out as part of a larger set of experiments investigating counterfactual reasoning and linguistic form (Garcia-Madruga, Byrne, Egan, Moreno, Quelhas & Juhos, 2004). The experiments reported in this chapter investigated the linguistic forms 'if then' and 'only if'. Two further experiments have been conducted in collaboration with colleagues in Spain and Portugal investigating other linguistic forms such as 'not A unless B' (e.g., Colette would not have been in Dublin unless Martin had been in Wexford) and 'if not B then not A' (e.g., if Martin had not been in Wexford then Colette would not have been in Dublin).

Before describing the findings of these two experiments it is necessary to introduce the 'unless' linguistic form, as it was used in both of the experiments. Although 'not A unless B' (e.g., Colette is not in Dublin unless Martin is in Wexford), and 'if A then B' (e.g., if Colette is in Dublin then Martin is in Wexford) are logically equivalent (they are both made false in the situation where Colette is in Dublin and Martin is not in Wexford), they do not appear to be psychologically equivalent. It has been suggested that it is more plausible to consider 'not A unless B' to be equivalent to 'if not B then not A' (e.g., if Martin is not in Wexford then Colette is not in Dublin) (e.g., Quine, 1972; Reichenbach, 1947). In fact 'not A unless B' may be closely related to 'not A except if B' (e.g., Colette is not in Dublin except if Martin is in Wexford) (Geis, 1973) and to 'A only if B' (e.g., Colette is in Dublin only if Martin is in Wexford) (Fillenbaum, 1986; see also Wright & Hull, 1986, 1988).

Psychological studies of 'unless' have been few (Fillenbaum, 1986; Wright and Hull, 1986; 1988). But what has been established is that reasoners make fewer inferences overall from 'not A unless B' compared to 'if A then B', 'A only if B', and 'if not B then not A' (Carriedo et al, 1999; García-Madruga *et al*, 2002; see also García-Madruga, Carriedo, Moreno, & Schaeken, 1998; Schaeken, García-Madruga & D'Ydewalle, 1997). A typical error that also arises from reasoning with an 'unless' assertion is drawing an asymmetric conclusion, i.e., not A therefore B (e.g., Colette is not in Dublin therefore Martin is in Wexford) (Garcia-Madruga et al, 2002; Schaeken et al, 1997).

One of the experiments carried out with colleagues Christina Quelhas and Csongor Juhos of I.S.P.A., Lisbon, directly compared reasoning from 'only if' and 'unless' factual and counterfactual conditionals using an inference task (Garcia-Madruga *et al.*, 2004, Experiment 2). Similar to the method used in the inference task reported in this chapter, participants were presented with a conditional assertion, a minor premise corresponding to MP, MT, DA or AC and then had to select a conclusion from a list of three choices. The experiment provided three main results. First, it replicated our predicted finding that there was no difference between the factual and the counterfactual group for any of the inferences from 'only if' conditionals (overall: 85% versus 87%). This finding lends further support to our suggestion that reasoners keep two possibilities in mind for 'only if' from the outset, for both factual and counterfactual conditionals (B and A, not B and not A). Secondly, the experiment also showed that there were very few differences between the factual and counterfactual groups for any of the inferences from 'unless' (overall: 66% versus 72%). This finding supports the idea that reasoners keep two possibilities in mind from the outset for both factual and counterfactual 'unless' (B and A, not B and not A). The third finding was that overall reasoners made less inferences from 'unless' than 'only if' in both the factual group (66% versus 85%) and the counterfactual group (72% versus

87%).

The other experiment carried out in collaboration with colleagues, Juan Garcia-Madruga of UNED, Madrid, and Sergio Moreno-Rios of Granada University, directly compared reasoning from 'if not B then not A' and 'unless' factual and counterfactual conditionals, again using an inference task with a similar method to the inference task reported in this chapter (Garcia-Madruga *et al.*, 2004, Experiment 3). The results of this experiment concerning 'unless' replicated those of the experiment described above (Garcia-Madruga *et al.*, 2004, Experiment 2). There was no difference between the factual and counterfactual group in the endorsement of any of the inferences from 'unless' (overall: 66% versus 70%). However, there was a predicted difference between the factual and counterfactual groups for 'if not B then not A': reasoners endorsed more negative inferences in the counterfactual than the factual group (75% versus 64%). This finding is similar to typical findings with factual and counterfactual 'if then' conditionals, that reasoners endorse more negative inferences from the counterfactual than the factual conditional (e.g., Byrne & Tasso, 1999). Although 'not A unless B' may be logically equivalent to 'if not B then not A' (Quine, 1972; Reichenbach, 1947), psychologically the two assertions appear to be interpreted quite differently. Based on the comparison of the factual and counterfactual versions of the conditionals it seems that 'if not B then not A' is more similar to 'if A then B' than 'not B unless A', because reasoners only keep one possibility in mind from the outset rather than two for 'if not B then not A'.

We proposed that reasoners keep in mind two possibilities to understand a factual 'unless' assertion (B and A, not B and not A) but just one possibility for 'if not B then not A' (not B and not A). Reasoners keep two possibilities (B and A, not B and not A) in mind for both counterfactual 'unless' and counterfactual 'if not B then not A'. The experiments reported in this chapter also show that reasoners initially keep two possibilities, 'B and A'

and 'not B and not A', in mind for counterfactual 'only if' and they keep in mind initially the two possibilities 'A and B' and 'not A and not B' for counterfactual 'if then' (see Table 4.5).

Table 4.6: A summary of the initial possibilities reasoners keep in mind for factual and counterfactual 'if then', 'only if', 'unless' and 'if not then'.

	Factual	Counterfactual
If A then B	A B ...	A B Not A not B ...
A only if B	B A Not B not A ...	B A Not B not A ...
Not A unless B	B A Not B not A ...	B A Not B not A ...
If not B then not A	Not B not A ...	B A Not B not A ...

Although reasoners keep two possibilities in mind (an affirmative and a negative one) for the counterfactual versions of these four linguistic forms (unless, if not then, only if, if then), differences in reasoning still arose (Garcia *et al.* 2004). For example, the inference experiment reported in this chapter comparing 'if then' and 'only if' showed some effect of the direction of the possibilities kept in mind. The experiment comparing 'only if' and

'unless' showed that reasoners endorsed fewer inferences from counterfactual 'unless' than 'only if'. These findings demonstrate that even though people keep in mind both the counterfactual conjecture and the presupposed facts for a counterfactual conditional, some differences in reasoning still arise.

Conclusion

The results of the two experiments reported in this chapter are consistent with previous findings (e.g., Byrne & Tasso, 1999) of a difference between factual and counterfactual 'if then' conditionals. More negative inferences were endorsed from, and the negative possibility was considered consistent more often for counterfactual than factual 'if then' conditionals. We have provided a new account of how people understand and represent 'only if' conditionals. The new account lead to novel predictions concerning the comparison of factual 'only if' with factual 'if then' and with counterfactual 'only if'. Our results show that the same rate of inferences were endorsed from factual and counterfactual 'only if', but more backwards and negative inferences were endorsed from factual 'only if' than factual 'if then'. Finally, and most importantly, we have shown that linguistic form plays a role in reasoning from counterfactual conditionals, just as it does for factual conditionals.

Chapter 5: General Discussion

Our primary aim in this thesis was to investigate conditional reasoning from counterfactuals (e.g., if Rosanna had been in Dublin then Anthony would have been in Longford) and to contribute to the body of research in both conditional reasoning and counterfactual thinking. The ability to reason conditionally is essential to everyday life and without it we would be unable to make plans or generalise from one situation to another (Johnson-Laird & Byrne, 1991). Counterfactual thinking is also an important part of daily life that has implications for emotions such as guilt and shame (Mandel, 2003) and for learning from past mistakes (Roese, 1994). Despite the fact that people regularly and spontaneously generate counterfactual thoughts (Kahneman & Tversky, 1982) very few studies have investigated how people reason from counterfactual conditionals until recently (e.g., Byrne & Tasso, 1999).

In this thesis we examined the role of content, tense and linguistic form in reasoning from counterfactual conditionals. We used a variety of tasks to examine these factors in order to obtain converging evidence regarding the possibilities people keep in mind when reasoning from counterfactual conditionals. The eight experiments reported in the previous chapters were guided by the mental model theory of conditional reasoning (Johnson-Laird & Byrne, 1991; 2002), as it is the only theory of conditional reasoning to have provided a corroborated account of reasoning from counterfactual conditionals. Although the primary aim of this thesis was to investigate counterfactual conditionals the experiments also investigated factual conditionals (e.g., if Rosanna was in Dublin then Anthony was in Longford) and each chapter considered the implications of these findings for other theories of conditional reasoning, such as formal inference rule theories (e.g., Braine & O'Brien 1991; 1998), domain-specific rule theories (Holyoak & Cheng, 1985) and the probabilistic theory (Oaksford & Chater, 1994).

This chapter is divided into four main sections. The first section summarises the main findings of the experiments investigating the role of content, tense and linguistic form and the implications of these findings for theories of conditional reasoning. The second section considers the implications of the work presented in the thesis for advancing our understanding of counterfactual conditionals and the mental model theory. The third section considers some of the strengths and limitations of this piece of work and the final section makes some suggestions for future work.

Summary

We summarise the findings for content, tense and linguistic form in turn in turn in this section.

The role of content in reasoning from counterfactual conditionals

Summary of findings

The aim of the three experiments reported in Chapter 2 was to investigate the role of content, specifically inducements, in reasoning from counterfactual conditionals. There is a wealth of research that shows that content plays a role in reasoning from factual conditionals (see Evans *et al.*, 1993, for a review). Some recent research has investigated reasoning from causal, definitional and deontic content counterfactual conditionals (e.g., Thompson & Byrne, 2002; Quelhas & Byrne, 2003). We investigated counterfactual conditionals with inducement content (i.e., promises and threats) because promises and threats specify an action and the outcome of that action (e.g., if you mow the grass then I will pay you 10 euro) and the counterfactual thoughts that people generate are often to undo actions and their outcomes (e.g., Kahneman & Tversky, 1982). Also, the study of

counterfactual promises and threats (e.g., if you had mowed the grass then I would have paid you 10 euro) may provide us with an insight into how counterfactual conditionals are used in everyday language.

Experiment 1 examined the inferences that factual and counterfactual promises and threats invite. Participants received both factual and counterfactual promises and threats (e.g., Laura's mother said to her 'if you mow the lawn then I will pay you 10 euro') and were then asked what, if anything, they thought would happen. Participants could select from a list of 5 responses such as 'Laura will definitely mow the lawn' (an invited inference to the truth of the antecedent) or 'Laura will definitely not mow the lawn' (an invited inference to the falsity the antecedent). We expected that factual promises would invite an inference to the truth of the antecedent (A) but that counterfactual promises would invite an inference to the negation of the antecedent (not A) because this information is presupposed by the counterfactual conditional. We expected that factual threats would invite an inference to the falsity of the antecedent (not A) as would counterfactual threats.

The results of Experiment 1 supported our hypotheses. The results showed that factual promises (e.g., if you mow the lawn then I will pay you 10 euro) invite an inference to the truth of the antecedent (e.g., you will mow the lawn) (95%) as we expected. We suggested that this invited inference would encourage reasoners to initially keep in mind a single affirmative possibility (e.g., mow the lawn and paid 10 euro) from the outset for a factual promise. Counterfactual promises on the other hand (e.g., if you had mowed the lawn then I would have paid you 10 euro) invited an inference to the falsity of the antecedent (84%) (e.g., you did not mow the lawn) as we expected. We suggested that for counterfactual promises reasoners would initially keep in mind both the affirmative possibility corresponding to the conjecture (mow the lawn and paid 10 euro) and the

negative possibility corresponding to the presupposed facts (e.g., do not mow the lawn and not paid 10 euro) when thinking about counterfactual promises.

Factual threats (e.g., if you hit your sister then I will ground you) invited an inference to the falsity of the antecedent (92%). We suggested that this invited inference would encourage reasoners to keep two possibilities in mind from the outset when thinking about factual threats: an affirmative possibility corresponding to the information in the threat (e.g., hit sister and grounded) and a negative possibility corresponding to the invited inferences (e.g., do not hit sister and not grounded). Counterfactual threats (e.g., if you had hit your sister then I would have grounded you) also invited an inference to the falsity of antecedent (90%), as expected. Based on this finding we suggested that reasoners keep two possibilities in mind from the outset for counterfactual threats corresponding to the conjecture and the presupposed facts (e.g., hit sister and be grounded, do not hit sister and not grounded).

Experiment 2 tested our predictions regarding the possibilities people keep in mind for factual and counterfactual promises and threats using an inference task. In this task reasoners were presented with a conditional (e.g., if you hit your sister then I will ground you) and some additional information that corresponded to the minor premise for the MP, MT, DA or AC inference (e.g., the child was grounded). Reasoners were then asked what they could conclude and had to choose their response from a set of 3 options (e.g., the child hit her sister, the child did not hit her sister, the child may or may not have hit her sister). Participants were randomly assigned to the factual or the counterfactual group (or one of two control groups: the factual control group or the counterfactual control group) and received both promises and threats.

The results of Experiment 2 showed that reasoners endorsed more affirmative than negative inferences from factual promises (95% versus 69%), consistent with our

suggestion that reasoners keep a single affirmative possibility in mind from the outset for factual promises. In contrast, reasoners endorsed more negative than affirmative inferences from counterfactual promises (86% versus 66%). We suggested that reasoners keep both an affirmative and a negative possibility in mind from the outset for counterfactual promises and therefore did not expect a difference between the rates of affirmative and negative inferences. The results suggest however, that reasoners may just keep a single *negative* possibility in mind from the outset for counterfactual promises.

The results of Experiment 2 also showed that there were no differences in the rates of affirmative (83%) and negative (77%) inferences from factual threats. This finding is consistent with our suggestion that reasoners keep both an affirmative possibility and a negative possibility in mind from the outset to understand factual threats. For counterfactual threats, however, reasoners endorsed more negative (86%) than affirmative (67%) inferences from counterfactual threats. This result suggests that reasoners just keep a single *negative* possibility in mind from the outset for counterfactual threats, similar to counterfactual promises.

In Experiment 3 we gave participants a consistency judgement task. They were randomly assigned to the factual or the counterfactual group (or one of two control groups) and received both promises and threats. Each problem consisted of a conditional assertion followed by four possibilities listed in random order (A and B, not A and not B, not A and B, A and not B). Participants had to judge if each possibility was consistent, inconsistent or irrelevant with regard to the conditional assertion.

The results showed that the majority of reasoners interpreted both factual and counterfactual promises and threats as biconditionals, that is, they only considered the 'A and B' and 'not A and not B' possibilities to be consistent (factual promises: 90%; counterfactual promises: 62%; factual threats: 83%; counterfactual threats: 62%).

However, for counterfactual inducements a significant minority of reasoners arrived at a one model interpretation, that is, only the 'A and B' or the 'not A and not B' possibility was judged as consistent. This pattern emerged for both counterfactual promises (37%) and counterfactual threats (35%), more so than for factual promises (17%) or factual threats (8%).

Other theoretical accounts of findings

In Chapter 2 we considered how some of the other major theories of conditional reasoning might attempt to explain our findings from Experiments 1, 2 and 3. Specifically we considered the implications of the results for the formal inference rule theories of reasoning (e.g., Braine & O'Brien, 1991; Rips, 1994), the domain-specific rule theories of reasoning (e.g., Fiddick, Cosmides & Tooby, 2000; Holyoak & Cheng, 1995) and the probabilistic theory of reasoning (e.g., Oaksford & Chater, 2001). None of these theories provide an adequate account of our findings.

The formal inference rule theories of conditional reasoning (e.g., Braine & O'Brien, 1991) suggest that people have an internal set of logic-like rules for reasoning. The most important factor in reasoning, therefore, is the form of the problem. The form of promises and threats is the same (i.e., if A then B) and therefore there should be no difference between them in reasoning according to a formal inference rule theorist. The findings reported in Chapter 2 do not support this idea. For example, reasoners endorsed more affirmative inferences than negative inferences from factual promises but the same amount of affirmative inferences and negative inferences for factual threats. The formal inference rule theories cannot adequately account for content effects in reasoning without drawing on other theories, such as domain-specific theories.

The domain-specific rule theories of reasoning (e.g., Cosmides, 1989; Cheng &

Holyoak, 1985) suggest that people reason about situations using schemas that are specific to those situations. These theories have difficulty accounting for differences that arise in reasoning when there are no differences in the content of the problem. Consider for example factual (e.g., if you mow the lawn then I will pay you 10 euro) and counterfactual (e.g., if you had mowed the lawn then I would have paid you 10 euro) promises. The content of both is the same (a promise) but they differ in tense and mood. Domain-specific theories do not make any predictions regarding the role of tense or mood in reasoning and therefore cannot explain the differences we observed between factual and counterfactual promises (e.g., they invite different inferences and the inference endorsement patterns are also different).

