Terms and Conditions of Use of Digitised Theses from Trinity College Library Dublin

Copyright statement

All material supplied by Trinity College Library is protected by copyright (under the Copyright and Related Rights Act, 2000 as amended) and other relevant Intellectual Property Rights. By accessing and using a Digitised Thesis from Trinity College Library you acknowledge that all Intellectual Property Rights in any Works supplied are the sole and exclusive property of the copyright and/or other IPR holder. Specific copyright holders may not be explicitly identified. Use of materials from other sources within a thesis should not be construed as a claim over them.

A non-exclusive, non-transferable licence is hereby granted to those using or reproducing, in whole or in part, the material for valid purposes, providing the copyright owners are acknowledged using the normal conventions. Where specific permission to use material is required, this is identified and such permission must be sought from the copyright holder or agency cited.

Liability statement

By using a Digitised Thesis, I accept that Trinity College Dublin bears no legal responsibility for the accuracy, legality or comprehensiveness of materials contained within the thesis, and that Trinity College Dublin accepts no liability for indirect, consequential, or incidental, damages or losses arising from use of the thesis for whatever reason. Information located in a thesis may be subject to specific use constraints, details of which may not be explicitly described. It is the responsibility of potential and actual users to be aware of such constraints and to abide by them. By making use of material from a digitised thesis, you accept these copyright and disclaimer provisions. Where it is brought to the attention of Trinity College Library that there may be a breach of copyright or other restraint, it is the policy to withdraw or take down access to a thesis while the issue is being resolved.

Access Agreement

By using a Digitised Thesis from Trinity College Library you are bound by the following Terms & Conditions. Please read them carefully.

I have read and I understand the following statement: All material supplied via a Digitised Thesis from Trinity College Library is protected by copyright and other intellectual property rights, and duplication or sale of all or part of any of a thesis is not permitted, except that material may be duplicated by you for your research use or for educational purposes in electronic or print form providing the copyright owners are acknowledged using the normal conventions. You must obtain permission for any other use. Electronic or print copies may not be offered, whether for sale or otherwise to anyone. This copy has been supplied on the understanding that it is copyright material and that no quotation from the thesis may be published without proper acknowledgement.
Cognitive Processes in Causal and Counterfactual Thinking

Caren A. Frosch

Ph.D.

Trinity College Dublin, University of Dublin
2007
Declaration

(a) The work contained in this thesis has not been submitted as an exercise for a degree at this, or any other University.

(b) This thesis is the result of my own investigations, except where otherwise stated. The contributions of others are duly acknowledged in the text wherever included.

(c) I give permission to the Library to lend or copy this thesis upon request.

Signed: [Signature]

Date: 30.4.07
Acknowledgments

I would like to thank all the people who have been my ‘enabling conditions’ along the way. First of all, I would like to thank Ruth Byrne for giving me the opportunity to come to Dublin and work with her. Her guidance has been invaluable and I thank her for teaching me about the rigours of research and writing. The IRCHSS provided the funding for this research which included generous support for research travel.

I thank Phil Johnson-Laird for welcoming me in Princeton during my two month research visit and for all his mentorship ever since. I am grateful to Louis Lee and Geoffrey Goodwin for welcoming me into their office and making my time in Princeton very enjoyable. I am also glad I was able to share the Princeton experience with Sonja Geiger.

Without the constant encouragement and support from my brother, Dominick, I may never have embarked on this journey. I am forever grateful for his belief in me and the regular kicks to make sure I stay on the ball. Merideth Gattis has also been instrumental in starting me off on this path; she inspired me to become a great researcher and teacher.

During my three years in Dublin I was very lucky to meet some wonderful people. Michelle Cowley has been a tremendous friend and scholar to bounce ideas off throughout. I thank Julie Meehan for her friendship, encouragement and support, and for introducing me to pita bread, avocado and hummus. I thank Suzanne Egan for all her advice, for allowing me to keep ‘the chair’ and for listening to my pet hates. I am grateful to the UCD/TCD cognition group for providing an environment to practice my presenting skills and discuss ideas with, especially Aisling Murray, Amy Bohan and Rebecca Grimes.

Thank you to my fellow postgrads and staff in the department for creating a very friendly and welcoming environment for me to spend three years in. I particularly want to thank Rabea Morrison for her friendship and always lending an open ear. I thank Alex Pereda for allowing me to see the world through his eyes and for making me laugh a lot. Caoilte, Justin and James made the last year, and in particular the write-up, so much more enjoyable than I thought possible. Julie kept me going during the second year, especially during all the testing, and Redmond, Achille and Michelle made sure the first year was very memorable: “I’m not saying anything”.

I am grateful for having met June Switzer, the kindest person ever. Her friendship means so much and I thank her for always putting a smile on my face. I will miss her greatly! Thank you also to Lisa Gilroy and David Hennigan for technical assistance and
David for general amusement. I also thank Gry Wester for typing up the 600 plus paraphrases generated in Experiment 3.

I had the great opportunity to present and discuss my research, both in Dublin and at conferences. In particular, I would like to thank Clare Walsh for always taking an interest in my research and offering many great suggestions. Orlando Espino deserves a special mention for all his advice and unrelenting patience.

A massive thank you to the wonderful Mary Liddy for providing me with a place I can call home. I am grateful for the long distance support from my friends and family, my dear friends Nicola, Britta, Galin, and Marie for encouraging me all the way, and my wonderful mother for taking an interest in my work even if it didn’t always make sense to her. I thank my husband, Ian Gallimore, for supporting me, making sure I look after myself and always being there for me, even from afar.

Lastly, I would like to thank my father for bowing out of my life early and forcing me to become independent and develop the ability to see something positive in every situation.
# Table of Contents

## CHAPTER 1  INTRODUCTION 1
- Conditional reasoning 2
- Causal relations 18
- Counterfactual thinking 27
- Theoretical accounts of causal and counterfactual thinking 32
- Thesis overview 38

## CHAPTER 2  COUNTERFACTUAL ALTERNATIVES 44
- Conditional inferences 44

**EXPERIMENT 1: REASONING FROM COUNTERFACTUAL CONDITIONALS WITH A CONTEXT** 48
- Method 50
- Results and discussion 52
- Summary 54

**EXPERIMENT 2: REASONING FROM COUNTERFACTUAL CONDITIONALS IN CONTEXT – WHAT INFORMATION MODULATES THE INTERPRETATION?** 56
- Method 57
- Results and discussion 58
- Summary 60

**GENERAL DISCUSSION** 60

## CHAPTER 3  PARAPHRASES OF CAUSAL AND COUNTERFACTUAL CONDITIONALS 66
- Counterfactuals 67
- Paraphrases and the mental representation of causal and counterfactual conditionals 68