The probabilistic theory of reasoning (e.g., Oaksford & Chater, 2003) suggests that people reason by making choices that will give them the most information about a situation. The probabilistic theory has difficulty explaining the pattern of inferences in promises and threats Some recent work by Ohm & Thompson (2004) has shown that although people perceived there to be a high probability of the reward or punishment occurring if the action occurred (e.g., a high probability of the child being given 10 euro if they mowed the lawn), probability was not an important predictor of reasoning on a inference task. This finding poses a challenge to probabilistic theories if they are to account for, and predict, how people reason in everyday life.

The role of tense in reasoning from counterfactual conditionals

Summary of findings

The experiments reported in Chapter 2 raised an issue regarding the role of tense in reasoning from subjunctive conditionals. Specifically, people reasoned from present tense

antecedent, future tense consequent conditionals in the subjunctive mood (the counterfactual control group in Experiment 2 and 3) in a manner more similar to their indicative counterparts than to subjunctive past tense (i.e., counterfactual) conditionals. The three experiments reported in Chapter 3 investigated this matter further by examining the role of tense in reasoning from subjunctive conditionals. Tense has only recently begun to be explored as a factor in conditional reasoning (e.g., Byrne & Tasso, 1999; Schaeken *et al.*, 2001). Schaeken *et al.* (2001) found that there is no difference in reasoning from past tense, present tense and future tense indicative conditionals. They suggested that regardless of tense, for indicative conditionals people keep one possibility in mind, the affirmative one (A and B). Byrne and Tasso (1999) investigated past and present subjunctive conditionals and found no difference in reasoning from the two tenses. They suggested that both past and present subjunctive conditionals encourage reasoners to keep two possibilities in mind, an affirmative one corresponding to the conjecture (A and B) and a negative one corresponding to the presupposed facts (not A and not B).

The aim in Chapter 3 was to investigate future subjunctive conditionals, that is prefactual conditionals (e.g., if it were to rain tomorrow then Jonathan would bring an umbrella), which have not been considered before (Byrne & Egan, 2004). We predicted that, unlike past and present subjunctive conditionals (e.g., if it had rained then Jonathan would have brought an umbrella; if it were to rain then Jonathan would bring an umbrella), for future subjunctive conditionals people keep just one affirmative possibility in mind (e.g., rain tomorrow and Jonathan brings an umbrella) because the future tense does not convey any presupposed facts. We expected that the pattern of endorsed inferences, and possibilities judged as consistent, from future subjunctive conditionals should be more similar to future indicative conditionals rather than to past subjunctive conditionals.

Experiment 4 compared the possibilities reasoners judge to be consistent with

future and past indicative and subjunctive conditionals. Participants were randomly assigned to the indicative or subjunctive group. Half the conditionals they received were in the past tense and half were in the future tense. Each conditional (e.g., if it had rained then Jonathan would have brought an umbrella) was followed by one of four possible situations that could arise from the conditional (A and B, not A and not B, not A and B, A and not B) such as 'it did not rain and Jonathan brought an umbrella'. Participants had to judge if each possibility was consistent, inconsistent or irrelevant with regard to the conditional.

Our main prediction concerned the role of tense in reasoning from subjunctive conditionals. We predicted that there would be no difference in the number of consistent judgements for the 'A and B' possibility between the past and future subjunctive conditionals because reasoners should keep the 'A and B' possibility in mind for both. However, we predicted that there would be a difference for the 'not A and not B' possibility: reasoners should think it is consistent more often for the past than the future subjunctive conditional. We suggested that reasoners keep the negative possibility (not A and not B) in mind from the outset for past subjunctive conditionals (e.g., if it had rained then Jonathan would have brought an umbrella) because this information is presupposed by the conditional. We suggested that this information is not presupposed by future subjunctive conditionals (e.g., if it were to rain tomorrow then Jonathan would bring an umbrella) and reasoners therefore should not keep it in mind from the outset.

The results provided some support for these predictions. Reasoners considered the negative possibility (not A and not B) to be consistent somewhat more often with the past than the future subjunctive conditionals (67% versus 55%) and there was no difference for the affirmative possibility as expected (A and B: 99% versus 94%). In contrast to the subjunctive group, there were no differences between the past and the future conditionals in the indicative group for the negative possibility (55% versus 57%) or the affirmative

possibility (99% versus 99%) as we expected. This finding is consistent with Schaeken et al's (2001) study. We also predicted there would be no difference between the future indicative and the future subjunctive conditionals for both the affirmative possibility (A and B: 99% versus 94%) and the negative possibility (not A and not B: 57% versus 55%) because reasoners keep one possibility in mind for both (A and B). This hypothesis was supported. In contrast, the trend in the data showed a difference between the past indicative and past subjunctive conditionals for the negative possibility (not A and not B: 55% versus 67%) but not for the affirmative possibility (99% versus 99%). This result is consistent with the suggestion that reasoners keep one possibility in mind for past indicative conditionals but two possibilities in mind for past subjunctive conditionals.

Experiment 5 compared the inferences that are drawn from past and future indicative and subjunctive conditionals. As in Experiment 4, participants were randomly assigned to the indicative or subjunctive group and received both past and future tense conditionals. Participants were presented with a conditional (e.g., if it had rained then Jonathan would have brought an umbrella) followed by some additional information that either affirmed or negated the antecedent or the consequent of the conditional. This additional information corresponded to one of the four logical inferences, MP (e.g., it rained), AC (e.g., Jonathan brought an umbrella), MT (Jonathan did not bring an umbrella) or DA (e.g., it did not rain). After the additional information was presented for each conditional, participants had to indicate from a set of three options what, if anything, they could conclude. We also measured the time it took participants to endorse an inference.

We predicted that reasoners would endorse more of the negative inferences (MT and DA) from the past subjunctive conditionals than from the future subjunctive conditionals because reasoners keep the negative possibility in mind from the outset for the past subjunctive but not for the future subjunctive conditional. We did not expect to find a

difference between the past and the future subjunctive conditionals for the affirmative inferences (MP and AC) however because reasoners keep the affirmative possibility (A and B) in mind from the outset for both.

The results showed that reasoners made somewhat more of the negative MT inference from the past than the future subjunctive conditionals (73% versus 63%) although the difference was not reliable. There was no difference between the past and the future subjunctive conditionals for the negative DA inference (57% for both). Previous research has shown the increase in negative inferences from counterfactual conditionals to be somewhat labile (Thompson & Byrne 2002). As we predicted there was no difference between the past and the future subjunctive conditionals in the number of affirmative inferences endorsed (MP: 98% versus 95%; AC: 73% versus 75%). Comparing the past and the future indicative conditionals showed that there was no difference in endorsement rates of any of the inferences (MP: 92% versus 95%; AC: 72% versus 73%; MT: 53% versus 57%; DA: 55% versus 65%) as we expected.

We also predicted that because the future tense does not presuppose any information reasoners would keep the same possibility in mind for future indicative and future subjunctive conditionals (A and B). The results supported this hypothesis: there were no differences between the groups for any of the inferences (MP: 98% versus 95%; AC: 73% versus 75%; MT: 57% versus 63%; DA: 62% versus 57%). In contrast, reasoners made more of the negative MT inference (73% versus 53%) from the past subjunctive than the past indicative conditionals as we expected. Although they did not make significantly more DA inferences (57% versus 55%) they did make them slightly faster from the past subjunctive than the past indicative conditionals (9.02 versus 9.33). These findings support the suggestion that reasoners keep the negative possibility (not A and not B) in mind from the outset for counterfactual conditionals and are consistent with previous studies (e.g.,

Byrne & Tasso, 1999). There were few differences between the groups in the number of AC inferences endorsed (72% versus 73%) or in the number of MP inferences endorsed (98% versus 92%). Surprisingly, the difference between the past subjunctive and the past indicative conditionals for MP inferences was reliable.

Experiment 6 investigated what is implied by future indicative and future subjunctive conditionals. We considered conditionals with neutral content like that used in Experiments 4 and 5 (e.g., if Laura were in Dublin tomorrow then Mary would be in Galway) and also conditionals with fantasy-realistic content (e.g., if I win the lottery tomorrow then I will buy a yacht) in order to generalise the findings of the previous experiments to more realistic contents. Participants were randomly assigned to the indicative or the subjunctive group and received both neutral and fantasy realistic contents. They were then presented with a series of conditionals and after each one were asked what, if anything, they thought was implied by it, and they could select their response from a number of options. We predicted for both indicative and subjunctive conditionals that the majority of participants would indicate that nothing was implied. We also did not expect to find any differences between the groups for either the neutral or the fantasy-realistic contents because we suggested that future conditionals, regardless of content do not presuppose any information. We hypothesised that there would be no difference between the two contents.

The results supported our hypotheses. There were no differences between the indicative and subjunctive groups in any of the options selected as implied by the conditional (A: 14% versus 19%; B: 27% versus 32%; not A: 7% versus 14%; not B: 6% versus 9%). As we predicted the majority of participants indicated that nothing was implied by future conditionals (69% versus 63%) and there were very few differences between the neutral and fantasy-realistic contents in either the indicative group (64%

versus 73%) or the subjunctive group (59% versus 68%). The finding that nothing was implied by future subjunctive conditionals is different to findings with past subjunctive conditionals. With the latter the majority of participants typically indicate that the negated antecedent (not A) or negated consequent (not B) or both are implied (e.g., Thompson & Byrne, 2002). This experiment showed that future subjunctive conditionals are more like future indicative conditionals rather than like past subjunctive conditionals because people judge that nothing is implied by them.

The results of the three experiments reported in Chapter 3 provided support for the hypothesis that future subjunctive conditionals are represented the same way as future indicative conditionals. We found no difference between them on a selection of tasks that have previously shown differences between past indicative and past subjunctive conditionals (e.g., Thompson & Byrne, 2002). For future conditionals, regardless of the mood of the conditional, reasoners keep a single affirmative possibility in mind (A and B). These results provide some support for our hypothesis that future subjunctive conditionals do not convey any presupposed facts in the way past subjunctive conditionals do. Our results suggest that tense plays a role in reasoning from subjunctive conditionals, unlike indicative conditionals (Schaeken et al., 2001).

Other theoretical accounts of findings

In Chapter 3 we also considered the implications of our findings with future subjunctive conditionals for probabilistic (Oaksford & Chater, 1994), formal inference rule (e.g., Braine & O'Brien, 1991) and domain specific rule theories of conditional reasoning (e.g., Cosmides, 1989; Holyoak & Cheng, 1995). The domain specific rule theories have made no predictions regarding the role of tense in reasoning. Those predictions we can extrapolate from the theory are not supported by the experimental findings reported in

Chapter 3. Domain specific rule theories suggest that differences in reasoning arise due to different contents (such as those about permissions or obligations) invoking different reasoning schemas. However, in experiments 4 and 5 we used only neutral contents yet differences in reasoning still arose (e.g., between the past indicative and past subjunctive groups). Also, even when we did use two different types of content in experiment 6 (neutral and fantasy realistic) there were few differences between them.

The probabilistic theory (e.g., Oaksford & Chater, 2003) also does not make any predictions regarding the role of tense in conditional reasoning. However, given that the model is based on the probability of events, and the probability of future events occurring may be considered to be lower than the probability of past events having occurred, the theory may have difficulty accounting for our findings. To be consistent with our results, the probabilistic theory would have to propose that the probability of B given A is the same for past indicative, future indicative and future subjunctive conditionals? The idea seems counterintuitive. The mental model theory however, does not draw on the probabilities of events and therefore does not suffer from this criticism.

The formal inference rule theories of deductive reasoning (e.g., Braine & O'Brien, 1991) state that the form of the problem is important for reasoning. They can explain our finding that people reason from past indicative, future indicative and future subjunctive conditionals in a similar manner because all of the conditionals have the same basic form: if A then B. What they cannot explain however is that reasoning differs for past subjunctive conditionals. The form of the conditional is still the same (if A then B) yet reasoners tend to endorse more negative inferences and rate the negative possibility (not A and not B) as consistent more often following a past subjunctive conditional than a future subjunctive conditional or a past indicative conditional. This finding is easily explained by the mental model theory because the past subjunctive conditional conveys information

about the presupposed facts of the situation and therefore reasoners keep in mind from the outset the negative possibility that corresponds to the presupposed facts. Past indicative and future subjunctive conditionals do not convey any presupposed facts and reasoners therefore do not keep the negative possibility in mind from the outset for these conditionals.

The domain specific rule theories, the probabilistic theory and the formal inference rule theories all struggle with aspects of the results reported in Chapter 3. The mental model theory however, is consistent with the findings that tense plays a role in reasoning from subjunctive conditionals but not indicative conditionals, based on the possibilities that reasoners keep in mind.

The role of linguistic form in reasoning from counterfactual conditionals

Summary of findings

The final factor we considered in reasoning from counterfactual conditionals was linguistic form. Experiments 1 to 6 all investigated counterfactual conditionals of the linguistic form 'if A then B'. However, counterfactual thoughts are not necessarily only in this form. People can counterfactual thoughts in other forms such as 'A only if B' or 'not A unless B' (e.g., Anna would have been in Dublin only if Joe had been in Galway; Anna would not have been in Dublin unless Joe had been in Galway). Previous research has shown that different linguistic forms, such as 'only if' and 'unless', influence the possibilities people initially keep in mind for factual conditionals (e.g., Garcia-Madruga, Carriedo, Moreno-Rios & Schaeken, 1998; Evans & Beck, 1981). Chapter 4 investigated if linguistic form also influences the possibilities people keep in mind for counterfactual conditionals. We carried out two experiments that compared factual and counterfactual reasoning from 'if

then' and 'only if'.

Our main prediction in this series of experiments concerned counterfactual 'only if' and counterfactual 'if then'. Previous research (e.g., Byrne & Tasso, 1999) shows that for counterfactual 'if then' (e.g., if David had been in Wicklow then Gary would have been in Limerick) reasoners keep in mind two possibilities in the direction of A to B, an affirmative possibility (David in Wicklow and Gary in Limerick) and a negative possibility (David not in Wicklow and Gary not in Limerick). We suggested, on the basis of previous research with factual 'only if' (e.g., Evans & Beck, 1981; Garcia-Madruga et al, 1998) that for counterfactual 'only if' reasoners keep in mind two possibilities, an affirmative one and a negative one in the direction of B to A (e.g., Joe in Galway and Anna in Dublin, Joe not in Galway and Anna not in Dublin). A second prediction in this series concerned factual 'only if'. We proposed that for factual 'only if', like counterfactual 'only if' reasoners also keep two possibilities in mind from the outset in the direction of B to A. First we tested the hypothesis that reasoners keep two possibilities in mind from the outset for both factual and counterfactual 'only if' using a consistency judgement task in Experiment 7. We then investigated the influence of the direction of the possibilities people keep in mind (i.e., from A to B or from B to A) on the inferences that they draw (Experiment 8).

Experiment 7, a consistency judgement task, compared the possibilities people judge to be consistent with factual and counterfactual 'only if' and 'if then'. Participants were randomly assigned to the factual or the counterfactual group and received both 'if then' and 'only if' conditionals. Each conditional was followed by four possibilities (e.g., A and B, not A and not B, not A and B, A and not B) presented in random order for each problem. For each possibility participants had to indicate if it was consistent, inconsistent or irrelevant with regard to the conditional assertion. We did not expect to find a difference between counterfactual 'if then' and counterfactual 'only if' in the possibilities participants

judged to be consistent because they keep an affirmative and a negative possibility in mind for both. For the same reason, we also did not expect to find a difference between factual and counterfactual 'only if'. We did however expect that participants would judge the negative possibility to be consistent more often following a factual 'only if' than a factual 'if then' conditional because reasoners keep this possibility in mind from the outset for 'only if' but not 'if then'.

The results supported our predictions. Firstly they showed that there were few differences in the possibilities participants judged as consistent between counterfactual 'if then' conditionals and counterfactual 'only if' conditionals as we expected, because reasoners keep an affirmative and a negative possibility in mind for both (A and B: 100% versus 100%; not A and not B: 90% versus 89%; not A and B: 0% versus 13%; A and not B: 0% versus 0%). However, a comparison of the two linguistic forms in the factual group revealed that more people considered the negative possibility (not A and not B: 70% versus 58%) to be consistent with 'only if' than 'if then', as we expected because people keep the negative possibility in mind from the outset for 'only if' but not for 'if then'.

One surprising finding that emerged in Experiment 7 was that reasoners judged the negative possibility to be consistent more often following counterfactual than factual 'only if' (89% versus 70%). We suggested this finding may have resulted from the direction of the response options in the task: they were all in the direction of A to B rather than B to A to control for the order. The direction of the possibilities reasoners keep in mind for 'only if' is B to A. We hypothesised that the consistent judgements were somewhat suppressed in the factual group because of the direction of the response options. We suggested that the rate was not suppressed in the counterfactual group however because the counterfactual conditional conveys in addition the information about the presupposed facts of the situation, which correspond to the negative possibility.

We tested this hypothesis in Experiment 8 by giving reasoners an inference task. In this task reasoners were presented with inferences of both a forwards direction (where the inference is drawn in the direction of A to B, e.g., MP) and a backwards direction (where the inference is drawn in the direction of B to A, e.g., MT). We predicted that there would no differences in reasoning from factual and counterfactual 'only if' on this task. In contrast we predicted that reasoners would endorse more negative inferences (MT and DA) from counterfactual than factual 'if then' conditionals because they keep the negative possibility in mind from the outset for the counterfactual but not the factual. Finally, we predicted that differences in reasoning would arise between counterfactual 'only if' and counterfactual 'if then' because even though reasoners keep two possibilities in mind for both, the direction of these possibilities differs for the two linguistic forms.

Firstly, the results showed that there was no difference in the inferences reasoners endorsed from factual and counterfactual 'only if' (MP: 95% versus 98%; MT: 84% versus 73%, DA: 96% versus 92%; AC: 79% versus 68%). This finding supports our suggestion that reasoners keep two possibilities in mind for both factual and counterfactual 'only if' from the outset. Secondly, the results showed that reasoners endorsed more of the negative DA inference (84% versus 63%) from counterfactual than factual 'if then' conditionals and there were no differences between the groups for the affirmative inferences (MP: 100% for both; AC: 67% for both). This finding is consistent with previous research (e.g., Byrne & Tasso, 1999). Although we did not find an increase for MT in the counterfactual group as expected, we suggest that this may be because MT was already endorsed at a high rate, perhaps close to ceiling level, in the factual group (79%). Finally, the comparison of counterfactual 'only if' and counterfactual 'if then' revealed some effects of the direction of the possibilities people keep in mind. For example, reasoners endorse more of the backwards MT inference (92% versus 71%), less of the forwards DA (68% versus 84%)

inference and made the forwards DA and MP more slowly (9.00 versus 8.72; 8.85 versus 8.57 respectively) from counterfactual 'only if' than 'if then'.

Overall, the results of the two experiments, in conjunction with the results of the experiments on counterfactual 'not A unless B' and 'if not B then not A' (Garcia-Madruga et al, 2004) described in Chapter 4, provided some support for our suggestion that linguistic form plays a role in reasoning from counterfactual conditionals. Some support was found for this hypothesis even though reasoners keep two possibilities in mind, an affirmative and a negative one, for counterfactual conditionals for a number of different linguistic forms. Experiments 7 and 8 also provided support for our new account of 'only if', that reasoners keep two possibilities in mind from the outset in the direction of B to A (e.g., B and A, not B and not A).

Other theoretical accounts of findings

As described in Chapter 4 none of the other theories of reasoning can adequately explain our findings. The formal inference rule theories (e.g., Braine & O'Brien, 1991; Rips, 1994), the domain specific theories (e.g., Fiddick, Cosmides & Tooby, 2000; Holyoak & Cheng, 1995) and the probabilistic theory (e.g., Oaksford & Chater, 2003) have considered the role of linguistic form in reasoning from factual conditionals (e.g., Mary is in Dublin only if Tony is in Cork) to varying degrees.

Cheng and Holyoak (1985) considered the use of 'only if' in permission rules such as the action is to be taken only if the precondition is satisfied. They compared these 'only if' permission rules to 'if then' permission rules (e.g., if the action is to be taken then the precondition must be satisfied) using the Wason selection task. They found that reasoners were more accurate (i.e., selected the correct combination of cards on the Wason selection task) when reasoning from 'if then' than 'only if'. Cheng and Holyoak do not detail how

they would expect reasoners to perform on other types of tasks such as an inference task so it is difficult to determine what they might predict in this regard. However, given their finding that reasoning is more accurate from 'if then' than 'only if' for the selection task, this finding might suggest that therefore reasoners should make more of the valid inferences (i.e., MP and MT) than the invalid inferences from 'if then' than 'only if'. Neither previous research (e.g., Evans, 1977; Johnson-Laird & Byrne, 1989), nor the findings reported in Chapter 4 show that this difference emerges between 'if then' and 'only if' conditionals.

The probabilistic theory has also considered factual 'only if' conditionals (e.g., Oaksford & Chater, 2003). Oaksford and Chater (2003) did not make any predictions regarding how people might reason from 'only if' but rather tried to model the results of a previous study of 'only if' (Evans, 1977). Their attempt at modelling Evans' findings however was not entirely successful. The probabilities and parameters they set for the model did not produce the pattern of inferences as was found in Evans' (1977) study.

The formal inference rule theories (e.g., Braine & O'Brien, 1991) suggest that the form of the problem is the most important factor in determining reasoning performance. Based on this idea it would initially seem that formal inference rule theories should be able to account for our data and previous findings that show systematic differences in reasoning from difference linguistic forms (e.g., Garcia-Madruga et al, 2002; Schaeken et al 1997). In fact, they have provided an account of 'only if' which suggests that reasoners understand it as 'if not B then not A', which explains why MT (not B therefore not A) is made more easily from 'only if' than 'if then'. However, this account of 'only if' does not hold up to examination. On this account MP (A therefore B) should then become more difficult to make because it is in fact MT from 'if not B then no A' and it is not, as our findings, and those of previous studies show (e.g., Evans, 1977).

None of these three theories of conditional reasoning, the domain specific, the probabilistic or the formal inference rule theories, provide a satisfactory explanation for experimental findings regarding 'only if'. The mental model theory has explained the typical pattern of inferences that are drawn, and the possibilities that are judged consistent with 'only if'. The findings are consistent with the proposed possibilities that reasoners keep in mind from the outset for 'only if'. Our novel suggestion is that to understand 'only if', regardless of whether the conditional is phrased in the factual or counterfactual mood, people keep in mind two possibilities in the direction of B to A (B and A, not B and not A).

Implications

Implications for Counterfactual Conditionals

The work presented in this thesis has added to our body of knowledge about counterfactual conditionals in a number of ways such as how people think about realistic events, the role counterfactual conditionals may play in everyday language, and how counterfactual conditionals are similar and different to factual conditionals with regards to the factors that influence the possibilities people keep in mind. This section considers what contribution has been made to our knowledge about counterfactual conditionals as a result of the research in this thesis.

Firstly, the work in this thesis showed that counterfactual conditionals are similar to factual conditionals in some of the factors that modulate the possibilities people keep in mind. For example, previous research has shown that the content of a factual conditional affects the number of possibilities reasoners keep in mind from the outset. The work in this thesis showed the same to be true of counterfactual conditionals. In general, when reasoners represent a counterfactual conditional they initially keep in mind two

possibilities from the outset, an affirmative and a negative one, corresponding to counterfactual conjecture and the presupposed facts respectively. This result had been found for counterfactual conditionals with neutral, causal and definitional content (Thompson & Byrne, 2002). However, the results of the experiments in Chapter 2 show that reasoners only keep one possibility in mind from the outset for counterfactual conditionals with inducement content. They initially keep in mind the negative possibility, the presupposed facts. This finding shows that like factual conditionals, the possibilities people keep in mind for counterfactual conditionals are modulated by content (Johnson-Laird & Byrne, 2002).

Counterfactual conditionals are also similar to factual conditionals in that they are affected by the linguistic form of the conditional. Previous research has established that the linguistic form of the conditional can greatly affect reasoning, such as the inferences that reasoners draw (e.g., Evans 1977; Evans & Beck, 1981; Garcia-Madruga et al, 1997). The experiments on 'only if' reported in Chapter 4 showed that even though reasoners keep two possibilities in mind for both counterfactual 'if then' and 'only if', differences still arose in reasoning. This finding was explained by the direction of the possibilities reasoners keep in mind, which is influenced by the linguistic form of the conditional. For example, regardless of whether 'if then' is phrased in the factual or counterfactual mood reasoners think about possibilities in the direction of A to B. In contrast, people think about the possibilities for 'only if' in the direction of B to A, regardless of whether it is phrased in the factual or counterfactual mood. Overall, the results of chapters 2 and 4 suggest that, like factual conditionals, the possibilities people keep in mind for counterfactual conditionals are modulated by content and linguistic form.

However, although both factual and counterfactual conditionals are modulated by content and linguistic form, not all factors that affect one, affect the other. For example, the

results reported in Chapter 3 showed that the possibilities reasoners keep in mind for subjunctive conditionals are affected by the tense of the conditional. In contrast, the possibilities people keep in mind for indicative conditionals are not affected by tense, as previous findings (e.g., Schaeken et al 2001) and our results show. Overall, the results of Chapter 3 suggest that, unlike indicative conditionals, subjunctive conditionals are affected by tense. The reason is that future tense subjunctive conditionals do not convey any presupposed facts, unlike past and present tense subjunctive conditionals.

The experiments reported in Chapter 2 also have implications for how people think about how realistic events could have been different. For realistic events, such as inducements about an action and the outcome of that action (i.e., promises and threats) reasoners keep in mind a single negative possibility from the outset that corresponds to the presupposed factual situation (not A and not B). They do not focus on the conjecture (A and B) mentioned in the counterfactual conditional (e.g., if you had been bold then I would have grounded you). This result has not been demonstrated before with counterfactual conditionals. With a realistic content reasoners may attend more to the facts of what actually happened (e.g., you were not bold and I did not ground you) rather than to the conjecture about what could have happened but did not (e.g., you were bold and I grounded you). Even though reasoners may easily and regularly generate counterfactual thoughts about what could have happened, when they reason they may tend to focus on the facts of what happened for inducements rather than on what could have happened.

The final implication of the results that we wish to consider for counterfactual conditionals is the role of counterfactuals in everyday language and conversations. Previous research has identified the importance of counterfactual thinking in everyday life for emotions (e.g., Mandel, 2003) and for learning (e.g., Roese, 1994). However, people do not only engage in counterfactual thinking; they also make counterfactual utterances.

Given that the events counterfactual utterances refer to have already taken place, the communicative function of counterfactual utterances in everyday language and conversational exchange is important to explore. One possibility, relating to counterfactual thinking, is that people utter a counterfactual such as 'if I had arrived on time I could have prevented the accident' in order to communicate their emotions to other people. For example, people often express their regret by uttering a counterfactual conditional, such as the previous example, rather than by just saying that they regret a particular action. Another possible function of counterfactual utterances, suggested by the results of the experiments in Chapter 2, may be to manipulate or guide the future behaviour of others. By making people aware of the outcomes of their potential actions, even though the action has not occurred, the awareness of the outcome may then increase, or decrease, the likelihood of the action being performed in the future.

Implications for the Mental Model Theory

The experiments in this thesis were guided by the mental model theory of conditional reasoning (Johnson-Laird & Byrne, 1991; 2002; Johnson-Laird, et al, 1992). This theory suggests that people reason by keeping in mind possibilities. Given that the mental model theory is the only theory to have provided a corroborated account of reasoning from counterfactual conditionals it was the obvious theoretical background for the research in this thesis. One of the aims of the thesis was to test the mental model theory and extend it to account for the various factors that play a role in reasoning from counterfactual conditionals. In this section we consider the role played by semantics and pragmatics in modulating the possibilities reasoners keep in mind.

Johnson-Laird and Byrne (2002, p. 13) state that 'the meaning of the antecedent and consequent, and co-referential links between these two clauses, can add information to

the models, prevent the construction of otherwise feasible models of the core meaning, and aid the process of constructing fully explicit models'. They call this idea the principle of semantic modulation. The principle of pragmatic modulation, which makes claims about the effects of general knowledge on the possibilities people keep in mind, proposes that the modulation of a conditional 'depends on general knowledge in long-term memory and knowledge of the specific circumstances of its utterance. This context is normally represented in explicit models. Those models can modulate the interpretation of a conditional, taking precedence over contradictory models. They can add information to models, prevent the construction of otherwise feasible models, and aid the process of constructing fully explicit models' (Johnson-Laird & Byrne, 2002, p. 14).

The principles of semantic modulation and pragmatic modulation propose that the possibilities people keep in mind for a conditional (if A then B) are affected by the meaning of the antecedent (A) and the consequent (B), the relationship between these variables and by knowledge of the context in which the conditional occurs. Consider for example the conditional 'Rosanna is in Dublin only if Tony is in Longford'. 'Only if' emphasises the necessity of the consequent for the antecedent, that is, the necessity of Tony being in Longford if Rosanna is in Dublin. This necessity leads to the modulation of possibilities in two ways. Firstly, instead of reasoners keeping in mind the possibility 'Rosanna in Dublin and Tony in Longford' (A and B) they keep in mind the possibility 'Tony in Longford and Rosanna in Dublin (B and A). This change in the direction (from A to B, to B to A) of the possibilities reasoners initially keep in mind leads to systematic differences in reasoning when 'only if' is compared to 'if then'. Reasoners keep possibilities in mind for 'if then' in the direction of A to B. As a result, reasoners endorse more inferences in the direction of B to A for 'only if' than for 'if then' (e.g., AC: Tony is in Longford, therefore Rosanna is in Dublin). We demonstrated this effect in Experiment 8,

for example, and it has also been shown in previous studies (e.g., Evans & Beck, 1981). The second way that semantic and pragmatic modulation affects the possibilities people keep in mind for 'only if' is that, by emphasising the necessity of the consequent for the antecedent, reasoners are more likely to consider the possibility of 'Tony not in Longford and Rosanna not in Dublin' from the outset. This suggestion is supported by the finding in Experiment 8 that reasoners make more negative inferences (e.g., MT: Tony is not in Longford, therefore Rosanna is not in Dublin) from 'only if' than 'if then'.

The idea that semantics and pragmatics can modulate the possibilities that reasoners keep in mind is also evident in the experiments investigating inducements reported in Chapter 2. For example, in Experiment 1 we found that the value of the outcome for an action (i.e., whether the action was to be rewarded or punished) led to different invited inferences for promises and threats. We also found that promises and threats are interpreted as biconditional in Experiment 3. This finding means that people do not keep in mind the possibility where the consequent could occur without the antecedent (e.g., the situation where a person could be rewarded without having carried out the required action) (not A and B). This finding is unsurprising because given background knowledge, promises and threats would lose all force if a person could reap the reward without having carried out the required action.

In summary, the research presented in this thesis supports the principles of semantic modulation and pragmatic modulation. Our exploration of the factors that influence reasoning from counterfactual conditionals has also extended the mental model theory to counterfactual inducements, prefactual conditionals and counterfactual 'only if', as well as in the new account we provided for the possibilities kept in mind for factual inducements and in the new account of the representation of factual 'only if'.

Future Directions

In this section we discuss some of the strengths and weaknesses of the results and make some suggestions for future research.

One weakness is that some of the findings reported were weak, even though there was sufficient power in the experiments (80% power to detect a difference of .2 or less) in the thesis, as established by power tests, and yet some of the findings were weak. In a number of experiments we found results that tended to support our hypotheses but that failed to reach significance at the alpha .05 level4. First, although a number of results did not reach significance as predicted, on the whole the trends in each experiment supported our predictions. There were very few results that contradicted our predictions. Admittedly, these trends are not strong evidence in themselves. However, when considered across all eight experiments reported here, and in conjunction with the results that did reach significance we suggest that our account of the role of content, tense and linguistic form in reasoning from counterfactual conditionals is, broadly speaking, supported.

A strength of this thesis is in the past, studies of conditional reasoning set out to encourage participants to reason in a logical manner. Typically participants were given strict deductive reasoning instructions to enable them to reason more 'logically' on both inference tasks and truth table tasks, for example (see Evans & Thompson, 2004). These instructions ask participants to assume that the premises are true and to only draw necessary conclusions. Instructions are now often modified to ensure that participants give a more natural response (e.g., Ohm & Thompson, 2004), as is the case in the experiments reported in this thesis. These instructions allow the influence of uncertainty and

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4 Should a finding that is not significant at the alpha .05 level or less be discarded? When significance testing was introduced by R.A. Fisher (see Goodman, 1993, 1999; Lehmann, 1993) it was intended to give an indication of the strength of the evidence against the null hypothesis, not as an all or nothing test of significance. Fisher strongly argued that the interpretation of a p-value was ultimately for the researcher.

background knowledge in deductive reasoning tasks (Evans & Thompson, 2004) thereby giving them greater ecological validity. Newer tasks (e.g., asking participants to judge probabilities of conditionals, or the prediction task and the implications task used in this thesis) also allow researchers to learn more about conditionals without measuring participant's responses against formal logic norms. Although some of the tasks used may still seem somewhat artificial, the modified instructions (i.e., that do not instruct the participants to only draw necessary conclusion), combined with the new tasks, help provide an insight into everyday reasoning in a controlled manner.