**EXPERIMENT 3: PARAPHRASING COUNTERFACTUALS** 70
- Method 71
- Results and discussion 72
- Summary 77

**EXPERIMENT 4: PARAPHRASING DIFFERENT CAUSES** 78
- Method 79
- Results and discussion 81
- Summary 84
CHAPTER 4 PRIMING CAUSAL RELATIONS

Different types of causal relations

EXPERIMENT 5: PRIMING ENABLING CAUSAL RELATIONS

Method

Results and discussion

Summary

EXPERIMENT 6: PRIMING STRONG AND WEAK CAUSES

Method

Results and discussion

Summary

CHAPTER 5 CAUSES AND ENABLING CONDITIONS

Causes and enabling conditions

EXPERIMENT 7: INCONSISTENT INFORMATION ABOUT CAUSES AND ENABLING CONDITIONS

Method

Results and discussion

Summary

EXPERIMENT 8: DISTINGUISHING BETWEEN CAUSES AND ENABLING CONDITIONS

Method

Results and discussion

Summary

CHAPTER 6 DISCUSSION

Summary of findings

Implications

Future directions

Conclusion

REFERENCES

APPENDIX A

A1. Instructions for Experiments 1 and 2
<table>
<thead>
<tr>
<th>Section Description</th>
<th>Page</th>
</tr>
</thead>
<tbody>
<tr>
<td>A2. Materials for Experiments 1 and 2</td>
<td>182</td>
</tr>
<tr>
<td>A3. Debriefing for Experiments 1 and 2</td>
<td>187</td>
</tr>
<tr>
<td><strong>APPENDIX B</strong></td>
<td></td>
</tr>
<tr>
<td>B1. Instructions for Experiment 3</td>
<td>188</td>
</tr>
<tr>
<td>B2. Materials for Experiment 3</td>
<td>188</td>
</tr>
<tr>
<td>B3. Instructions and materials for memory task (post-test) in Experiment 4</td>
<td>189</td>
</tr>
<tr>
<td>B4. Debriefing sheet for Experiments 3 and 4</td>
<td>191</td>
</tr>
<tr>
<td>B5. Instructions for Experiment 4</td>
<td>191</td>
</tr>
<tr>
<td>B6. Materials for Experiment 4</td>
<td>191</td>
</tr>
<tr>
<td><strong>APPENDIX C</strong></td>
<td></td>
</tr>
<tr>
<td>C1. Instructions for pre-tests 5.1 and 6.1</td>
<td>195</td>
</tr>
<tr>
<td>C2. Materials for pre-test 5.1</td>
<td>195</td>
</tr>
<tr>
<td>C3. Instructions for Experiments 5 and 6</td>
<td>201</td>
</tr>
<tr>
<td>C4. Materials for Experiment 5</td>
<td>201</td>
</tr>
<tr>
<td>C5. Results of Power tests for the planned comparisons in Experiment 5</td>
<td>207</td>
</tr>
<tr>
<td>C6. Materials for pre-test 6.1</td>
<td>207</td>
</tr>
<tr>
<td>C7. Materials for Experiment 6</td>
<td>215</td>
</tr>
<tr>
<td>C8. Results of Power tests for the planned comparisons in Experiment 6</td>
<td>220</td>
</tr>
<tr>
<td><strong>APPENDIX D</strong></td>
<td></td>
</tr>
<tr>
<td>D1. Instructions for Experiment 7</td>
<td>221</td>
</tr>
<tr>
<td>D2. Materials for Experiment 7</td>
<td>221</td>
</tr>
<tr>
<td>D3. Debriefing for Experiment 7</td>
<td>221</td>
</tr>
<tr>
<td>D4. Instructions for Experiment 8</td>
<td>221</td>
</tr>
<tr>
<td>D5. Materials for Experiment 8</td>
<td>222</td>
</tr>
<tr>
<td>D6. Debriefing sheet for Experiment 8</td>
<td>223</td>
</tr>
<tr>
<td><strong>APPENDIX E – ETHICS</strong></td>
<td></td>
</tr>
<tr>
<td></td>
<td>224</td>
</tr>
</tbody>
</table>
### List of Tables

<table>
<thead>
<tr>
<th>Table</th>
<th>Description</th>
<th>Page</th>
</tr>
</thead>
<tbody>
<tr>
<td>Table 1.1:</td>
<td>Biconditional and conditional interpretations of ‘if there is a B then there is a D’</td>
<td>3</td>
</tr>
<tr>
<td>Table 1.2:</td>
<td>Four inferences and their classification as valid or invalid depending on the interpretation of the conditional from the assertion ‘if there is a B then there is a D’</td>
<td>4</td>
</tr>
<tr>
<td>Table 1.3:</td>
<td>Some proposed means of differentiating between causes and enablers</td>
<td>25</td>
</tr>
<tr>
<td>Table 2.1:</td>
<td>Percentages of each type of inference in the three conditions of Experiment 1</td>
<td>53</td>
</tr>
<tr>
<td>Table 2.2:</td>
<td>Percentages of each type of inference in the four conditions of Experiment 2</td>
<td>258</td>
</tr>
<tr>
<td>Table 3.1:</td>
<td>Categories and connectives in Experiment 3</td>
<td>73</td>
</tr>
<tr>
<td>Table 3.2:</td>
<td>Percentages of each type of connective as a function of type of conditional, factual or counterfactual</td>
<td>74</td>
</tr>
<tr>
<td>Table 3.3:</td>
<td>Percentages of each type of connective as a function of type of cause, strong, weak, enabler</td>
<td>75</td>
</tr>
<tr>
<td>Table 3.4:</td>
<td>Percentages of each type of connective as a function of type of conditional, factual or counterfactual</td>
<td>82</td>
</tr>
<tr>
<td>Table 3.5:</td>
<td>Percentages of each type of connective as a function of type of cause, strong, weak, enabler</td>
<td>83</td>
</tr>
<tr>
<td>Table 4.1:</td>
<td>Predicted mental representation for strong causes, weak causes and enabling conditions</td>
<td>89</td>
</tr>
<tr>
<td>Table 4.2:</td>
<td>Percentages of consistency ratings for the three types of causes</td>
<td>95</td>
</tr>
<tr>
<td>Table 4.3:</td>
<td>Percentage of consistency ratings for the three types of causes</td>
<td>105</td>
</tr>
<tr>
<td>Table 5.1:</td>
<td>Sample of the materials and task for Experiment 7</td>
<td>126</td>
</tr>
<tr>
<td>Table 5.2:</td>
<td>The percentages of trials on which participants maintained their belief about the enabler after disambiguating sentences that were consistent or inconsistent with this identification.</td>
<td>130</td>
</tr>
<tr>
<td>Table 5.3:</td>
<td>The percentages of trials on which the participants maintained their belief about the cause after disambiguating sentences that were consistent or inconsistent with this identification.</td>
<td>131</td>
</tr>
<tr>
<td>Table 5.4:</td>
<td>Percentage of trials on which a particular cause and/or a particular enabling condition were selected for the different contents</td>
<td>133</td>
</tr>
<tr>
<td>Table 5.5:</td>
<td>Comparison of the five different contents on rates (in percentages) of switching causal assignments.</td>
<td>134</td>
</tr>
</tbody>
</table>
Table 5.6: Mean number of trials consistent with MM and ‘given’ with standard deviations in parenthesis 139
Table 5.7: Mean number of trials consistent with MM and ‘given’ with standard deviations in parenthesis 140
Table 5.8: Mean number of trials consistent with MM and location of enabler in first sentence, with standard deviations in parenthesis 143
List of Figures