The work presented in this thesis arose primarily out of research in the domain of conditional reasoning. It has drawn on findings from studies of reasoning with factual conditionals to investigate whether similar factors play a role in reasoning with counterfactual conditionals. We suggest that future work on reasoning from counterfactual conditionals should draw more on the counterfactual thinking literature, for example the types of events people mutate. Research shows that people tend to undo the past in a typical manner. For example, people undo controllable rather than uncontrollable events (Girotto, Legrenzi & Rizzo, 1991), exceptional rather than routine events (Kahneman & Tversky, 1982), the first event in a causal sequence of events (Wells, Taylor & Turtle, 1987) but the last in a temporal sequence (Miller & Gunasegaram, 1990). We suggest future experiments could be guided by these factors to investigate if people reason differently about counterfactual conditionals that are typical (e.g., about a controllable event) or non-typical (e.g., about an uncontrollable event). For example, a typical scenario investigating the events people mutate is about a man driving home from work who is delayed by a number of factors and gets home late to find that his wife has just died from a heart attack. The typical factors that people undo are those that are under the man's control, such as stopping to go to the gym or having a drink rather than those that are not

under his control, such as being stuck in a traffic jam. People can more easily think about alternatives to controllable factors (e.g., not going to the gym) rather than the uncontrollable factors (e.g., because he would be stuck in traffic jam anyway). This difference may lead to differences in the way they reason about events, that is, the conditional inferences they draw. Future research is needed to clarify how these factors interact with reasoning from counterfactual conditionals.

Conclusion

In this thesis we have investigated the mental representations of counterfactual conditionals and the factors that modulate these representations in a series of eight experiments. The results of our experiments have implications for theories of human reasoning and for advancing knowledge about reasoning from counterfactual conditionals. Our findings demonstrate the role played by content, tense and linguistic form in reasoning from counterfactual conditionals.

References

Athanasiadou, A. & Dirven, R. (1997). Conditionality, hypotheticality, counterfactuality. In A. Angelika & R. Dirven (Eds.) *On Conditionals Again.* New York: John Benjamins.

Au, T.K. (1983). Chinese and English counterfactuals: the Sapir-Whorf hypothesis revisited. *Cognition, 15,* 155 – 187.

Barrouillet, P., Grosset, N., & Lecas, J. (2000). Conditional reasoning by mental models: Chronometric and developmental evidence. *Cognition, Vol., 75 (3),* 237-266.

Bonnatti, L. (1994). Propositional reasoning by model? *Psychological Review, 101,* 725-733.

Bonnefon, J.F. & Hilton, D.J. (2002). The suppression of Modus Ponens as a case of pragmatic preconditional reasoning. *Thinking and Reasoning, 8,* 21-40.

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). The theory of mental-propositional logic: Description and illustration. In M.D.S.Braine & D. P. O'Brien (Eds.), *Mental logic* (pp. 79-89). Mahway, NJ: Lawrence Erlbaum Associates.

Braine, M.D.S. & O'Brien, D.P. (1991). A theory of If: A lexical entry, reasoning program, and pragmatic principles. *Psychological Review, 98,* 182-203.

Braine, M.D.S., Reiser, B.J. & Rumain, B. (1984). Some empirical justification for a theory of natural propositional logic. In G.H. Bower (Ed.) *The psychology of learning and motivation, 18.* New York: Academic Press.

Byrne, R.M.J. (2002). Mental models and counterfactual thinking about what might

havebeen. *Trends in Cognitive Sciences, Vol 6 (10),* 426-431.

Byrne, R.M.J. (1997). Cognitive processes in counterfactual thinking about what might have been. In D.L. Medin (Ed.) *The psychology of learning and motivation*, Vol. 37, pp.105-154. San Diego, CA: Academic Press.

Byrne, R.M.J. (1991). Can valid inferences be suppressed? *Cognition, 39, 71-78.*

Byrne, R.M.J. (1989). Suppressing valid inferences with conditionals. *Cognition, 31,* 61-83.

Byrne, R.M.J. & Egan, S.M. (2004). Counterfactual and Pre-factual Conditionals. *Canadian Journal of Experimental Psychology, 58* (2), 113-120.

Byrne, R.M.J., Egan, S.M. & Garcia Madruga, J.A. (2003). *Counterfactual "only if" conditionals.* In R. Alterman, & D. Kirsh (Eds.) *Proceedings of the 25th Annual Conference of the Cognitive Science Society.* Boston, MA; Erlbaum

Byrne, R.M.J., Espino, O., & Santamaria, C. (1999). Counterexamples and the suppression of inferences. *Journal of Memory and Language, 40,* 347-373.

Byrne, R.M.J., Handley, S.J. & Johnson-Laird, P.N. (1995). Reasoning from suppositions. *Quarterly Journal of Experimental Psychology: Human Experimental Psychology, 48A*(4), 915-944.

Byrne, R.M.J. & Johnson-Laird, P.N. (1989). Spatial reasoning. *Journal of Memory & Language, 28,* 564-575.

Byrne, R.M.J. & Tasso, A. (1999). Deductive reasoning with factual, possible and counterfactual conditionals. *Memory and Cognition*, 27, 726-740.

Carriedo, N., García-Madruga, J., Gutiérrez, F. and Moreno, S. (1999). How does content affect 'unless' conditional reasoning. In *Proceedings of the European Conference on Cognitive Science* (pp. 271-277). Sienna, Italy.

Chater, N. & Oaksford, M. (1999). The probability heuristics model of syllogistic reasoning. *Cognitive Psychology, 38* (2), 191-258.

Cheng, P.W. & Holyoak, K.J. (1985). Pragmatic reasoning schemas. *Cognitive Psychology, 17,* 391-416.

Cheng, P.W., Holyoak, K.J., Nisbett, R.E. & Oliver, L.M. (1986). Pragmatic versus syntactic approaches to training deductive reasoning. *Cognitive Psychology, 18,* 293-328.

Cheng, P.W., Nisbett, R.E. (1993). Pragmatic constraints on causal deduction. In R.E. Nisbett (Ed.) *Rules for reasoning.* Hillsdale: Lawrence Erlbaum Associates.

Copi, I.M. & Cohen, C. (1994). *An introduction to logic.* New York: Prentice Hall.

Cosmides, L. (1989) The logic of social exchange: Has natural selection shaped how humans reason? *Cognition, 31,* 187-276.

Costello, T. & McCarthy, J. (1999). Useful counterfactuals. *Linkoping Electronic Articles in Computer and Information Science, 3,* 1-28.

Cummins, D.D., Lubart, T., Alksnis, O., & Rist, R. (1991). Conditional reasoning and causation. *Memory and Cognition, 19,* 274-282.

Creyer, E.H. & Gurhan, Z. (1997). Who's to blame? Counterfactual reasoning and the assignment of blame. *Psychology & Marketing, 14* (3), 209-222.

Dudman, V.W. (1988). Indicative and subjunctive. *Analysis, 48,* 113-122.

Evans, J.St.B.T. (1993). The mental model theory of conditional reasoning: critical appraisal and revision. *Cognition, 48,* 1-20.

Evans, J.St.B.T. (1977). Linguistic factors in reasoning. *Quarterly Journal of Experimental Psychology, 29,* 297-306.

Evans, J.St.B.T. (1972). Interpretation and "matching" bias in a reasoning task. *Quarterly Journal of Experimental Psychology, 29*, 297-306.

Evans, J.St.B.T. & Beck, M. A. (1981). Directionality and temporal factors in conditional reasoning. *Current Psychological Research, 1,* 111-120.

Evans, J.St.B.T., Clibbens, J., & Rood, B. (1995). Bias in conditional inference: implications for mental models and mental logic. *Quarterly Journal of Experimental Psychology, 48A,* 644-670.

Evans, J.St.B.T., Clibbens, J., & Rood, B. (1996). The role of implicit and explicit negation in conditional reasoning bias. *Journal of Memory and Language, 35,* 392-409.

Evans, J.St.B.T., Legrenzi, P. & Girotto, V. (1999). The influence of linguistic form on reasoning: The case of matching bias. *Quarterly Journal of Experimental Psychology: Human Experimental Psychology. 52A* (1), 185-216.

Evans, J.St.B.T. & Over, D.E. (in press). *If.* Oxford: Oxford University Press.

Evans, J.St.B.T. & Newstead, S. E. (1977). Language and reasoning: A study of temporal factors. *Cognition, 5,* 265-283.

Evans, J.St.B.T., Newstead, S. E., & Byrne, R. M. J. (1993). *Human Reasoning: The Psychology of Deduction.* Hove & London: Erlbaum.

Evans, J.St,B.T. & Thompson, V.A. (2004). Informal reasoning: Theory and method. *Canadian Journal of Experimental Psychology, 58* (2), 69-74.

Evans, J.St.B.T. & Twyman-Musgrove, J. (1998). Conditional reasoning with inducements and advice. *Cognition, 69,* B11-B16.

Eysenck, M.J. & Keane, M.T. (2000). *Cognitive Psychology: A Student's Handbook.* Hove: Psychology Press.

Fiddick, L., Cosmides, L., & Tooby, J. (2000). No interpretation without representation: the role of domain-specific representations and inferences in the Wason selection task. *Cognition, 77,* 1-79.

Fillenbaum, S. (1974). Information amplified: memory for counterfactual conditionals. *Journal of Experimental Psychology, 102,* 44-49.

Fillenbaum, S. (1975). If: some uses. *Psychological Research, 37,* 245-260.

Fillenbaum, S. (1976). Inducements: on phrasing and logic of conditional promises, threats and warnings. *Psychological Research, 38,* 231-250.

Fillenbaum, S. (1978). How to do some things with IF. In J.W.Cotton & R. L. Klatzky (Eds.), *Semantic Factors in Cognition.* Hillsdale N.J.: Erlbaum.

Fillenbaum, S. (1986). The use of conditionals in inducements and deterrents. In G. Ferguson, J. Reilly, A. Meulen & E.C. Trangott (Eds.) *On Conditionals.* Cambridge: Cambridge University Press.

Garcia-Madruga, J.A., Byrne, R.M.J., Egan, S.M., Moreno-Rios, S., Quelhas, A.C. & Juhos, C. (2004). *Reasoning with 'Only If' and 'Unless' counterfactual conditionals.* Manuscript submitted for publication.

Garcia-Madruga, J.A., Carriedo, N., Moreno, S. & Schaeken, W. (1998). *Conditional reasoning from different formulations: "if", "only if" and "unless".* Unpublished manuscript.

Garcia-Madruga, J.A., Guttierez, F., Carriedo, N., Moreno, S. & Johnson-Laird, P.N. (2002). Mental models in deductive reasoning. *The Spanish Journal of Psychology, 5,* 125-140.

Geis, M.L. (1973). If and unless. In B.B. Kachu, R.B. Lees, Y. Malkiel, A. Pietrangeli & S. Saporta (Eds.) *Issues in linguistics.* Urbana, Chicago: University of Illinois Press.

Geis, M. & Zwicky, A.M. (1971). On invited inferences. *Linguistic Inquiry, 2,* 561-566.

Gigerenzer, G., & Hug, K. (1992). Domain-specific reasoning: Social contracts, cheating and perspective change. *Cognition., 43,* 127-171.

Girotto, V., Legrenzi, P. & Rizzo, S. (1991). Event controlability in counterfactual thinking. *Acta Psychologica, 78,* 111-133.

Girotto, V., Mazzacco, A. & Cherubini, P. (1992). Judgements of deontic relevance in reasoning: A reply to Jackson & Griggs. *Quarterly Journal of Experimental Psychology, 45A,* 547-574.

Goldman, A.I. (1986). *Epistemology and Cognition.* Cambridge, M.A: Harvard University Press.

Goodman, S.N. (1999). Toward evidence-based medical statistics. 1: The P-value fallacy. *Annual International Medicine,* 995-1004.

Goodman, S.N. (1993). P values, hypothesis tests, and likelihood: implications for epidemiology of a neglected historical debate. *American Journal of Epidemiology, 137,* 485-496.

Goodwin, G.P. & Johnson-Laird, P.N. (2005). Reasoning about relations. *Psychological Review, Vol. 112 (2),* 468-493.

Griggs, R.A. & Cox, J.R. (1982). The elusive thematic materials effect in the Wason selection task. *British Journal of Psychology, 73,* 407-420.

Harris, P.L. (2000). *The work of the imagination.* Oxford: Blackwell.

Hofstadter, D.R. (1979). *Godel, Escher, Bach: An Eternal Golden Braid.* New York: Basic Books.

Holyoak, K.J. & Cheng, P.W. (1995). Pragmatic reasoning about human voluntary action:

Evidence from Wason's selection task. In S.E. Newstead & J.St.B. T. Evans (Eds.) *Perspectives on thinking and reasoning: Essasys in honour of Peter Wason.* Hillsdale: Lawrence Erlbaum Associates.

Jeffrey, R. (1971). *Formal logic: its scope and limits.* New York: McGraw-Hill.

Johnson-Laird, P.N. (1983). *Mental Models.* Cambridge: Cambridge University Press.

Johnson-Laird, P.N. (1999). Deductive reasoning. *Annual Review of Psychology, 50,* 109-135.

Johnson-Laird, P.N. & Byrne, R.M.J. (2002). Conditionals: a theory of meaning, pragmatics and inference. *Psychological Review, 109,* 646-678.

Johnson-Laird, P.N. & Byrne, R.M.J. (1992). Modal reasoning, models and Manktelow & Over. *Cognition, 43,* 173-182.

Johnson-Laird, P.N. & Byrne, R.M.J. (1991). *Deduction.* Hove & London: Erlbaum.

Johnson-Laird, P.N. & Byrne, R.M.J. (1989). *Only* reasoning. *Memory and Language, 28,* 313-330.

Johnson-Laird, P.N., Byrne, R.M.J., and Schaeken, W. (1994). Why models rather than rules give a better account of propositional reasoning: a reply to Bonatti, and to O'Brien, Braine and Yang. *Psychological Review, 101,* 734-739.

Johnson-Laird, P.N., Byrne, R.M.J., and Schaeken, W. (1992). Propositional reasoning by model. *Psychological Review, 99,* 418-439.

Johnson-Laird, P.N., Legrenzi, P., Girotto, V., Legrenzi, M.S., & Caverni, J. P. (1999). Naive probability: A mental model theory of extensional reasoning. *Psychological Review, 106,* 62-88.

Johnson-Laird, P.N., Legrenzi, P. & Legrenzi, M.S. (1972). Reasoning and a sense of

reality. *British Journal of Psychology, 63*, 395-400.

Johnson-Laird, P.N. & Savary, F. (1999). Illusory inferences: a novel class of erroneous deductions. *Cognition, 71,* 191-299.

Johnson-Laird, P.N. & Savary, F. (1996). Illusory inferences about probabilities. *Acta Psychologica, 93*, 69-90.

Johnson-Laird, P.N. & Tagart, J. (1969). How implication is understood. *American Journal of Psyhology, 2,* 367-373.

Kahneman, D. & Tversky, A. (1982). The simulation heuristic. In A.Kahneman, P. Slovic, & A. Tversky (Eds.), *Judgment Under Uncertainty: Heuristics and Biases* (pp. 201-210). Cambridge: Cambridge University Press.

Keenan, E. (1971). Quantifier structures in English. *Foundations o Language, 7*, 255-284.

Khong, Y.F. (1996). Confronting Hitler, and its consequences. In P.E. Tetlock & A. Belkin (eds.) *Counterfactual thought experiments in world politics: Logical, methodological and psychological perspectives.* Princeton: Princeton University Press.

Klauer, K.C. & Musch, J. (2005). Accounting for Belief Bias in a Mental Model Framework? No Problem! Reply to Garnham and Oakhill. *Psychological Review, Vol. 112 (2),* 519-520.

Kneale, W., & Kneale, M. (1962). *The development of logic.* Oxford: Clarendon.

Knight, R.T. & Grabowecky, M. (1995). Escape from linear time: prefrontal cortex and conscious experience. In *The Cognitive Neurosciences.* M.S. Gazzaniga (Ed.) Cambridge, Mass. : MIT Press.

Legrenzi, P., Girrotto, V. & Johnson-Laird, P.N. (2003). Models of consistency. *Psychological Science, 14* (2), 131-137.

Lehman, E.L. (1993). The Fisher, Neyman-Pearson theories of testing hypotheses: one theory or two? *Journal of the American Statistical Association, 88*, 1242-1249.

Lewis, D. (1973). *Counterfactuals*. Oxford: Basil Blackwell.

Mandel, D.R. (2003). Counterfactuals, emotions and context. *Cognition & Emotion.*

Manktelow, K.I. & Evans, J.St.B.T. (1979). Facilitation of reasoning by realism: effect or non-effect? *British Journal of Psychology, 70,* 477-488.

Manktelow, K.I. & Over, D.E. (1991). Social roles and utilities in reasoning with deontic conditionals. *Cognition, 39,* 85-105.

Manktelow, K.I. & Over, D.E. (1995). Deontic reasoning. In S.E.Newstead & J. St. B. T. Evans (Eds.), *Perspectives on Thinking and Reasoning* (pp. 91-114). Hove: Erlbaum.

Markovits, H., Schleifer, M., & Fortier, L. (1989). Development of Elementary Deductive Reasoning in Young Children. *Developmental Psychology. Vol. 25 (5)*, 787-793.

Miller, D.T. & Gunasegaram, S. (1990). Temporal order and the perceived mutability of events: Implications for blame assignment. *Journal of Personality and Social Psychology, 59*, 1111-1118.

Newstead, S.E., Ellis, M.C., Evans, J.St.B.T. & Dennis, I. (1997). Conditional reasoning with realistic material. *Thinking and Reasoning, 3* (1), 49 – 76.

Oaksford, M. & Chater, N. (2003). Conditional probability and the cognitive science of conditional reasoning. *Mind & Language, 18*(4), 359-379.

Oaksford, M. & Chater, N. (1998). *Rationality in an Uncertain World.* Hove, UK: Psychology Press.

Oaksford, M. & Chater, N. (1994). A rational analysis of the selection task as optimal data selection. *Psychological Review, 101,* 608-631.

Oaksford, M., Chater, N., & Grainger, B. (1999). Probabilistic effects in data selection. *Thinking and Reasoning, 5,* 193-244.

Oaksford, M., Chater, N., & Larkin, J. (2000). Probabilities and polarity biases in conditional inference. *Journal of Experimental Psychology: Learning, Memory and Cognition, 26,* 883-889.

O'Brien, D. (1993). *How to develop a perfect memory.* London: Pavilion Books.

Ohm. E. & Thompson, V.A. (2004). Everyday reasoning with inducements and advice. *Thinking & Reasoning, 10*(1), 241-272.

Orrmerod, T.C., Manktelow, K.I. & Jones, G.V. (1993). Reasoning with three types of conditional: Biases and mental models. *Quarterly Journal of Experimental Psychology: Human Experimental Psychology. 46A* (4), 653-677.

Pearl, J. (2000). *Causality: Models, reasoning and inference.* Cambridge: Cambridge University Press.

Pollard, P. (1990). Natural selection for the selection task: Limits to social exchange theory. *Cognition, 36,* 195-204.

Politzer, G. & Bourmand, G. (2002). Deductive reasoning from uncertain conditionals. *British Journal of Psychology, 93,* 345-381.

Politzer, G. & Braine, M. D.S. (1991). Responses to inconsistent premises cannot count as suppression of valid inferences. *Cognition, 38,* 103-108.

Politzer, G., & Nguyen-Xuan, A. (1991). Reasoning about promises and warnings: Darwinian algorithms, mental models, relevance judgements or pragmatic schemas? *Quarterly Journal of Experimental Psychology, 44A,* 401-421.

Quelhas, A.C. and Byrne, R.M.J. (2003). Reasoning with Deontic Counterfactual

Conditionals. *Thinking and Reasoning, 9,* 43 -66.

Quine, W.V.O. (1972). *The methods of logic.* London: Routledge.

Polk, T.A. & Newell, A. (1995). Deduction as verbal reasoning. *Psychological Review, 102,* 533-566.

Reichenbach, H. (1947). *The elements of symbolic logic.* New York: Free Press.

Rips, L.J. (1994). *The Psychology of Proof.* Cambridge, MA: MIT Press.

Roberge, J.J. (1978). Linguistic and psychometric factors in propositional reasoning. *Quarterly Journal of Experimental Psychology, 30*(4), 705-716.

Roese, N.J. (1994). The functional basis of counterfactual thinking. *Journal of Personality & Social Psychology, 66,* 805 – 818.

Rumain, B., Connell, J., and Braine, M.D.S. (1983). Conversational comprehension processes are responsible for reasoning fallacies in children as well as adults. *Developmental Psychology, 19,* 471-481.

Santamaria, C. & Espino, O. (2002). Conditionals and directionality: On the meaning of if vs. only if. *Quarterly Journal of Experimental Psychology: Human Experimental Psychology, 55A* (1), 41-57.

Schaeken, W., Garcia-Madruga, J.A. & d'Ydewalle, G. (1997). *Unless reasoning.* Unpublished paper.

Schaeken, W., Johnson-Laird, P.N. & d'Ydewalle, G. (1996). Mental models and temporal reasoning. *Cognition, 60,* 205-234.

Schaeken, W. & Schroyens, W. (2000). The effect of explicit negatives and of different contrast classes on conditional syllogisms. *British Journal of Psychology, 91,* 533-550.

Schaeken, W., Schroyens, W. & Dieussaert, K. (2001). Conditional assertions, tense and

explicit negatives. *European Journal of Cognitive Psychology, 13* (4), 433-450.

Schroyens, W. & Schaeken, W. (2003). A critique of Oaksford, Chater and Larkin's (2000) conditional probability model of conditional reasoning. *Journal of Experimental Psychology: Learning, Memory and Cognition, 29,* 140-149.

Schroyens, W., Schaeken, W., & d'Ydewalle, G. (2000). A meta-analytic review of conditional reasoning by model and/or rule: Mental models theory revised.

Schroyens, W., Schaeken, W., & d'Ydewalle, G. (2001). The processing of negations in conditional reasoning: A meta-analytic study in mental models and/or mental logic theory. *Thinking and Reasoning, 7,* 121-172.

Schroyens, W., Schaeken, W., Fias, W., & d'Ydewalle, G. (2000). Heuristic and analytic processes in propositional reasoning with negative conditionals. *Journal of Experimental Psychology: Learning, Memory and Cognition, xx,* xx.

Searle, J.R. (1969). *Speech Acts: an essay in the philosophy of language.* London: Cambridge University Press.

Seeleu, E.P. *Et al.* (1995). Counterfactual constraints. In N.J. Roese & J.M. Olson (Eds.) *What Might Have Been: The Social Psychology of Counterfactual Thinking.* Hillsdale: Erlbaum.

Sperber, D. & Girotto, V. (2002). Use or misuse of the selection task? Rejoinder to Fiddick, Cosmides and Tooby. *Cognition, 85,* 277-290.

Stalnaker, R. (1968). A theory of conditionals. *American Philosophical Quarterly Monograph Series, 2,* 98-112.

Tetlock, P.E. & Belkin, A. (eds.) (1996). *Counterfactual thought experiments in world politics: Logical, methodological and psychological perspectives.* Princeton: Princeton University Press.

Thompson, V.A. (1996). Reasoning from false premises: The role of soundness in making logical deductions. *Canadian Journal of Experimental Psychology, 50* (3), 315-319.

Thompson, V.A. (1994). Interpretational factors in conditional reasoning. *Memory and Cognition, 22,* 742-758.

Thompson, V.A. & Byrne, R.M.J. (2002). Reasoning counterfactually: Making inferences about things that didn't happen. *Journal of Experimental Psychology: Learning, Memory and Cognition, 28,* 1-18.

Thompson, V.A. & Mann, J. (1995). Perceived necessity explains the dissociation between logic and meaning: the case of "only if". *Journal of Experimental Psychology: Learning, Memory and Cognition, 21,* 1554-1567.

Vandierendonck, A., Dierckx, V., & De Vooght, G. (2004). Mental model construction in linear reasoning: Evidence for the construction of initial annotated models. *Journal of Experimental Psychology: Human Experimental Psychology, Vol 57A (8), 1369-1391.*

Verbrugge, S., Dieussaert, K. & Schaeken, W. (2004). Promise is debt, threat another matter: The effect of credibility on the interpretation of conditional promises and threats. *Canadian Journal of Experimental Psychology, 58* (2), 106-112.

Wason, P.C. (1966). Reasoning. In B.M.Foss (Ed.), *New Horizons in Psychology I* (pp. 106-137). Harmandsworth: Penguin.

Wason, P.C. & Johnson-Laird, P. N. (1972). *Psychology of Reasoning: Structure and Content*. London: Batsford.

Wells, G.L. & Gavanski, I. (1989). Mental simulation of causality. *Journal of Personality & Social Psychology 56* (2), 161-169.

Wells, G.L., Taylor, B.R. & Turtle, J.W. (1987). The undoing of scenarios. *Journal of Personality & Social Psychology, 53* (3), 421-430.

Wierzbicka, A. (1998). The semantics of English causative constructions in a universal-typological. Tomasello, M. (Ed.) *New Psychology of Language: Cognitive and functional approaches to language structure*. Mahwah: Lawrence Erlbaum Associates.

Winer, B.J. (1971). *Statistical principles in experimental design*. New York: McGraw-Hill.

Wright, P. & Hull, A.J. (1988). Reading to do: Creating contingent action plans. *British Journal of Psychology*, *79* (2), 187-211.

Wright, P. & Hull, A.J. (1986). Answering questions about negative conditions. *Journal of Memory & Language*, *25* (6), 691-709.

Appendix A: Experiment 1

1. The consent form given to all participants before all experiments

I, the undersigned, consent to participate in this study on everyday reasoning and understanding of conditional statements, conducted as part of research for a doctoral thesis in the Psychology Department, Trinity College Dublin, Dublin 2. I understand that I may withdraw my participation at any time, including at any time during the study. I understand that the data obtained through my participation is confidential and anonymous and will only be used for research purposes. Under the Freedom of Information Act I may request access to any data stored under my name; however, I understand that in most studies the data are stored anonymously.

I will be informed of the general nature of the study before participating and an explanation of the aims of the study will be provided after I have completed my participation, at which time any further questions will be discussed.

I understand that I will not be requested to participate in a study that would be detrimental to a persons well being under normal circumstances. I can confirm that I am over 18 years of age.

Signed:_____ Date:_____

Witness:_____

2. Instructions given to participants in Experiment 1

Thank you for agreeing to participate in this study. The study examines everyday reasoning and understanding of conditional statements. They are not tests of intelligence. Your answers will be treated as confidential and anonymous, and you may withdraw your participation at any time.

You will be presented with 12 problems in this booklet. The problems are based on typical things a parent might say to their child. For example:

Ronan's father said to him 'if you tidy your room then I will give you some ice-cream'

Other situations will involve a teacher speaking to a pupil, a boss speaking to an employee and a nightclub owner speaking to a customer. You will then be presented with the following, for example:

What, if anything, do you think will happen?

1. *Ronan will definitely tidy his room*
2. *Ronan will probably tidy his room*
3. *Nothing follows*
4. *Ronan will probably not tidy his room*
5. *Ronan will definitely not tidy his room*

Please indicate your conclusion by writing the number 1, 2, 3, 4 or 5 in the space provided after each of the 12 problems. Please also indicate whether you think the main statement in each problem is a promise (p), a threat (t) or neither (n). Thank you for participating.

Age:_____ Gender:_____

3. An example of the sort of problem given to participants in Experiment 1

Laura's mother says to her "if you put that package in the bin then I will ground you for a week".

What, if anything, do you think will happen?

1. Laura will definitely put the package in the bin
2. Laura will probably put the package in the bin
3. Nothing follows
4. Laura will probably not put the package in the bin
5. Laura will definitely not put the package in the bin

Conclusion:
Main Statement:

4. A description of the materials used in Experiment 1

The materials listed below are all phrased as factual conditionals (i.e., phrased in the indicative mood with a present tense antecedent and a future tense consequent). A sample of a counterfactual phrasing (i.e., phrased in the past tense subjunctive mood) appears at the end of this section. Participants received two situations phrased as factual conditionals and two situations phrased as counterfactual conditionals (12 conditionals in total). Random assignment was used to decide for each participant which two situations were phrased as factual (e.g., the boss – employee situation and the teacher - pupil situation) and which two were phrased as counterfactual (e.g., the parent - child situation and the nightclub owner – customer situation).

Parent – Child Situation

- Laura's mother says to her "if you put that package in the bin then I will ground you for a week"
- Colette's father says to her "if you put that package in the bin then I will double your pocket money this week"
- Simon's mother says to him "if you put that package in the bin then I will put this box on the shelf"

Boss – Employee Situation

- Lisa's boss says to her "if you arrive at work at 10am then I will dock you a day's pay"
- Mary's boss says to her "if you arrive at work at 10am then I will give you a bonus"
- John's boss says to him "if you arrive at work at 10am then I will take lunch at 2pm"

Nightclub Owner – Customer Situation

- The nightclub owner says to Rory "if you bring more than 8 people with you to the club then I will give you free drinks for a month"
- The nightclub owner says to Ciara "if you bring more than 8 people with you to the club then I will ban you for a month"
- The nightclub owner says to David "if you bring more than 8 people with you to the club then I will have over 200 customers that night"

Teacher – Pupil Situation

- Micheal's teacher says to him "if you use up the rest of the red paint in your picture then I will give you no homework for a week"
- Jason's teacher says to him "if you use up the rest of the red paint in your picture then I will give you detention for a week"
- Rita's teacher says to her "if you use up the rest of the red paint in your picture then I will put away the paper"

Teacher – Pupil Situation

- Micheal's teacher said to him "if you had used up the rest of the red paint in your picture then I would have given you no homework for a week"
- Jason's teacher said to him "if you had used up the rest of the red paint in your picture then I would have given you detention for a week"
- Rita's teacher said to her "if you had used up the rest of the red paint in your picture then I would have put away the paper"

5. Debriefing given to participants in Experiment 1

This study aims to examine the way people reason with promises and threats. The study also compares the way people reason with sentences about possible future events (e.g., if you mow the lawn then I will pay you 10 euro) and those about possible past events (e.g., if you had mowed the lawn then I would have paid you 10 euro). People seem to reason differently with these different types of sentence.

If you have any further questions please ask the experimenter. Thank you again for your participation.

Appendix B: Experiment 2

1. Instructions given to participants in Experiment 2 (presented on computer)

Thank you for agreeing to participate in this study. The study examines everyday reasoning and understanding, specifically, the inferences people make when presented with conditional statements. They are not tests of intelligence. Your answers will be treated as confidential and anonymous, and you may withdraw your participation at any time.

You will be presented with 24 problems on this computer each consisting of a pair of statements. You will have to decide the correct conclusion that follows from each of them. There are right and wrong answers so please think carefully about each one.

Please press the space bar to continue

You will be given problems based on typical promises or threats a parent might say to their child. Sometimes the parent might threaten the child with chores if they are misbehaving (e.g. being bold or lazy). Other times they might reward them with treats if they are being good (e.g. doing the housework). For example:

Laura's mother said to her "if you mow the lawn then I will give you 10 euro

You will then be presented with a statement giving some information about what happened, such as:

Laura mowed the lawn

And you will be asked to infer what follows from this statement from a number of possible choices. You can select your answer by pressing either a, b or c

(a) Laura's mother gave her 10 euro
(b) Laura's mother did not give her 10 euro
(c) Laura's mother may or may not have given her 10 euro

Please press the space bar to continue

Before the 24 problems there will be 3 practice problems so that you are familiar with the task presentation and the keys on the keyboard.

Overall, the study will last less than an hour. You will be timed but please complete each problem at your own pace. If you have any questions, the experimenter will be pleased to answer them either after the 3 practice tests or at the end of the experiment. If you have any questions during the 24 problems please raise your hand and the experimenter will come over to you. After you have completed the 24 problems, you will be given an explanation of the main aims of this study. Thank you again for your participation.

Please press the space bar to continue

Practice Problem 1

There is a circle on the blackboard or there is a triangle

Please press the space bar after you have read the sentence and are ready to continue

There is a circle

Please press the space bar after you have read the sentence and are ready to continue

Therefore:

(a) There is a triangle

(b) There is not a triangle

(c) There may or may not be a triangle

Please indicate your answer by selecting one of the keys on the keyboard that has been labelled a, b, or c.

Please press the space bar when you are ready to continue

Practice Problem 2

There is a square on the blackboard or there is an oval

There is not an oval

Therefore:

(a) There is a square

(b) There is not a square

(c) There may or may not be a square

Please indicate your answer by selecting one of the keys on the keyboard that has been labelled a, b, or c.

Please press the space bar when you are ready to continue

Practice Problem 3

There is a rectangle on the blackboard and there is a star

There is a rectangle

Therefore:
(a) There is a star
(b) There is not a star
(c) There may or may not be a star

Please press the space bar when you are ready to continue

2. An example of the problem given to participants in Experiment 2

Aoife's mother said to her "if you leave your clothes on the floor then I will make you do the dishes"

Aoife left her clothes on the floor

(a) Aoife's mother made her do the dishes
(b) Aoife's mother did not make her do the dishes
(c) Aoife's mother may or may not have made her do the dishes

3. A description of the materials in Experiment 2

The threats and promises listed below are all phrased as factual conditionals (indicative mood, present/future tense). Sample phrasings of the conditionals in the counterfactual group (subjunctive mood, past tense), factual control group (indicative mood, past tense) and counterfactual control group (subjunctive mood, present/future tense) follow the full set of materials.