Figure 4.1: The mean reading times (in milliseconds) for the baseline and after the conditional. 98

Figure 4.2: The mean reading times (in milliseconds) for the baseline and after the strong and weak cause conditionals. 108
Summary

The aim of this thesis is to examine the mental representation of and cognitive processes involved in causal and counterfactual thinking. In particular we examine differences between different types of causes, that is, strong causes, weak causes, and enabling conditions. In addition, we examine the effect of context on reasoning from causal counterfactual conditionals. We test predictions derived from the mental model theory of causal and counterfactual thinking. According to this account people understand different types of causes by keeping different possibilities in mind.

In Chapter 1 we review the literature on causal and counterfactual thinking, as well as conditional reasoning, which is closely linked to causal and counterfactual thinking. The research described in this thesis derived its predictions from the mental model theory (Johnson-Laird & Byrne, 2002). However, we consider the implications of this research for other theories of conditional reasoning, such as mental logic theories (e.g., Braine & O’Brien, 1991), domain specific rule theories (e.g., Cheng & Holyoak, 1985) and the suppositional theory of *if* (Evans & Over, 2004) throughout.

In Chapter 2 we report two experiments in which we examined the effect of context on the inferences people make from causal counterfactual conditionals. The results suggest that a context which includes a counterfactual alternative leads to a modulation of the interpretation of the conditional and thus has an effect on the inferences people make.

In Chapter 3 we examine the mental representation of factual and counterfactual conditionals and also investigate the mental representation of different types of causes. We continue our investigation of the mental representation of different types of causes in Chapter 4. We use two very different methodologies in Chapters 3 and 4. Most previous research investigating the mental representation of conditionals has examined people’s mental representations by either inferring them from the deductions people make, or by directly asking people to list true and false possibilities, or by using truth table tasks. We rely on more subtle and direct methods.

In Chapter 3 we report two experiments in which we employed a paraphrasing task to examine factual and counterfactual conditionals as well as different causes. The results are consistent with previous findings on the difference between factual and counterfactual conditionals in that factual conditionals are understood by keeping in mind only one possibility and counterfactual conditionals are understood by keeping in mind multiple possibilities. The paraphrases reveal no differences between the different types of causes. The results suggest that the mood of the conditional (the indicative mood for factual
conditionals and the subjunctive mood for counterfactual conditionals) may sometimes take precedence over the content of the conditional.

In Chapter 4 we examine the mental representation of different types of causes by means of a priming paradigm. In two experiments we test the prediction made by the mental model theory that different causes are understood by keeping in mind different possibilities. The results support the hypothesis.

In Chapter 5 we focus on the distinction between causes and enabling conditions. We report two experiments in which participants are asked to identify the cause and the enabling condition from a description of two antecedent events and an outcome. The results suggest that people are able to consider different possibilities when they distinguish between causes and enabling conditions. However, they may sometimes make use of cognitively less demanding cues when they are available.

In Chapter 6 we summarise our findings. We consider our results with reference to the mental model theory and other theories of conditional reasoning. We discuss the implications of our results for understanding causal and counterfactual thinking, as well as for the mental model theory, and we suggest some questions for future research.
Chapter 1  Introduction

An understanding of cause and effect is central to our everyday thinking. Understanding how one event causes another enables us to operate our new mobile phone or understand why a person may have behaved in a certain way. Our causal understanding also allows us to predict future outcomes (e.g., ‘if I press this button then the TV will come on’) as well as enabling us to think about how a particular event could have been prevented (e.g., ‘if there had been more resources the July 7th attacks could have been prevented’, Guardian Unlimited 11/5/06). Thoughts about how an event could have been different are termed counterfactual thoughts (for a review see Byrne, 2005). Causal thoughts (e.g., ‘if the water was heated to 100°C then it boiled’) and counterfactual thoughts (e.g., ‘if the water had been heated to 100°C then it would have boiled’) are closely related and there is a large literature, particularly in philosophy, discussing this relationship (e.g., Berofsky, 1973). A central theme of this thesis is the examination of different types of causes, including strong causes (e.g., ‘if the water was heated to 100°C then it boiled’), weak causes (e.g., ‘if the apples were ripe then they fell from the tree’), and enabling conditions (e.g., ‘if there was oxygen then there was a fire’). In recent years it has been suggested that counterfactual thoughts focus on prevention and in particular on enabling conditions (see Byrne, 2005 for a review). We draw on the theories and methods of conditional reasoning research to explore our research question: how do people understand factual and counterfactual conditionals about strong causes, weak causes and enabling conditions?

This chapter is divided into five sections. Many causal and counterfactual thoughts are conditional ‘if...then’ assertions and much of the research into causal and counterfactual thinking has made use of the theories and methods of conditional reasoning research. We therefore begin with an overview of conditional reasoning and discuss some of the theories that have been developed to account for people’s reasoning performance. The second section examines different types of causes and research relevant to the distinction between different types of causes, including causes and enabling conditions. The third section introduces counterfactual thinking and gives a brief overview of the relation between causality and counterfactual thinking. In the fourth section we discuss how theories of conditional reasoning attempt to explain causal and counterfactual thinking. Finally, in section five we provide an overview of the thesis by outlining our research questions and describing the variety of methods that were used in the research.
Conditional reasoning

Among reasoning researchers the word ‘if’ plays a central role in investigations of human reasoning. Evans and Over (2004) assert that the word ‘if’ allows hypothetical thought and as such distinguishes us from other animals.

“It is the linguistic device for stimulating hypothetical thought, and it is this facility—above all others—that identifies the extraordinary and unique kind of intelligence that defines us as human beings.” (p. 172)

Conditional ‘if...then’ sentences signal hypothetical thought which is characteristic of counterfactual thinking as well as assertions about cause and effect. In this first section we examine two important topics relating to the word ‘if’ and we then consider a number of theories of conditional reasoning. First, we examine the interpretation of ‘if’, that is, how people typically interpret a conditional ‘if...then’ assertion. Second, we examine the inferences people typically make from a conditional and how these inferences relate to the inferences outlined in the propositional calculus. Third, we discuss the main theories that have been proposed to account for people’s reasoning performance.