Threats

Factual Group – Full set of conditionals

- Aoife's mother said to her "if you leave your clothes on the floor then I will make you do the dishes"
- William's father said to him "if you tease your sister then I will make you wash the car"
- Charlotte's father said to her "if you forget to do your homework then I will make you mop the floor"
- Vincent's mother said to him "if you are rude to the guests then I will make you scrub the pots"
- Bridget's mother said to her "if you break that plate then I will make you sweep the garden"
- Tony's father said to him "if you play in the muck then I will make you clean the bathroom"
- Maura's mother said to her "if you are late home from school then I will make you polish the silver"
- Rory's father said to him "if you keep shouting then I will make you weed the flowerbeds"
- Sinead's father said to her "if you curse then I will make you wash the windows"
- David's mother said to him "if you spill that drink then I will make you dust the ornaments"
- Linda's father said to her "if you hit him again then I will make you rake the grass"
- Cathal's mother said to him "if you leave your books on the stairs then I will make you hoover the carpet"

Sample phrasing of conditionals for the counterfactual group, factual control group and the counterfactual control group:

- *Counterfactual*: Tony's father said to him "if you had played in the muck then I would have made you clean the bathroom"
- *Factual Control*: Tony's father said to him "if you played in the muck then I made you clean the bathroom"
- *Counterfactual Control*: Tony's father said to him "if you were to play in the muck then I would make you clean the bathroom"

Promises

Factual Group – Full set of conditionals

- Alan's father said to him "If you feed the dog then I will give you some ice-cream"
- Ciara's father said to her "If you watch your sister then I will buy you a computer game"
- Stephen's mother said to him "If you chop the vegetables then I will take you to the fun-fair"
- Sandra's mother said to her "If you water the plants then I will play draughts with you"
- Rachel's father said to her "If you peel the potatoes then I will buy you new clothes"
- Nigel's mother said to him "If you empty the bin then I will give you some sweets"
- Richard's mother said to him "If you hang out the washing then I will take you to the cinema"
- Mary's mother said to her "If you dry the dishes then I will take you to the zoo"
- Gareth's father said to him "If you set the table then I will give you pizza for dinner"
- Joanne's father said to her "If you tidy your room then I will take you to the circus"
- Robert's father said to him "If you make your bed then I will give you some cake"
- Paula's mother said to her "If you clear the table then I will buy you a book"

Sample phrasing of conditionals for the counterfactual group, factual control group and the counterfactual control group:

- *Counterfactual*: Joanne's father said to her "If you had tidied your room then I would have taken you to the circus"
- *Factual Control*: Joanne's father said to her "If you tidied your room then I took you to the circus"
- *Counterfactual Control:* Joanne's father said to her "If you were to tidy your room then I would take you to the circus"

4. Debriefing given to participants in Experiment 2

This study aims to examine the way people reason with promises and threats. The study also compares the way people reason with sentences about possible future events (e.g. if you mow the lawn then I will pay you 10 euro) and those about possible past events (e.g., if you had mowed the lawn then I would have paid you 10 euro). People seem to reason differently with these different types of sentence.

If you have any further questions please ask the experimenter. Thank you again for your participation.

5. Order Tests for Experiment 2

Inferences

We controlled for order effects by presenting promises and threats in two separate blocks and which block participants received first was counterbalanced. However, to confirm there was no effect of order we conducted a 5 way ANOVA on the factors order (promises or threats first), tense (past, present/future), mood (factual, counterfactual), inducement type (promise, threat) and inference (MP, AC, MT and DA). The results (see Table B.1 below) showed that there was no main effect of order and that it did not interact with any other factors.

Table B.1: Results of the ANOVA to test for order effects in inference endorsements in Experiment 2 (Key: Induce = Inducement; Infer = Inference)

Factors	df	Mean Square	F	Sig.
ORDER	1, 60	4.402	1.613	.209
TENSE * ORDER	1, 60	.309	.113	.738
MOOD * ORDER	1, 60	1.965	.720	.399
TENSE * MOOD * ORDER	1, 60	4.464	1.636	.206
INDUCEMENT * ORDER	1, 60	.548	.628	.431
INDUCEMENT * TENSE * ORDER	1, 60	9.712E-02	.111	.740
INDUCEMENT * MOOD * ORDER	1, 60	.107	.123	.727
INDUCEMENT * TENSE * MOOD * ORDER	1, 60	.132	.152	.698
INFERENCE * ORDER	3, 180	4.139E-02	.074	.974
INFERENCE * TENSE * ORDER	3, 180	.223	.397	.755
INFERENCE * MOOD * ORDER	3, 180	.844	1.502	.216
INFERENCE * TENSE * MOOD * ORDER	3, 180	1.660	2.956	.064
INDUCEMENT * INFERENCE * ORDER	3, 180	7.296E-02	.135	.939
INDUCEMENT * INFERENCE * TENSE * ORDER	3, 180	.112	.208	.891
INDUCEMENT * INFERENCE * MOOD * ORDER	3, 180	5.512E-02	.102	.959
INDUCEMENT * INFERENCE * TENSE * MOOD * ORDER	3, 180	.692	1.28	.282

Latencies

We controlled for order by presenting promises and threats in two separate blocks and which block participants received first was counterbalanced. However, we checked that there was no effect of order on the latency to endorse an inference by conducting a 5 way ANOVA on the factors order (promises or threats first), tense (past, present/future), mood (factual, counterfactual), inducement type (promise, threat) and inference (MP, AC, MT and DA). The results showed that there was no main effect of order and that it did not interact with any other factors (see Table B.2 below).

Table B.2: Results of the ANOVA to test for order effects in inference endorsement latencies in Experiment 2 (Key: Induce = Inducement; Infer = Inference)

Factor	df	Mean Square	F	Sig.
ORDER	1, 38	.715	.786	.381
ORDER * MOOD	1, 38	.481	.529	.472
ORDER * TENSE	1, 38	2.381E-02	.026	.872
ORDER * MOOD * TENSE	1, 38	.167	.184	.670
INDUCE * ORDER	1, 38	1.427	1.941	.131
INDUCE * ORDER * MOOD	1, 38	.302	.411	.525
INDUCE * ORDER * TENSE	1, 38	.336	.457	.503
INDUCE * ORDER * MOOD * TENSE	1, 38	1.263	1.718	.198
INFER * ORDER	3, 114	4.728E-02	.368	.776
INFER * ORDER * MOOD	3, 114	.225	1.750	.161
INFER * ORDER * TENSE	3, 114	4.618E-02	.359	.783
INFER * ORDER * MOOD * TENSE	3, 114	.258	2.005	.117
INDUCE * INFER * ORDER	3, 114	.219	1.836	.145
INDUCE * INFER * ORDER * MOOD	3, 114	.127	1.063	.368
INDUCE * INFER * ORDER * TENSE	3, 114	.242	2.024	.114
INDUCE * INFER * ORDER * MOOD * TENSE	3, 114	.278	2.332	.078

6. Results of Power Tests for the planned comparisons in Experiment 2

Power was calculated using the following formula (Hinkle, 1998):

$$(\mu 1 - \mu 2) - (1.645)(s_{\bar{X}1 - \bar{X}2}) = 0 - (1.645)(1.78)$$

Where $(s_{\bar{X}1-\bar{X}2}) = \sqrt{s^2(1/n_1+1/n_2)}$

Table B.3: Power tests comparing factual and counterfactual promises and factual and counterfactual threats

Inducement	Inference	80% Power to detect a difference of:
Threats	MP	.07
	AC	.06
	MT	.07
	DA	.06
Promises	MP	.07
	AC	.05
	MT	.06
	DA	.07

7. Control Group Comparisons in Experiment 2

Table B.4: Comparison of the factual group and the factual control group for promises and threats in Experiment 2

Inducement	Inference	t	df	Sig
Threats	MP	.148	31	.442
	AC	-.449	31	.328
	MT	-.652	31	.256
	DA	.239	31	.407
Promises	MP	-.059	31	.477
	AC	1.259	21.064	.111
	MT	-.631	31	.267
	DA	-1.258	31	.109

Table B.5: Comparison of the factual control group and the counterfactual group for promises and threats in Experiment 2

Inducement	Inference	t	df	Sig
Threats	MP	-1.931	31.750	.031
	AC	-1.231	34	.114
	MT	.181	34	.479
	DA	1.115	34	.137
Promises	MP	-2.627	24.827	.007
	AC	-1.947	34	.030
	MT	1.348	21.269	.096
	DA	-.170	34	.433

Table B.6: Comparison of the counterfactual control group and the counterfactual group for promises and threats in Experiment 2

Inducement	Inference	t	df	Sig
Threats	MP	-2.394	27.710	.012
	AC	-1.889	33	.034
	MT	-.338	33	.369
	DA	-.238	33	.407
Promises	MP	-1.507	33	.071
	AC	-1.405	33	.084
	MT	1.529	18.840	.071
	DA	.284	33	.389

Table B.7: Comparison of the counterfactual control group and the factual group for promises and threats in Experiment 2

Inducement	Inference	t	df	Sig
Threats	MP	-.289	30	.387
	AC	-1.081	30	.144
	MT	-1.168	30	.126
	DA	-1.168	30	.126
Promises	MP	.957	30	.173
	AC	1.711	18.708	.104
	MT	-.317	30	.377
	DA	-.799	30	.215

Appendix C: Experiment 3

1. Instructions given to participants in Experiment 3

Thank you for agreeing to participate in this study. The study examines everyday reasoning and understanding, specifically the possibilities people keep in mind when presented with conditional statements. They are not tests of intelligence. Your answers will be treated as confidential and anonymous, and you may withdraw your participation at any time.

You will be given 6 problems, each of which consist of a statement and four sentences. Your task is to decide for each of the four sentences if it is consistent, inconsistent or irrelevant with regard to the statement. For example, you may be told that:

Either Laura was in Dublin or Mary was in Galway, but not both

You will then be presented with four sentences about four possible situations that could arise from this statement and you must tick the box to indicate if you think each situation is consistent, inconsistent or irrelevant with regard to the statement:

	Consistent	Inconsistent	Irrelevant
Laura was in Dublin and Mary was not in Galway	☐	☐	☐
Laura was not in Dublin and Mary was in Galway	☐	☐	☐
Laura was in Dublin and Mary was in Galway	☐	☐	☐
Laura was not in Dublin and Mary was not in Galway	☐	☐	☐

In this example the first two sentences are consistent with the original statement but the

last two are inconsistent. You may also decide to use the irrelevant option for some of the problems you receive. The problems you will receive will be based on typical promises and threats that might be said by a parent to a child, by a boss to an employee or by a schoolteacher to a pupil, for example:

Laura's mother said to her "if you mow the grass then I will give you 10 euro"

The 6 problems are all separate. After the 6 problems there are two final questions to be answered, one about a promise and one about a threat. Overall the study will last approximately 10 minutes. Please complete each problem at your own pace and do not confer with others while completing the booklet. Please complete the problems in the order they are presented and do not change any of your answers or go back to problems. If you have any questions, the experimenter will be pleased to answer them. After you have completed the booklet you will be given an explanation of the main aims of the study.

Please complete the following details.

Age: _____ Gender:_____

Thank you for your participation.

2. An example of the problem given to participants in Experiment 3

Laura's mother said to her "if you mow the grass the I will give you 10 euro"

	Consistent	Inconsistent	Irrelevant
Laura mowed the grass and her mother gave her 10 euro	☐	☐	☐
Laura did not mow the grass and her mother gave her 10 euro	☐	☐	☐
Laura mowed the grass and her mother did not give her 10 euro	☐	☐	☐
Laura did not mow the grass and her mother did not give her 10 euro	☐	☐	☐

3. A description of the materials in Experiment 3

The list of conditionals below are the conditionals that were presented to the factual group. Following this list is a sample of the conditionals phrased for the counterfactual group, factual control group and counterfactual control group

Threats

Factual Group - Full set of conditionals

- The boss said to the employee "if you forget your uniform then I will dock your pay"
- The schoolteacher said to the pupil "if you talk in class then I will give you lines"
- The parent said to the child "if you are rude then I will give you chores to do"

Sample phrasing of conditionals for the counterfactual group, factual control group and the counterfactual control group

- *Counterfactual*: The boss said to the employee "if you had forgotten your uniform then I would have docked your pay"
- *Factual Control*: The boss said to the employee "if you forgot your uniform then I docked your pay"
- *Counterfactual Control*: The boss said to the employee "if you were to forget your uniform then I would dock your pay"

Promises

Factual Group - Full set of conditionals

- The boss said to the employee "if you are on time every day for a month then I will give you a bonus"
- The schoolteacher said to the pupil "if you behave then I will give you an extra gold star"
- The parent said to the child "if you are good then I will give you extra pocket money"

Sample phrasing of conditionals for the counterfactual group, factual control group and the counterfactual control group

- *Counterfactual*: The schoolteacher said to the pupil "if you had behaved then I would have given you an extra gold star"
- *Factual Control*: The schoolteacher said to the pupil "if you behaved then I gave you an extra gold star"
- *Counterfactual Control*: The schoolteacher said to the pupil "if you were to behave then I would give you an extra gold star"

4. Debriefing given to participants in Experiment 3

This study aims to examine the way people reason with promises and threats. The study also compares the way people reason with sentences about possible future events (e.g. if you mow the lawn then I will pay you 10 euro) and those about possible past events (e.g., if you had mowed the lawn then I would have paid you 10 euro). People seem to reason differently with these different types of sentence.

If you have any further questions please ask the experimenter. Thank you again for your participation.

5. Order Tests for Experiment 3

Inferences

We controlled for order effects by presenting promises and threats in two separate blocks and which block participants received first was counterbalanced. However, to confirm there was no effect of order we conducted a 5 way ANOVA on the factors order (promises or threats first), tense (past, present/future), mood (factual, counterfactual), inducement type (promise, threat) and inference (MP, AC, MT and DA). The results showed that there was no main effect of order and that it did not interact with any other factors, as Table C.1 below shows.

Table C.1: Results of the ANOVA to test for order effects in consistency judgements in Experiment 3 (Key: Induce = Inducement; Poss = Possibility)

Factors	df	Mean Square	F	Sig.
INDUCE * ORDER	1, 55	.02314	.234	.630
INDUCE * ORDER * MOOD	1, 55	.217	2.2	.144
INDUCE * ORDER * TENSE	1, 55	.02314	.234	.630
INDUCE * ORDER * MOOD * TENSE	1, 55	.217	2.2	.144
POSS * ORDER	1, 55	3.787	3.619	.062
POSS * ORDER * MOOD	1, 55	.297	.302	.585
POSS * ORDER * TENSE	1, 55	.838	.854	.359
POSS * ORDER * MOOD * TENSE	1, 55	.694	.707	.404
INDUCE * POSS * ORDER	1, 55	.189	1.308	.258
INDUCE * POSS * ORDER * MOOD	1, 55	.509	3.522	.066
INDUCE * POSS * ORDER * TENSE	1, 55	.160	1.104	.298
INDUCE * POSS * ORDER * MOOD * TENSE	1, 55	.03368	.233	.63
ORDER	1, 55	.09925	.157	.694
ORDER * MODD	1, 55	3.069	5.54	.082
ORDER * TENSE	1, 55	3.517	5.48	.072
ORDER * MOOD * TENSE	1, 55	2.039	3.216	.078

6. Results of Power Tests for the planned comparisons in Experiment 3

Table C.2: Power tests comparing factual and counterfactual promises and factual and counterfactual threats in Experiment 3

Inducement	Inference	80% Power to detect a difference of:
Threats	A and B	.07
	Not A and not B	.06
Promises	A and B	.07
	Not A and not B	.05

7. Control Group Comparisons in Experiment 3

Table C.3: Comparison of the factual group and the factual control group for promises and threats in Experiment 3

Inducement	Possibility	t	df	Sig
Threats	A and B	.000	30	.500
	Not A and not B	-1.022	30	.158
Promises	A and B	000	30	.500
	Not A and not B	.542	30	.296

Table C.4: Comparison of the factual control group and the counterfactual group for promises and threats in Experiment 3

Inducement	Possibility	t	df	Sig
Threats	A and B	1.584	15.295	.067
	Not A and not B	1.430	21.500	.083
Promises	A and B	1.871	14.000	.041
	Not A and not B	.470	29	.321

Table C.5: Comparison of the counterfactual control group and the counterfactual group for promises and threats in Experiment 3

Inducement	Possibility	t	df	Sig
Threats	A and B	1.584	15.295	.067
	Not A and not B	.861	29	.198
Promises	A and B	1.871	14.000	.041
	Not A and not B	.687	29	.248

Table C.6: Comparison of the counterfactual control group and the factual group for promises and threats in Experiment 3

Inducement	Possibility	t	df	Sig
Threats	A and B	.000	30	.500
	Not A and not B	-.419	30	.239
Promises	A and B	.300	30	.383
	Not A and not B	.000	30	.500

Appendix D: Experiment 4

1. Instructions given to participants in Experiment 4 (presented on computer)

Thank you for agreeing to participate in this study. The study examines everyday reasoning and understanding, specifically, the inferences people make when they think about conditional assertions. They are not tests of intelligence. Your answers will be treated as confidential and anonymous, and you may withdraw your participation at any time.

You will presented with 24 items each consisting of a pair of statements. Your task is to decide if the second assertion is consistent, inconsistent or irrelevant with regard to the first assertion.

Please press the space bar to continue

You will be given items based on different people doing different things or being in different locations or using different ingredients. For example:

Either Alex is in Carlow or Brendan is in Kerry, but not both.

You will then be presented with a second assertion such as:

Alex is in Carlow and Brendan is in Kerry

Your task is to decide whether this assertion is:

(a) *consistent*
(b) *inconsistent*
(c) irrelevant

with regard to the first assertion.

Please press the space bar to continue

The 24 items are all separate. Before them there will be 3 practice problems so that you are familiar with the task presentation and the keys on the keyboard.