Interpretations of ‘if’

A conditional such as ‘if there is a B then there is a D’ has four possibilities associated with it:

i. ‘there is a B and there is a D’,

ii. ‘there is a B and there is not a D’,

iii. ‘there is not a B and there is a D’,

iv. ‘there is not a B and there is not a D’.

The question we want to address in this section is which of the four possibilities people judge to be consistent and inconsistent with a statement such as ‘if there is a B then there is a D’. Conditionals such as this one have commonly been used in research on conditional reasoning, as they are statements which do not contain reference to people’s prior knowledge. People’s prior knowledge can affect how a person interprets and makes inferences from a conditional (e.g., Cummins, 1995). Researchers have been keen to

---

1 The propositional calculus is a formal system that represents the materials and principles of propositional logic.
separate the effects of logical form and prior knowledge in their investigation of conditional reasoning.

In many of the typical reasoning tasks with conditionals participants are asked to imagine a blackboard and are then presented with a conditional such as 'if there is a B then there is a D' (e.g., Braine & O'Brien, 1998). An assertion such as this one can be interpreted in many ways. However, we focus on the two most common interpretations: material equivalence (or biconditional) and material implication (or conditional). Participants’ interpretations have typically been examined by using truth table tasks. In these tasks participants are given a conditional and asked to evaluate each of the four possibilities above as either true or false (or irrelevant) with reference to the conditional.

A biconditional interpretation is equivalent to the conditional 'if and only if there is a B then there is a D'. This interpretation implies that there are only two consistent possibilities: 'there is a B and there is a D' and 'there is not a B and there is not a D' (options i and iv above). The other two possibilities in which either the 'B' or the 'D' is absent (options ii and iii above) are inconsistent with the conditional (see Table 1.1 for an illustration).

Table 1.1: Biconditional and conditional interpretations of ‘if there is a B then there is a D’

<table>
<thead>
<tr>
<th>Possibility</th>
<th>Biconditional</th>
<th>Conditional</th>
</tr>
</thead>
<tbody>
<tr>
<td>B and D</td>
<td>True</td>
<td>True</td>
</tr>
<tr>
<td>B and not D</td>
<td>False</td>
<td>False</td>
</tr>
<tr>
<td>not B and D</td>
<td>False</td>
<td>True</td>
</tr>
<tr>
<td>not B and not D</td>
<td>True</td>
<td>True</td>
</tr>
</tbody>
</table>

A material interpretation, or conditional interpretation, is consistent with three possibilities. In addition to the two possibilities consistent with the biconditional interpretation, the conditional interpretation is also consistent with the possibility ‘there is not a B and there is a D’. This third possibility arises from the fact that a ‘D’ could be present even if there is not a ‘B’. In the second section of this chapter we examine causal conditionals where this distinction between conditional and biconditional interpretations is
important. However, we first consider the types of inferences people make from conditionals.

**Inferences from 'if'**

We first examine the inferences that can be made from a conditional and how these inferences are viewed from a logician's point of view (see Table 1.2 for a summary). We will then review research on the inferences people actually make. Philosophers assert how inferences *ought* to be made whereas psychologists examine what inferences people *actually* make.

**Table 1.2:** Four inferences and their classification as valid or invalid depending on the interpretation of the conditional from the assertion 'if there is a B then there is a D'

<table>
<thead>
<tr>
<th>Inference</th>
<th>Biconditional Interpretation</th>
<th>Conditional Interpretation</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Modus Ponens</strong></td>
<td>Valid</td>
<td>Valid</td>
</tr>
<tr>
<td>B</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Therefore D</td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Modus Tollens</strong></td>
<td>Valid</td>
<td>Valid</td>
</tr>
<tr>
<td>Not D</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Therefore not B</td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Affirmation of the Consequent</strong></td>
<td>Valid</td>
<td>Invalid</td>
</tr>
<tr>
<td>D</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Therefore B</td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Denial of the Antecedent</strong></td>
<td>Valid</td>
<td>Invalid</td>
</tr>
<tr>
<td>Not B</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Therefore not D</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
A conditional such as 'if there is a B then there is a D' consists of two parts. The first part ('if there is a B') is the antecedent of the conditional and the second part ('there is a D') is the consequent. A conditional argument can be constructed corresponding to four different inferences. A conditional premise can be followed by one of four different premises. The second premise can make an assertion about the presence of the item mentioned in the antecedent of the conditional and therefore invite an inference about the consequent, or the second premise can make an assertion about the consequent and therefore invite an inference about the antecedent. We consider the four options in turn.

First, suppose a person is told that 'there is a B' (the item referred to in the antecedent is present). They can infer that 'there is a D' (the item referred to in the consequent is present). This inference is termed modus ponens (MP). Second, suppose a person is told 'there is not a D' (the item referred to in the consequent is absent). They can infer that 'there is not a B' (the item referred to in the antecedent is absent). This inference is termed modus tollens (MT). Both of these inferences are viewed as valid inferences. The inferences are valid as, given that the premises are true, these conclusions follow logically.

The third sort of inference invites a person to suppose that 'there is a D' (the item referred to in the consequent is present). The inference a person might be tempted to make is 'there is a B' (the item referred to in the antecedent is present). This inference is termed the affirmation of the consequent (AC). According to the propositional calculus, if we have come to a conditional interpretation of the assertion, this inference is invalid. The true possibilities outlined in Table 1.1 for a conditional interpretation illustrate why this conclusion is logically invalid. The possibility 'there is a B and there is a D' is consistent with a conditional interpretation, as is the possibility 'there is not a B and there is a D'. As a result a person can only conclude 'there may or may not be a B'.

Finally, the fourth sort of inference invites a person to suppose that 'there is not a B' (the item referred to in the antecedent is absent). They might be tempted to infer 'there is not a D' (the item referred to in the consequent is absent). This inference is termed the denial of the antecedent (DA), and again, according to the propositional calculus, this inference is invalid. It is invalid for a similar reason as that for the affirmation of the consequent inference. Table 1.1 illustrates two possibilities in which 'B' is absent, for one of them 'D' is present and for the other 'D' is absent. Therefore, a person can only conclude 'there may or may not be a D'. However, if the conditional is interpreted as a biconditional 'if and only if there is a B then there is a D', then all four inferences are valid (as can be seen in Table 1.2).
The most comprehensive review of studies investigating conditional inferences from conditionals containing an abstract content is reported in a meta-analysis by Schroyens, Schaeken, and d’Ydewalle (2001a). In the experiments reviewed, participants made the valid modus ponens inference on nearly 100% of trials and the valid modus tollens inference on 39% to 91% of trials. The two invalid inferences, affirmation of the consequent and denial of the antecedent, were made on 23% to 89% and 17% to 82% of trials respectively. As can be seen from this meta-analysis, the modus ponens inference is made consistently whereas there is a considerable amount of variability in the frequency of making the other three inferences. Our discussion of theories of conditional reasoning in the next part of this section will, among other things, address why the frequency of making inferences other than modus ponens is variable.