Overall, the study will last approximately 20 minutes. You will be timed but please complete each problem at your own pace. If you have any questions, the experimenter will be pleased to answer them either after the 3 practice tests or at the end of the experiment. If you have any questions during the 24 problems please raise your hand and the experimenter will come over to you. After you have completed the 24 problems, you will be given an explanation of the main aims of this study. Thank you again for your participation.

Please press the space bar to continue

Practice Problem 1

There is a circle on the blackboard or there is a triangle

Please press the space bar to continue

There is a circle and there is not a triangle

Please press the space bar to continue

Is the second assertion:

(a) Consistent

(b) Inconsistent

(c) Irrelevant

with regard to the first assertion?

Please indicate your answer by selecting one of the keys that has been labelled a, b, or c.

Please press the space bar when you are ready to continue

Practice Problem 2

There is a square on the blackboard or there is an oval, or both

There is not a square and there is not an oval.

Is the second assertion:

(a) Consistent

(b) Inconsistent

(c) Irrelevant

with regard to the first assertion?

Please indicate your answer by selecting one of the keys labelled a, b, or c.

Please press the space bar when you are ready to continue

Practice Problem 3

There is either a rectangle on the blackboard or there is a star

There is a rectangle and there is not a star

(a) Consistent

(b) Inconsistent

(c) Irrelevant

Please press the space bar when you are ready to continue

2. Examples of the problem given to participants in Experiment 4

If Peter was in Longford then Rory was in Cavan

Peter was in Longford and Rory was not in Cavan

(a) Consistent
(b) Inconsistent
(c) Irrelevant

If Nigel is in Kerry tomorrow then Philip will be in Mayo

Nigel will be in Kerry tomorrow and Philip will be in Mayo

(a) Consistent
(b) Inconsistent
(c) Irrelevant

3. A description of the materials in Experiment 4

Listed below are a sample of the indicative mood conditionals phrased in the past tense and the future tense. Following this list as a sample of conditionals phrased in the subjunctive mood.

Indicative Mood

Past Tense

- If Laura was in Dublin then Mary was in Galway
- If Peter was in Longford then Rory was in Cavan
- If Linda danced then Siobhan cried
- If Barry shouted then Donald prayed
- If Robert used lettuce then Billy used cumin
- If Gemma used beetroot then Maura used garlic

Future Tense

- If Gerard is in Carlow tomorrow then Martin will be in Antrim
- If Michael is in Wexford tomorrow then Cathal will be in Tyrone
- If Daragh types tomorrow then Stephen will hop
- If Sandra hums tomorrow then Colette will sigh
- If Robert uses lettuce tomorrow then Billy will use cumin
- If Sinead uses turnip tomorrow then Rachel will use parsley

Sample of Conditionals Phrased in the Subjunctive Mood

- *Past Tense*: If Laura had been in Dublin then Mary would have been in Galway
- *Future Tense*: If Gerard were in Carlow tomorrow then Martin would be in Antrim

4. Debriefing given to participants in Experiment 4

This study aims to examine how people reason with statements about possible future events. In particular, we are interested in investigating what is implied by these statements (e.g. if I win the lottery tomorrow then I will buy a yacht).

If you have any further questions please ask the experimenter. Thank you again for your participation.

5. Order Tests

Consistent Responses

Tense was manipulated within-participants so that participants received both past and future tense conditionals. To control for order effects in the experiment we counterbalanced the tense that participants received first. Before analysing the data to test our predictions we checked that there was no effect of order by conducting an ANOVA on the factors order (past or future tense conditionals first), mood (indicative, subjunctive), tense (past, future) and possibility (A and B, not A and not B, not A and B, A and not B). The results showed that there was no main effect of order but that there was a three way interaction between order, tense and mood. None of the other interactions were reliable. See Table D.1 below for these statistics

Table D.1: Results of the ANOVA to test for order effects in consistent responses in Experiment 4

Source	df	Mean Square	F	Sig.
ORDER	1, 42	5.462E-02	.054	.817
MOOD * ORDER	1, 42	1.909	1.893	.176
TENSE * ORDER	1, 42	.610	3.507	.068
TENSE * MOOD * ORDER	1, 42	.861	4.951	.032
POSSIBILITY * ORDER	3, 126	.343	.422	.738
POSSIBILITY * MOOD * ORDER	3, 126	1.639	2.018	.115
TENSE * POSSIBILITY* ORDER	3, 126	1.051E-02	.056	.983
TENSE * POSSIBILITY * MOOD * ORDER	3, 126	9.271E-02	.490	.690

The data file was split to compare the conditionals that were received in the first block ('first block data set') with those conditionals that received in the second block ('second block data set'). A series of comparisons were carried out between the first block data set and the second block data set to determine where the order effects had occurred. However, despite the significant interaction between order, tense and mood none of the comparisons were significant for any of the individual possibilities (e.g., A and B), as Tables D.2 and D.3 show.

Table D.2: Statistics for the comparisons between the first block data set and the second block data set for the indicative group consistent responses in Experiment 4

Tense	Possibility	t	df	Sig.
Past	A and B	1.000	9.000	.343
	Not A and not B	-1.022	21	.319
	Not A and B	-1.000	9.000	.343
	A and not B			
Future	A and B	-.872	21	.393
	Not A and not B	-1.049	20.311	.306
	Not A and B	-1.000	9.000	.343
	A and not B	.872	21	.393

Table D.3: Statistics for the comparisons between the first block data set and the second block data set for the subjunctive group consistent responses in Experiment 4

Tense	Possibility	t	df	Sig.
Past	A and B	-1.000	10.000	.341
	Not A and not B	.707	21	.487
	Not A and B	-1.414	12.594	.182
	A and not B			
Future	A and B	1.773	11.000	.104
	Not A and not B	1.281	21	.214
	Not A and B	.072	21	.943
	A and not B	1.491	10.000	.167

Latencies

Although we counterbalanced the presentation of the past tense and future tense conditionals we checked that there was no effect of order on the latencies for consistent judgements by conducting an ANOVA on the factors order (past or future tense conditionals first), mood (indicative, subjunctive), tense (past, future) and possibility (A & B, not A & not B, not A & B, A & not B). The results showed that there was no main effect of order and it did not interact with any other factors (see Table D.4).

Table D.4: Results of the ANOVA to test for order effects in consistent responses latencies in Experiment 4

Source	df	Mean Square	F	Sig.
ORDER	1, 21	.232	.178	.678
MOOD * ORDER	1, 21	.739	.567	.460
TENSE * ORDER	1, 21	1.866	2.191	.154
TENSE * MOOD * ORDER	1, 21	.303	.356	.557
POSSIBILITY * ORDER	1, 21	.809	1.245	.277
POSSIBILITY * MOOD * ORDER	1, 21	.182	.280	.602
TENSE * POSSIBILITY * MOOD * ORDER	1, 21	8.478E-02	.135	.717

6. Power Tests

Table D.5: Power tests comparing indicative and subjunctive future tense conditionals and indicative and subjunctive past tense conditionals

Tense	Possibility	80% Power to detect a difference of:
Future	A & B	.03
	Not A & not B	.08
	Not A & B	.03
	A & not B	.04
Past	A & B	.02
	Not A & not B	.08
	Not A & B	.07
	A & not B	.04

Table D.6: Power tests comparing future and past indicative conditionals and future and past subjunctive conditionals

Tense	Possibility	80% Power to detect a difference of:
Indicative	A & B	.08
	Not A & not B	.11
	Not A & B	.06
	A & not B	.03
Subjunctive	A & B	.07
	Not A & not B	.10
	Not A & B	.08
	A & not B	.04

7. Inconsistent and Irrelevant responses in Experiment 4

Table D.7: Percentages of consistent, inconsistent and irrelevant responses for the indicative and subjunctive groups in Experiment 4

		A and B	Not A and not B	A and not B	Not A and B
Future Indicative	Consistent	99	57	1	3
	Inconsistent	1	6	99	75
	Irrelevant	0	37	0	22
Future Subjunctive	Consistent	94	55	3	6
	Inconsistent	3	10	90	67
	Irrelevant	3	35	7	27
Past Indicative	Consistent	99	55	0	1
	Inconsistent	0	7	97	73
	Irrelevant	1	38	3	26
Past Subjunctive	Consistent	99	67	0	11
	Inconsistent	0	7	100	64
	Irrelevant	1	26	0	25

Appendix E: Experiment 5

1. Instructions given to participants in Experiment 5

Thank you for agreeing to participate in this study. The study examines everyday reasoning and understanding, specifically, the inferences people make when presented with conditional statements. They are not tests of intelligence. Your answers will be treated as confidential and anonymous, and you may withdraw your participation at any time.

You will presented with 24 problems each consisting of a pair of statements. You will have to decide the correct conclusion that follows from each of them. There are right and wrong answers so please think carefully about each one.

Please press the space bar to continue

You will be given problems based on different people doing different things or being in different locations or using different ingredients. For example:

Alex is in Carlow or Brendan is in Kerry

You will then be presented with a statement such as:

Alex is in Carlow

and you will be asked to infer what follows from this statement from a number of possible choices. You can select your answer by pressing either a, b or c

(a) *Brendan is in Kerry*
(b) *Brendan is not in Kerry*
(c) *Brendan may or may not be in Kerry*

Please press the space bar to continue

Before the 24 problems there will be 3 practice problems so that you are familiar with the task presentation and the keys on the keyboard.

Overall, the study will last approximately 20 minutes. You will be timed but please complete each problem at your own pace. If you have any questions, the experimenter will be pleased to answer them either after the 3 practice tests or at the end of the experiment. If you have any questions during the 24 problems please raise your hand and the experimenter will come over to you. After you have completed the 24 problems, you will be given an explanation of the main aims of this study. Thank you again for your participation.

Please press the space bar to continue

Practice Problem 1

There is a circle on the blackboard or there is a triangle
Please press the space bar after you have read the sentence and are ready to continue

There is a circle
Please press the space bar after you have read the sentence and are ready to continue

Therefore:
(a) There is a triangle
(b) There is not a triangle
(c) There may or may not be a triangle
Please indicate your answer by selecting one of the keys on the keyboard that has been labelled a, b, or c.

Please press the space bar when you are ready to continue

Practice Problem 2

There is a square on the blackboard or there is an oval

There is not an oval

Therefore:

(a) There is a square

(b) There is not a square

(c) There may or may not be a square

Please indicate your answer by selecting one of the keys on the keyboard that has been labelled a, b, or c.

Please press the space bar when you are ready to continue

Practice Problem 3

There is a rectangle on the blackboard and there is a star

There is a rectangle

Therefore:

(a) There is a star

(b) There is not a star

(c) There may or may not be a star

Please press the space bar when you are ready to continue

2. Examples of the problems given to participants in Experiment 5

If Linda danced then Siobhan cried

Siobhan cried

Therefore:

(a) Linda danced

(b) Linda did not dance

(c) Linda may or may not have danced

If Joanne is in Leitrim tomorrow then Rachel will be in Sligo

Joanne will not be in Leitrim tomorrow

Therefore:

(a) Rachel will be in Sligo

(b) Rachel will not be in Sligo

(c) Rachel may or may not be in Sligo

3. A description of the materials in Experiment 5

Listed below are a sample of the indicative mood conditionals phrased in the past tense and the future tense.

Indicative Mood

Past Tense

- If Laura was in Dublin then Mary was in Galway
- If Peter was in Longford then Rory was in Cavan
- If Linda danced then Siobhan cried
- If Barry shouted then Donald prayed
- If Robert used lettuce then Billy used cumin
- If Gemma used beetroot then Maura used garlic

Future Tense

- If Gerard is in Carlow tomorrow then Martin will be in Antrim
- If Michael is in Wexford tomorrow then Cathal will be in Tyrone
- If Daragh types tomorrow then Stephen will hop
- If Sandra hums tomorrow then Colette will sigh
- If Robert uses lettuce tomorrow then Billy will use cumin
- If Sinead uses turnip tomorrow then Rachel will use parsley

Sample of Conditionals Phrased in the Subjunctive Mood

- *Past Tense*: If Laura had been in Dublin then Mary would have been in Galway
- *Future Tense*: If Gerard were in Carlow tomorrow then Martin would be in Antrim

4. Debriefing given to participants in Experiment 5

This study aims to examine how people reason with statements about possible future events. In particular, we are interested in investigating what is implied by these statements (e.g. if I win the lottery tomorrow then I will buy a yacht).

If you have any further questions please ask the experimenter. Thank you again for your participation.

5. Order Tests

Inferences

To control for order effects we counterbalanced the presentation of the within participant factor tense so that half the participants received past tense conditionals first and half received future tense conditionals first. We conducted an ANOVA on the factors order (past or future tense conditionals first), mood (indicative, subjunctive), tense (past, future) and inference (MP, MT, DA and AC). The ANOVA showed that there was no main effect of order and it did not interact with any of the other factors (see Table E.1 below).

Table E.1: Results of the ANOVA to test for order effects in inference endorsements in Experiment 5

Source	df	Mean Square	F	Sig.
ORDER	1, 36	.425	.121	.730
MOOD * ORDER	1, 36	2.052	.586	.449
TENSE * ORDER	1, 36	1.718	1.716	.198
TENSE * MOOD * ORDER	1, 36	.953	.952	.336
INFERENCE * ORDER	3, 108	1.288	1.134	.339
INFERENCE * MOOD * ORDER	3, 108	1.220	1.074	.363
TENSE * INFERENCE * ORDER	3, 108	.880	1.984	.121
TENSE * INFERENCE * MOOD * ORDER	3, 108	4.456E-02	.100	.960

Latencies

We checked that there was no effect of order on the latencies for inference endorsements by conducting an ANOVA on the factors order (past or future tense conditionals first), mood (indicative, subjunctive), tense (past, future) and inference (MP, MT, DA, AC). The results showed that there was no main effect of order and that it did not interact with any other factors (see Table E.2).

Table E.2: Results of the ANOVA to test for order effects in inference endorsement latencies in Experiment 5

Source	df	Mean Square	F	Sig.
ORDER	1, 36	3.629	2.177	.149
MOOD * ORDER	1, 36	4.260	2.556	.119
TENSE * ORDER	1, 36	.621	1.715	.173
TENSE * MOOD * ORDER	1, 36	.839	2.318	.096
INFERENCE * ORDER	3, 108	.312	2.125	.101
INFERENCE * MOOD * ORDER	3, 108	.224	1.527	.212
TENSE * INFERENCE * ORDER	3, 108	.182	1.97	.123
TENSE * INFERENCE * MOOD * ORDER	3, 108	3.122E-02	.338	0.8

6. Power Tests

Table E.3: Power tests comparing indicative and subjunctive future tense conditionals and indicative and subjunctive past tense conditionals

Tense	Possibility	80% Power to detect a difference of:
Future	MP	.03
	MT	.11
	AC	.09
	DA	.10
Past	MP	.03
	MT	.11
	AC	.10
	DA	.08

Table E.4: Power tests comparing future and past indicative conditionals and future and past subjunctive conditionals

Tense	Possibility	80% Power to detect a difference of:
Indicative	MP	.05
	MT	.08
	AC	.07
	DA	.08
Subjunctive	MP	.04
	MT	.08
	AC	.08
	DA	.09

Appendix F: Experiment 6

1. Instructions given to participants in Experiment 6

Thank you for agreeing to participate in this study. The study examines everyday reasoning and understanding of conditional statements. They are not tests of intelligence. Your answers will be treated as confidential and anonymous, and you may withdraw your participation at any time. You will be presented with 6 questions and overall the study will take about 10 minutes

Please answer all of the questions in the order they are presented in the booklet and do not confer with others while completing the problems. Please do **not** flick ahead to look at questions or flick back to change answers to previous questions. Please raise your hand when you are finished. Thank you.

Please complete the following details

Age:_____ Gender:_____

2. An example of the problem given to participants in Experiment 6

Please consider the following:

If Michelle is in Belfast tomorrow then Julie will be in Wexford

What, if anything, do you think is implied by this sentence? Please tick as many options as you think appropriate.

(a) Michelle will be in Belfast
(b) Julie will not be in Wexford
(c) Julie will be in Wexford
(d) Michelle will not be in Belfast
(e) Nothing is implied

3. A description of the materials in Experiment 6

Listed below are the conditionals that were presented to the participants in the indicative group, followed by a sample of the conditionals phrased in the subjunctive mood.

Indicative Conditionals

Neutral Content

- If David laughs tomorrow then Alex will hum
- If Emmett uses spinach tomorrow then Richard will use fennel
- If Joanne is in Leitrim tomorrow then Rachel will be in Sligo

Realistic Content

- If I win the lottery tomorrow then I will buy a yacht
- If I die tomorrow then my family will have enough life insurance
- If I become a film star tomorrow then I will move to Hollywood

Sample of conditionals phrased in the subjunctive mood

- *Neutral content*: If David were to laugh tomorrow then Alex would hum
- *Realistic Content*: If I were to win the lottery tomorrow then I would buy a yacht

4. Debriefing given to participants in Experiment 6

This study aims to examine how people reason with statements about possible future events. In particular, we are interested in investigating what is implied by these statements (e.g. if I win the lottery tomorrow then I will buy a yacht).

If you have any further questions please ask the experimenter. Thank you again for your participation.

5. Order Tests

Participants received both neutral and realistic content and to control for order effects in the experiment we counterbalanced the type of content that participants received first. However, to confirm there was no effect of order we conducted an ANOVA on the factors order (neutral or realistic content first), mood (indicative, subjunctive), content (neutral, realistic) and possibility (A, B, not A, not B, nothing implied). The results revealed that there was a main effect of order and that there was a three way interaction between order, content and possibility. None of the other interactions were reliable (see Tables F.2 below).

Table F.1: Results of the ANOVA to test for order effects in implications in Experiment 6

Source	df	Mean Square	F	Sig.
ORDER	1, 75	4.527	4.180	.044
MOOD * ORDER	1, 75	3.423E-02	.032	.859
CONTENT * ORDER	1, 75	.201	.624	.432
CONTENT * MOOD * ORDER	1, 75	.214	.661	.419
POSSIBILITY * ORDER	4, 300	2.891	2.323	.067
POSSIBILITY * MOOD * ORDER	4, 300	2.518	2.023	.091
CONTENT * POSSIBILITY * ORDER	4, 300	4.083	9.155	.000
CONTENT * POSSIBILITY * MOOD * ORDER	4, 300	.442	.990	.413

We investigated the order effects further by comparing the possibilities selected in the first block data set with those possibilities selected in the second block data set. The only differences we found were in the indicative group for neutral content conditionals. Participants selected the options 'A' and 'B' more often, and 'nothing implied' less often, when they received the neutral content indicative conditionals first rather than second after realistic content indicative conditionals (A: 38% versus 5%, $t(35.32) = 3.21$, $p < .01$; B: 47% versus 5%, $t(35.51) = 4.13$, $p < .01$; nothing implied: 58% versus 93%, $t(33.32) = 3.95$, $p < .01$). As the order effects were minimal (only 3 out of a possible 20 cells differed significantly) and the pattern of the first block data set did not differ to the pattern of the overall data set we used the overall data to test our predictions as it consisted of the full sample of participants.

Table F.2: Results of comparisons between the first block data set and the second block data set for the indicative group in Experiment 6

Content	Possibility	t	df	Sig (2-tailed)
Neutral	A	3.206	35.322	.003
	Not A	.485	41	.630
	B	4.128	35.505	.000
	Not B	-.169	41	.867
	Nothing Implied	-3.946	33.318	.000
Realistic	A	1.387	27.195	.177
	Not A	.060	41	.952
	B	.735	41	.466
	Not B	.179	41	.859
	Nothing Implied	-.121	41	.904

Table F.3: Results of comparisons between the first block data set and the second block data set for the subjunctive group in Experiment 6

Content	Possibility	t	df	Sig (2-tailed)
Neutral	A	.733	34	.469
	Not A	.569	34	.573
	B	.788	34	.436
	Not B	1.173	25.619	.252
	Nothing Implied	-.646	34	.523
Realistic	A	1.172	31.552	.250
	Not A	.373	34	.712
	B	-1.000	34	.324
	Not B	1.673	25.426	.107
	Nothing Implied	1.106	34	.276

Appendix G: Experiment 7

1. Instructions given to participants in Experiment 7

Thank you for agreeing to participate in this study. The study examines everyday reasoning and understanding, specifically the inferences people make when they think about conditional statements. They are not tests of intelligence. Your answers will be treated as confidential and anonymous, and you may withdraw your participation at any time.

The study consists of 6 problems. Each problem consists of a statement and then four possible situations. For each situation you have to indicate whether it is consistent, inconsistent or irrelevant with regard to the statement. For example:

Either Stewart is in France or Hugh is in Germany but not both

	Consistent	*Inconsistent*	*Irrelevant*
Stewart is in France and Hugh is not in Germany	☐	☐	☐
Stewart is not in France and Hugh is in Germany	☐	☐	☐
Stewart is in France and Hugh is in Germany	☐	☐	☐
Stewart is not in France and Hugh is not in Germany	☐	☐	☐

In this problem the first two situations are consistent with the statement but the third and fourth situations are inconsistent. In the problems that follow you may also consider some of the situations irrelevant.

Overall, the study will last approximately 10 minutes. Please complete each problem at your own pace and do not confer with others while completing the booklet. If you have any questions, please raise your hand and the experimenter will be pleased to answer them. After you have completed the booklets you will be given an explanation of the main aims of the study. Thank you for your participation.

Please complete the following details:

Age: _____ Gender: _____

2. An example of the problem given to participants in Experiment 7

Laura was in Dublin only if Mary was in Galway

	Consistent	Inconsistent	Irrelevant
Laura was in Dublin and Mary was not in Galway	☐	☐	☐
Laura was not in Dublin and Mary was in Galway	☐	☐	☐
Laura was in Dublin and Mary was in Galway	☐	☐	☐
Laura was not in Dublin and Mary was not in Galway	☐	☐	☐

3. A description of the materials in Experiment 7

Factual Conditionals

'If then'

- If Laura was in Dublin then Mary was in Galway
- If Peter was in Longford then Rory was in Cavan
- If Linda danced then Siobhan cried
- If Barry shouted then Donald prayed
- If Robert used lettuce then Billy used cumin
- If Gemma used beetroot then Maura used garlic

'Only if'

- Nigel was in Kerry only if Philip was in Mayo
- Colette was in Westmeath only if Rita was in Kildare
- David laughed only if Alex hummed
- Ellen jogged only if Aisling sighed
- Emmet used spinach only if Richard used fennel
- Ivy used carrot only if Jenny used parsley

Sample of counterfactual phrasings of factual conditionals

- 'If then': If Laura had been in Dublin then Mary would have been in Galway
- 'Only if': Nigel would have been in Kerry only if Philip had been in Mayo

4. Debriefing given to participants in Experiment 7

This study aims to examine the way people reason with sentences containing "if....then..." and sentences containing "..only if..". The two phrases seem to mean something similar but their emphasis can be a little different. The study also compares the way people reason about 'if' phrased about matters of possibility in the past, e.g., if Laura was in London then David was in Dublin, and about matters that were once possible but are so no longer, e.g., if Laura had been in London then David would have been in Dublin.

If you have any further questions please ask the experimenter. Thank you again for your participation.

5. Order Tests

We checked that there was no influence of order in the possibilities participants rated as consistent by conducting an ANOVA on the factors order ('if then' or 'only if' conditionals first), mood (indicative, subjunctive), linguistic form ('if then', 'only if') and possibility (A and B, not A and B, A and not B, not A and not B). The ANOVA confirmed that there was no main effect of order and that it did not interact with any other factors as Table G.1 shows.

Table G.1: Results of the ANOVA to test for order effects in consistent responses in Experiment 7

Factor	df	Mean Square	F	Sig.
ORDER	1, 40	.422	.840	.365
MOOD * ORDER	1, 40	1.020	2.030	.162
LINGUISTIC FORM * ORDER	1, 40	1.258E-03	.006	.937
LINGUISTIC FORM * MOOD * ORDER	1, 40	.110	.556	.460
POSSIBILITY * ORDER	3, 120	.218	.358	.784
POSSIBILITY * MOOD * ORDER	3, 120	7.017E-02	.115	.951
LINGUISTIC FORM * POSSIBILITY * ORDER	3, 120	9.819E-02	.498	.685
LINGUISTIC FORM * POSSIBILITY * MOOD * ORDER	3, 120	.149	.754	.522

6. Power Tests for comparisons in Experiment 7

Table G.2: Power tests of comparisons of 'Only if' versus 'If then' counterfactual conditionals and factual conditionals.

	Comparison	80% Power to detect a difference of:
Counterfactual	A and B	No difference
	Not A and not B	.05
	A and not B	.03
	Not A and B	.04
Factual	A and B	.03
	Not A and not B	.07
	A and not B	.03
	Not A and B	.03

Table G.3: Power tests of comparisons of counterfactual versus factual conditionals for 'only if' and 'if then'.

	Comparison	80% Power to detect a difference of:
Only if	A and B	.02
	Not A and not B	.05
	A and not B	.03
	Not A and B	.05
If then	A and B	.02
	Not A and not B	.07
	A and not B	.03
	Not A and B	.03

8. Percentages of Responses in Experiment 7

Table G.4: Percentages of consistent, inconsistent and irrelevant responses in Experiment 7

		A and B	Not A and not B	A and not B	Not A and B
If then factual	Consistent	99	58	3	4
	Inconsistent	0	14	86	94
	Irrelevant	1	28	11	1
If then counterfactual	Consistent	100	90	0	0
	Inconsistent	0	0	94	100
	Irrelevant	0	10	6	0
Only if factual	Consistent	97	70	10	3
	Inconsistent	3	4	78	93
	Irrelevant	0	26	12	4
Only if counterfactual	Consistent	100	89	13	0
	Inconsistent	0	6	84	100
	Irrelevant	0	5	3	0

Appendix H: Experiment 8

1. Instructions given to participants in Experiment 8

Thank you for agreeing to participate in this study. The study examines everyday reasoning and understanding, specifically, the inferences people make when presented with conditional statements. They are not tests of intelligence. Your answers will be treated as confidential and anonymous, and you may withdraw your participation at any time.

You will be presented with 24 problems each consisting of a pair of statements. You will have to decide the correct conclusion that follows from each of them. There are right and wrong answers so please think carefully about each one.

Please press the space bar to continue

You will be given problems based on different people doing different things or being in different locations or using different ingredients. For example:

Alex was in Carlow or Brendan was in Kerry

You will then be presented with a statement such as:

Alex was in Carlow

and you will be asked to infer what follows from this statement from a number of possible choices. You can select your answer by pressing either a, b or c

(a)*Brendan was in Kerry*
(b)*Brendan was not in Kerry*
(c) *Brendan may or may not have been in Kerry*

Please press the space bar to continue

Before the 24 problems there will be 3 practice problems so that you are familiar with the task presentation and the keys on the keyboard.

Overall, the study will last approximately 20 minutes. You will be timed but please complete each problem at your own pace. If you have any questions, the experimenter will be pleased to answer them either after the 3 practice tests or at the end of the experiment. If you have any questions during the 24 problems please raise your hand and the experimenter will come over to you. After you have completed the 24 problems, you will be given an explanation of the main aims of this study. Thank you again for your participation.

Please press the space bar to continue

Practice Problem 1

There is a circle on the blackboard or there is a triangle

Please press the space bar after you have read the sentence and are ready to continue

There is a circle

Please press the space bar after you have read the sentence and are ready to continue

Therefore:

(a) There is a triangle

(b) There is not a triangle

(c) There may or may not be a triangle

Please indicate your answer by selecting one of the keys on the keyboard that has been labelled a, b, or c.

Please press the space bar when you are ready to continue

Practice Problem 2

There is a square on the blackboard or there is an oval

There is not an oval

Therefore:

(a) There is a square

(b) There is not a square

(c) There may or may not be a square

Please indicate your answer by selecting one of the keys on the keyboard that has been labelled a, b, or c.

Please press the space bar when you are ready to continue

Practice Problem 3

There is a rectangle on the blackboard and there is a star

There is a rectangle

Therefore:

(a) There is a star

(b) There is not a star

(c) There may or may not be a star

Please press the space bar when you are ready to continue

2. An example of the problem given to participants in Experiment 8

If Peter was in Longford then Rory was in Cavan

Rory was not in Cavan

Therefore:

(a) Peter was in Longford

(b) Peter was not in Longford

(c) Peter may or may not have been in Longford

3. A description of the materials in Experiment 8

Factual Conditionals

'If then'

- If Laura was in Dublin then Mary was in Galway
- If Peter was in Longford then Rory was in Cavan
- If Linda danced then Siobhan cried
- If Barry shouted then Donald prayed
- If Robert used lettuce then Billy used cumin
- If Gemma used beetroot then Maura used garlic

'Only if'

- Nigel was in Kerry only if Philip was in Mayo
- Colette was in Westmeath only if Rita was in Kildare
- David laughed only if Alex hummed
- Ellen jogged only if Aisling sighed
- Emmet used spinach only if Richard used fennel
- Ivy used carrot only if Jenny used parsley

Sample of counterfactual phrasings of factual conditionals

- 'If then': If Laura had been in Dublin then Mary would have been in Galway
- 'Only if': Nigel would have been in Kerry only if Philip had been in Mayo

4. Debriefing given to participants in Experiment 8

This study aims to examine the way people reason with sentences containing "if....then..." and sentences containing "..only if..". The two phrases seem to mean something similar but their emphasis can be a little different. The study also compares the way people reason about 'if' phrased about matters of possibility in the past, e.g., if Laura was in London then David was in Dublin, and about matters that were once possible but are so no longer, e.g., if Laura had been in London then David would have been in Dublin.

If you have any further questions please ask the experimenter. Thank you again for your participation.

5. Order Tests for Experiment 8

Inferences

To control for order effects we counterbalanced the presentation of the within participant factor linguistic form so that half the participants received 'if then' conditionals first and half received 'only if' conditionals first. We conducted an ANOVA on the factors order ('if then' or 'only if' conditionals first), mood (indicative, subjunctive), linguistic form ('if then', 'only if') and inference (MP, MT, DA and AC). The ANOVA showed that there was no main effect of order and it did not interact with any of the other factors (see Table H.1 below).

Table H.1: Results of the ANOVA to test for order effects in inference endorsements in Experiment 8

Source	df	Mean Square	F	Sig.
ORDER	1, 36	4.629E-02	.025	.875
MOOD * ORDER	1, 36	4.352	2.360	.133
LINGUISTIC FORM * ORDER	1, 36	3.144	3.930	.065
LINGUISTIC FORM * MOOD * ORDER	1, 36	.794	.992	.326
INFERENCE * ORDER	3, 108	.492	.616	.606
INFERENCE * MOOD * ORDER	3, 108	1.789	2.240	.088
LINGUISTIC FORM * INFERENCE * ORDER	3, 108	.601	1.255	.294

Latencies

We checked that there was no influence of order in response latencies by conducting an ANOVA on the factors order ('if then' or 'only if' conditionals first), mood (indicative, subjunctive), linguistic form ('if then', 'only if') and inference (MP, MT, DA and AC). The ANOVA revealed a main effect of order and it also interacted with linguistic form (see Table H.2).

Table H.2: Results of the ANOVA to test for order effects in inference endorsement latencies in Experiment 8

Source	df	Mean Square	F	Sig.
ORDER	1, 22	7.446	13.738	.001
MOOD * ORDER	1, 22	1.605	2.962	.099
LINGUISTIC FORM * ORDER	1, 22	.832	6.474	.018
LINGUISTIC FORM * MOOD * ORDER	1, 22	.197	1.530	.229
INFERENCE * ORDER	3, 66	2.669E-02	.279	.840
INFERENCE * MOOD * ORDER	3, 66	7.611E-02	.796	.500
LINGUISTIC FORM * INFERENCE * ORDER	3, 66	3.927E-02	.325	.807
LINGUISTIC FORM * INFERENCE * MOOD * ORDER	3, 66	.112	.928	.432

A series of comparisons were carried out between the first block data set and the second block data set to determine where the order effects had occurred (see Tables H.3 and H.4). The only significant differences in response latencies between the first block and the second block data were in the counterfactual group for 'only if'(see Table H.4). Specifically, reasoners made the MP and AC inferences more slowly (see Table H.4) when they received them in the first block of conditionals rather than in the second block after 'if then' conditionals (MP: 9.05 versus 8.62, t (19) = 2.80, p = .01; AC: (9.23 versus 8.68, t (16) = 2.42, p = .03).

Table H.3: Comparisons between the first block data set and the second block data set for the indicative group inference endorsement latencies in Experiment 8

		t	df	Sig. (2-tailed)
If then	MP	-.166	17	.870
	MT	-.574	15	.575
	DA	-.395	17	.697
	AC	-.205	9.778	.841
Only if	MP	-.531	17	.602
	MT	-.614	17	.547
	DA	.393	17	.700
	AC	-.843	16	0.41

Table H.4: Comparisons between the first block data set and the second block data set for the subjunctive group inference endorsement latencies in Experiment 8

		t	df	Sig. (2-tailed)
If then	MP	-1.001	19	.329
	MT	.661	17	.518
	DA	.583	17	.567
	AC	.078	14	.939
Only if	MP	-2.795	19	.012
	MT	-.609	19	.550
	DA	-1.168	16	.260
	AC	-2.423	16	.028

6. Power Tests

Linguistic Form: 'Only if' versus 'If then'

Table H.5: Power tests for 'Only if' versus 'If then' for Counterfactual and Factual.

	Comparison	80% Power to detect a difference of:
Counterfactual	MP	.02
	MT	.05
	AC	.08
	DA	.07
Factual	MP	.03
	MT	.05
	AC	.07
	DA	.07

Mood: Counterfactual versus Factual

Table H.6: Power tests for comparisons of Counterfactual versus Factual for 'Only if' and 'If then' conditionals.

Linguistic Form	Comparison	80% Power to detect a difference of:
Only If	MP	.03
	MT	.05
	AC	.07
	DA	.06
If Then	MP	0
	MT	.07
	AC	.09
	DA	.07