**Theories of conditional reasoning**

Several theories have been developed to explain performance on conditional reasoning experiments, including the mental model theory (e.g., Johnson-Laird & Byrne, 2002), mental logic theories (e.g., Braine & O’Brien, 1998; Rips, 1994), domain specific rule theories (e.g., Cheng & Holyoak, 1985; Fiddick, Cosmides, & Tooby, 2000), and the suppositional theory of if (Evans & Over, 2004). The mental model theory represents a semantic approach to reasoning, emphasising an understanding of the meaning of a problem - people use their understanding of the premises to construct mental models (Johnson-Laird & Byrne, 1991).

Mental logic theories derive from the study of logic in that they propose that people reason by constructing proofs similar to logical proofs (Rips, 1983). These theories represent a syntactic approach to reasoning and emphasise understanding the structure of a problem (Johnson-Laird, 1989). Domain specific rules and schema theories were developed in response to the discovery of content effects in the Wason selection task (Wason, 1966). In the original version of Wason’s selection task participants are presented with four cards laid out in front of them. Two cards have letters on them and the other two have numbers on them (e.g., ‘E’, ‘K’, ‘7’, ‘4’). The participants’ task is to evaluate an abstract rule, such as ‘if there is a vowel on one side of the card then there is an even number on the other side of the card’, by choosing only the cards that need to be turned over in order to decide whether the statement is true or false. The correct answer to this problem is to turn over the ‘E’ and the ‘7’ cards. Participants often make errors on this abstract task. However, when participants are asked to evaluate concrete materials, grounded in real life experience, they tend to choose the correct cards. For example when
the rule to be evaluated is ‘if a person is drinking beer then that person must be over 18 years of age’, participants readily select the correct cards (‘drinking beer’ and ‘under 18’) (for a review of the selection task see Evans, Newstead, & Byrne, 1993; Evans & Over, 2004). These theories represent a pragmatic approach to reasoning, emphasising the content of a problem as crucial to understanding how it will be solved. The suppositional theory of if is based on the mental model theory (Evans & Over, 2004). However, it uses a probabilistic approach to dealing with conditional assertions. We review each of these theories in the remainder of this section, beginning with the mental model theory.

The mental model theory

The mental model theory provides the most comprehensive account of conditional reasoning and reasoning from counterfactual and causal conditionals (Byrne, 1997; Goldvarg & Johnson-Laird, 2001; Johnson-Laird & Byrne, 2002). The research in this thesis is designed to test principles and predictions derived from the mental model theory.

The mental model theory assigns comprehension a central role in reasoning. When people are given a reasoning problem they comprehend the premises and build mental models, based on their understanding of these premises. A mental model is a mental representation of a premise that corresponds to the way the world would be if the premise was true. Johnson-Laird (1983) states that the models people create are structural analogues of the world as opposed to perceptual analogues. Mental models are incomplete and therefore simpler than the actual state of affairs they represent. An example will illustrate.

If a person were given the following conditional: ‘if Peter banged his head then it hurt’ then that person could construct the following fully explicit mental models of this premise:

<table>
<thead>
<tr>
<th>banged</th>
<th>hurt</th>
</tr>
</thead>
<tbody>
<tr>
<td>not banged</td>
<td>hurt</td>
</tr>
<tr>
<td>not banged</td>
<td>not hurt</td>
</tr>
</tbody>
</table>

Each line represents one model, where ‘banged’ stands for banging his head and ‘hurt’ stands for his head hurting and ‘not’ stands for the negation of the component (Johnson-Laird & Byrne, 1991). These three models represent all true possibilities assuming the original premise is true. According to the principle of true possibilities people do not represent instances where the premise is false, such as ‘Peter banged his head and it did not hurt’ (Johnson-Laird & Byrne, 2002). Furthermore, on hearing the conditional ‘if Peter banged his head then it hurt’ people would probably not construct the fully explicit models.
Due to processing limitations, i.e., working memory capacity, people represent as little as possible in order to understand and evaluate a statement. This is the principle of few possibilities. People generally represent explicitly the possibilities in which the event mentioned in the antecedent is present (e.g., ‘he banged his head and it hurt’) and they represent implicitly possibilities in which the event mentioned in the antecedent of the conditional is absent (e.g., ‘he did not bang his head and it hurt’). People tend to focus on possibilities they have represented explicitly (Johnson-Laird & Byrne, 1991). As a result people tend to make errors when an inference they want to make requires access to a possibility that has been represented implicitly (e.g., the modus tollens inference). According to the mental model theory, people initially only represent one possibility for the conditional ‘if Peter banged his head then it hurt’:

```
banged  hurt
...
```

This set of models represents the possibility ‘Peter banged his head and it hurt’. In addition it represents an implicit model, the three dots (ellipsis) beneath the first line of the model indicate that there are other, alternative models. If people are now given a further premise (‘Peter banged his head’) they need to combine it with the initial model and evaluate whether they are able to draw a conclusion (‘Peter’s head hurt’). The difficulty of this task depends on whether the model of the minor premise can easily be integrated with the initial models of the conditional. If it cannot be integrated with the initial models then people must flesh out the initial models to include further explicit models. Suppose the further premise is ‘Peter did not bang his head’. People’s initial representation of the conditional does not include this possibility. They therefore must flesh out their initial models. Depending on their interpretation of the conditional (biconditional or conditional) they can flesh out the models in two ways:

```
banged  hurt  or  banged  hurt
not banged  not hurt  not banged  not hurt
```

They can now integrate the new premise with their fleshed out model and will either conclude ‘his head did not hurt’ (if they come to a biconditional interpretation) or ‘his head may or may not hurt’ (if they come to a conditional interpretation).

Johnson-Laird and Byrne (2002) outline other factors that affect the construction of models. Accordingly, the content of the two components of a conditional, the meanings of
the words, can add information to models, prevent the construction of models and aid the process of constructing fully explicit models. This is the principle of semantic modulation (Johnson-Laird & Byrne, 2002). Consider the assertion ‘if Mary is in Ireland then she is in Dublin’. On a conditional interpretation this conditional is consistent with the following possibilities:

<p>| | |</p>
<table>
<thead>
<tr>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Ireland</td>
<td>Dublin</td>
</tr>
<tr>
<td>not Ireland</td>
<td>Dublin</td>
</tr>
<tr>
<td>not Ireland</td>
<td>not Dublin</td>
</tr>
</tbody>
</table>

However, people’s knowledge of the fact that Dublin is in Ireland will prevent the construction of the second model (‘Mary is not in Ireland, and she is in Dublin’).

The linguistic context within which an assertion is made also has an effect on the construction of models. The effect of context is captured by the principle of pragmatic modulation:

“The context 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. These models can modulate the core interpretation of a conditional, taking precedence over contradictory models. They can add information to models, and aid the process of constructing fully explicit models.” (p. 659)

An example will illustrate. Consider the conditional ‘if a match is struck properly then it lights’. Given a conditional interpretation of the assertion, the following inference is logically valid: ‘therefore, if a match is soaking wet and it is struck properly, then it lights’. However, general knowledge will prevent people from making this inference as they will construct the model

<p>| | |</p>
<table>
<thead>
<tr>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>match soaked</td>
<td>not lights</td>
</tr>
</tbody>
</table>

The next step in the reasoning process is to validate the models a person has in mind, by searching for inconsistencies in the models, i.e., counterexamples. There are three processing assumptions, which have a bearing on this process (Johnson-Laird & Byrne, 1991). Firstly, the greater the number of explicit models that need to be considered, the harder the task and the greater the likelihood of making errors. Secondly, inferences from an initial model are easier to make than from ones that require models to be fleshed out. Thirdly, detecting inconsistencies between elements takes time.
Criticism of the mental model theory

The mental model theory distinguishes between initial representations of premises and fully fleshed out representations. The more fleshed out the representation of a premise the more demands are made on working memory and hence the more difficult it is to keep all the relevant models in mind. O'Brien, Braine, and Yang (1994) assert that the mental model theory must rely on people creating fully explicit models to account for the blocking of certain fallacies (invalid inferences), which is difficult for most people. One of the examples O'Brien et al. provide is the conditional 'if A and B then C' followed by the premise ‘A’. The conclusion to this problem is ‘cannot tell whether there is a C’ as there is not enough information to make a determinate inference. O'Brien et al. argue that the mental model theory is unable to account for people’s performance on this inference as the initial models

A  B  C

would lead to the inference (‘C is present’). Johnson-Laird, Byrne and Schaeeken (1994) counter this criticism by pointing out that O’Brien et al. neglected the differing levels of expertise of reasoners. Individuals performing at an intermediate level go beyond the initial representation but may not fully flesh out their representation, that is, consider all of the possible models. Johnson-Laird et al. demonstrate that people can reach the correct conclusion to the problem posed by O’Brien et al. by considering just two models:

A  B  C
A

The second model does not include ‘C’ and therefore people will make the correct conclusion of ‘cannot tell whether there is a C’.

Researchers investigating a variety of reasoning domains have provided further support for the suggestion that fully fleshed out models are not always necessary for reaching the correct conclusion. Accordingly, a modus tollens inference can be made if people only consider two models instead of three models for a conditional (for example by coming to a biconditional rather than a conditional interpretation). Similarly, when people reason about spatial and temporal relations, a partial fleshing out of models may be sufficient to reach the correct conclusion (e.g., Byrne & Johnson-Laird, 1989; Schaeeken, Johnson-Laird, & d’Ydewalle, 1996).

Evans and Over (2004) criticise the mental model theory for proposing that people are able to consider more than one mental model at a time. Instead they argue, people are only able to consider one possibility at a time and consider multiple possibilities in a sequential fashion. However, this proposal cannot account for recent data on the number of
possibilities people keep in mind, such as the finding that counterfactual conditionals prime two possibilities (Santamaria, Espino, & Byrne, 2005). We will examine this evidence in further detail in our discussion of counterfactual thinking in the third section of this chapter.

Although Evans is one of the most vocal critics of the mental model theory of recent times, he asserts "...the mental model theory is by far the most popular in the psychological study of conditionals and constitutes in effect the dominant paradigm for this field of study." (Evans & Over, 2004, p. 59).

In this thesis we examine the principles of true possibilities (that is, people only consider possibilities consistent with a premise), and the principles of semantic and pragmatic modulation (the effect of content and context on people's understanding of premises) by testing people's understanding of different causal relations. Our predictions are derived from the mental model theory and its extension to causal and counterfactual conditionals. We will describe the mental model theory of causal and counterfactual thinking in section four, after providing an overview of causal and counterfactual thinking.

We now consider some of the other theories that have been proposed to explain how people reason from conditionals. Our research is designed to test the predictions made by the mental model theory, and throughout the thesis we consider how other theories can account for our findings.

Mental logic theories

Braine and O'Brien (1998) and Rips (1994), are among the proponents of reasoning theories based on mental logic. The basic premise of these theories is that people are inherently rational and reason by applying abstract, content-free rules, which are similar to the derivation of proofs in logic and can be applied to any domain of knowledge.

When people understand the premises of an argument they encode them into abstract rules, language-like mental representations that make their logical form explicit (Rips, 1983), and make inferences based on these. Errors are made because the task is misunderstood (comprehension error) or misrepresented (this could be due to working memory limitations, lapses of attention or errors due to the inadequacy of the heuristics used) (Braine & O'Brien, 1998).

The theory of 'if' (Braine & O'Brien, 1991) proposes that people have a "lexical entry" for the word 'if'. This means that the meaning of the word 'if' (as well as other logical connectives, such as 'and' and 'or') is stored in people's semantic memory in the
form of schemas. There are two schemas for 'if': modus ponens, i.e. the rule for modus ponens, and the schema for conditional proof:

“This schema states that when one can derive the consequent of a conditional from a set of premises taken together with the antecedent of the conditional as a hypothetical assumption, then one can assert the conditional on the premises alone.” (p.183)

In addition to the lexical entry there is a “pragmatic comprehension process”. Together these two components lead to an understanding of a premise in context. Braine and O’Brien (1998) assert that the processes they describe may not be the only ones involved in human reasoning and there may be a role for reasoning schemas as well as mental models. They therefore see a role for pragmatic reasoning schemas (Cheng & Holyoak, 1985) in the pragmatic comprehension process. Mental logic theories by themselves are unable to account for content effects.

A further part of the theory of ‘if’ is a reasoning program. This program contains information on a person’s typical mode of reasoning with conditionals. It models how the schemas are used to construct a chain of reasoning. However, when the typical reasoning routine fails, people fall back on to reasoning strategies. These strategies are not universal and therefore, result in large individual differences. Braine and O’Brien do not specify what determines which strategies are available and how someone would select between different strategies.

Rips (1994) proposes a reasoning system called the Psychology of Proof (PSYCOP), which accounts for deductive reasoning rather than conditional reasoning alone. The system comprises a number of deduction rules, which derive from logic. These deduction rules are used to construct mental proofs in working memory. This is an iterative process during which further proofs are applied until no more rules apply and a conclusion is reached.

Mental logic theories explain the different rates at which inferences are made by appealing to the number of steps involved in arriving at a conclusion. The modus ponens inference is easy as people have a rule for it. The modus tollens inference on the other hand is more difficult as people do not have a specific rule for it and must construct a proof consisting of several rules in order to reach the correct conclusion, as the following example shows, (from Braine & O'Brien, 1998, p. 207):

1. If A then B (premise)
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. :. Not A (reductio)
9. :. If not B then not A (Conditional Proof)

People are more likely to make errors when making a modus tollens inference, and conclude that nothing follows, than when making a modus ponens inference, as there are many more steps involved. Braine, Reiser and Rumain (1998) provide evidence for the hypothesis that multiple step problems are more difficult than single step problems. The authors examined a variety of problems which included 'one step' problems, that is, the problems could be solved by applying one schema, and 'multistep' problems, whose solution required the application of two or more inference rules. Braine et al. measured how long it took participants to evaluate a conclusion for each of the 121 problems presented to them. They also carried out a rating study in which participants had to rate the difficulty of each of the inferences. In addition to distinguishing problem difficulty by the number of steps involved, the various steps also have different difficulty ratings associated with them. Across the studies and measures reported, Braine et al. report correlations of .73 and above between predicted difficulty, reaction time and rated difficulty.

The errors made with regard to the invalid inferences (denial of the antecedent and affirmation of the consequent) are attributed to comprehension errors rather than a fault in reasoning (Braine & O'Brien, 1991). Rumain, Connell and Braine (1983) demonstrated that providing alternative antecedents suppresses invalid inferences. 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 'if there is a tiger in the box then there is an orange in the box'. Participants were then told 'there is an orange in the box' (the affirmation of the consequent inference) and asked if they could conclude that there was a dog in the box. Most of the participants (75%) said they 'cannot tell', which is the logically correct response. When participants only received the first conditional ('if there is a dog in the box then there is an orange in the box') only 33% responded in the logically correct way and said 'cannot tell'. The pattern for the denial of the antecedent inferences was similar, 69% responded in the logically correct way when they were given an alternative and just 27% responded this way when they received only one conditional. This research
has been cited as evidence that there are no mental rules for invalid inferences (Braine et al., 1998).

Byrne (1989) demonstrated that a similar procedure could lead to the suppression of valid inferences (modus ponens and modus tollens). Instead of combining two conditionals suggesting alternative antecedents, she gave participants conditionals suggesting additional requirements. For example, participants were told ‘if Lisa met her friend then she went to a play’ and ‘if Lisa had enough money then she went to a play’. Participants were then told that ‘Lisa met her friend’ and asked if they could conclude ‘Lisa went to the play’. Only 51% made the modus ponens inference and said ‘Lisa went to the play’ compared to 98% who made the modus ponens inference when they did not receive the conditional ‘if Lisa had enough money then she went to the play’. These findings would suggest that people do not have mental rules for the valid inferences either which would cast doubt on mental logic theories. Politzer and Braine (1991) criticised Byrne’s findings by suggesting that the additional requirements cast doubt on the truth of the premises. However, doubt in the premises does not explain the data (Byrne, 1991; Byrne, Espino, & Santamaria, 1999).

Criticism of mental logic theories

Evidence from experiments where predictions from mental logic theories have been pitted against those of competing theories, especially the mental model theory, goes against the mental logic theories (e.g., Byrne & Johnson-Laird, 1989). Mental logic theories cannot explain why participants make more modus tollens inferences from a biconditional than from a conditional, while making the same number of modus ponens inferences (Johnson-Laird, Byrne, & Schaeken, 1992). According to the mental logic theories the number of steps involved in making the modus tollens inference should be the same for conditionals and biconditionals. The mental model theory can account for this difference as, according to the mental model theory, the mental representation for conditionals and biconditionals differs.

Furthermore, these theories are unable to account for content effects without drawing on another theory, i.e., pragmatic reasoning schemas. They are also not able to account for the systematic errors people make. According to Braine and O’Brien (1998) errors in reasoning are accounted for by errors in comprehension. However, the comprehension component is underspecified and the authors provide little detail on how this component works.
Domain specific theories

As suggested previously, domain specific rules and schema theories were developed in response to the discovery of content effects on Wason's selection task (Wason, 1966). Domain specific theories explain these content effects by appealing to the use of pragmatic reasoning schemas or content sensitive rules.

There are two main theories in this area: the pragmatic reasoning schema theory (Cheng & Holyoak, 1985; Holyoak & Cheng, 1995) and the social contract theory (Cosmides & Tooby, 1989; Fiddick et al., 2000). Cheng and Holyoak propose that people reason by applying appropriate reasoning schemas (e.g., permissions and obligations, causality) which are sensitive to the pragmatics of a situation, whereas Fiddick et al. (2000) focus on social contracts and hazard management and therefore maintain that responses to reasoning problems are determined by how the situation is interpreted with respect to social exchange.

According to Cheng and Holyoak (1985), reasoning schemas are sets of rules that are generalised, context sensitive and defined in relation to classes of goals. For example the permission schema comprises four rules that encompass all the goals related to permissions. These rules are generalised in that they should apply to all instances of permission. However, they are context sensitive in that they only apply to the domain of permissions. There are numerous reasoning schemas (permission, obligation, causality and evidence), but Cheng and Holyoak focus on the permission schema in their experiments and do not provide much further information on the other reasoning schemas. There are four rules for the permission schema (Cheng & Holyoak, 1985) which map onto the four inferences that can be made from a conditional in the following way:

*Modus Ponens:*

Rule 1: If the action is to be taken, then the precondition must be satisfied

*Denial of the Antecedent:*

Rule 2: If the action is not to be taken, then the precondition need not be satisfied

*Affirmation of the Consequent:*

Rule 3: If the precondition is satisfied, then the action may be taken

*Modus Tollens:*

Rule 4: If the precondition is not satisfied, then the action must not be taken

Errors in reasoning arise when situations cannot be mapped easily on to one of the schemas or when the rules of a schema do not conform to those sanctioned by propositional logic. If none of the schemas can be applied to a problem then people use various other strategies, such as mental logic or nonlogical strategies (Cheng & Holyoak, 1985).
Fiddick et al. (2000) advocate a domain-specific theory for social contracts and reducing risks in hazardous situations. They introduce the principle of pre-emptive specificity according to which domain specific inference systems override content-general systems. They therefore, acknowledge that there are content-general inference systems. However, whenever the two systems compete the domain specific system takes precedence. Accordingly, people reason most efficiently when they are reasoning about specific domains, because these systems are specially evolved for their content domains. With reference to people's improved performance on the concrete versions of Wason's selection task, Fiddick et al. suggest the selection rule is interpreted 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.

**Criticism of domain specific theories**

Cheng and Nisbett (1993) acknowledge that there is strong evidence for natural logic rules. However, they assert that pragmatic schemas always take priority and people will only fall back on to natural logic rules when none of the schemas can be applied. Drawing on 'other strategies' whenever their own account cannot explain the data makes it difficult to derive strong predictions from their theoretical account. Furthermore, Cheng and Holyoak assert that variation in performance can result when different schemas are evoked. But they do not provide information on how we can test which schema is being evoked.

Byrne (1989) asserts that the theory is unable to predict what will happen with unfamiliar material, hence, its applicability is limited. Fiddick et al. (2000) go further in their criticism citing research in which permission rules did not result in the content effects predicted by Cheng and Holyoak's theory, stating this finding is an especially strong falsification. In their examination of deontic conditionals, Quelhas and Byrne (2003) argue that reasoning well depends on situations that clarify relevant counterexamples rather than on situations that elicit particular rules and schemas.

Domain specific rule theories suffer the same weakness as pragmatic reasoning schema theory in that they are not complete theories of reasoning and are only able to account for very specific findings from Wason's selection task. They are not able to predict what will happen outside of these domains and both theories invoke the help of other strategies and theories when they are unable to account for findings. There are also many underspecified components.
A suppositional theory of if

Evans et al. have recently proposed a suppositional theory of if (Evans & Over, 2004; Evans, Over, & Handley, 2003). The suppositional theory is a dual process theory that is, it asserts that there are two cognitive mechanisms underlying implicit and explicit thinking. According to Evans et al. (2003) the implicit system (system 1) consists of domain specific neural networks which reflect the learning history of the individual. The explicit system (system 2) is uniquely human and provides the basis for reasoning. This system is limited by working memory capacity and effective functioning is linked to general intelligence. Errors in reasoning are attributed to preconscious heuristic processes which lead people to represent the wrong information as relevant.

The theory is related to the mental model theory, although the authors reject the “limited propositional formats that Johnson-Laird proposes to describe the content of such models” (Evans et al., 2003, p. 4). The authors put forward three principles of hypothetical thinking, the singularity principle, the relevance principle, and the satisficing principle. According to the singularity principle people consider only one single hypothetical possibility, or mental model, at a time. The principle derives from limited working memory and from observations from hypothesis testing research. Accordingly, people tend to consider only one hypothesis as people cannot keep more than one possibility in mind at a time; two or more possible worlds are modeled sequentially not simultaneously.

The relevance principle postulates that people consider the most relevant model, which generally speaking is the most plausible or probable, in the current context. The models people consider are preconsciously cued by the implicit system in accordance with the relevance principle. This pragmatic process reflects an interplay of: features of the task environment, the current goal, and long term memory and stored knowledge.

According to the satisficing principle, models are evaluated with reference to the current goal and accepted if satisfactory. Satisficing means employing heuristics that find solutions which are satisfactory, or good enough, but are not guaranteed to be optimal. Evans et al propose a three step process. In the first step the implicit system generates a single hypothetical possibility in line with the relevance principle. In the next step the model is evaluated by the explicit system and accepted if it is satisfactory. In the third step accepted models are processed by the explicit system in order to generate inferences.

Another important feature of this theory is that reasoning is viewed as probabilistic. This view entails that conditionals ("if p then q") are assessed with reference to the subjective probability of q given p (P(q|p)). The Ramsey test provides an explanation of how this subjective probability is assessed. Accordingly p is added hypothetically to a
person's stock of knowledge and they will argue on that basis about q (Evans & Over, 2004). Therefore, the representation of a hypothetical possibility includes some indicator of its own plausibility and probability. Finally, Evans and Over insist that people only consider cases in which 'p' (the antecedent of the conditional) holds, stating that cases in which 'p' is negated are considered irrelevant for the evaluation of a conditional.

Evans, Over, and Handley (2005) propose that the modus tollens inference is made, just as mental logic theorists have proposed, by 'reductio reasoning'. However, Handley and Feeney (2006) report that there is also a pragmatic route for making this inference which is observed in children. They suggest that children adopt a pragmatically cued biconditional representation of conditionals and as a result they make the same amount of all four types of inferences (see Barrouillet, Grosset, & Lecas, 2000 for supporting data).

Criticism of the suppositional theory of if
The singularity principle is inconsistent with research which supports the idea that people keep more than one possibility in mind (e.g., Byrne & Tasso, 1999; Thompson & Byrne, 2002). The proposal that people only consider cases in which the antecedent of the conditional is true is inconsistent with research in which participants judge negated antecedent cases to be consistent with a conditional (e.g., Byrne & Egan, 2004; Egan, 2005). Egan gave participants conditionals describing promises and threats and asked them to evaluate the four possibilities associated with the conditional as either consistent, inconsistent or irrelevant. The possibility in which the antecedent and the consequent of the conditional were absent was rated as consistent in between 80% and 94% of the cases.

In this first section we have introduced conditional reasoning with conditionals describing an abstract content and some of the theories that have been proposed to explain how people reason from conditional assertions. The research reported in this thesis tests predictions from the mental model theory of conditional reasoning and makes use of some of the methods used in reasoning research. In the second section of this chapter we consider the differentiation of different types of causes. Causal relations can be asserted as conditional ‘if...then’ assertions and we therefore draw on findings from conditional reasoning research investigating causal conditionals in our discussion of the distinction of different types of causes.

Causal relations
Knowledge about how things are causally related allows people to understand why something happened and to make predictions about what will happen next. Causation is not always a matter of considering one cause and its effect. In reality, there are many outcomes
which can be caused by a variety of events; for example, headaches can be caused by dehydration, straining one’s eyes, being hit on the head, or a brain tumour. These are termed *weak causes* as each of these events is sufficient to bring about a headache but not one of them is individually necessary. Of course, some causes are *strong causes*. Heating water to 100°C causes the water to boil, and there is no other means of making water boil, hence it is a strong cause. The cause (heating the water to 100°C) is both necessary and sufficient to produce the effect.

Causes however, do not always exert their effect in isolation. There are many occasions in which a cause works together with one or more *enabling conditions*, such as when a spark comes together with oxygen and fuel to create a fire. The enabling condition (oxygen) is necessary but by itself not sufficient to produce the effect.

In the first and second part of this section we consider the concepts of *necessity and sufficiency* and *counterexamples* and how they relate to the distinction between different types of causes. In the third part of this section we discuss the distinction between causes and enabling conditions in more detail.

*Necessity and sufficiency*

A distinction between different types of causes in terms of necessity and sufficiency has been proposed by a number of researchers (e.g., Cummins, 1995; Thompson, 1994). Consider the causal relation “A causes B”. It is a necessary relation if “…event B only occurs when event A occurs” and it is a sufficient relation when “…the occurrence of event A guarantees the occurrence of event B” (Thompson, 1995, p. 6). In identifying the cause of an event people need to consider whether an event was necessary and also sufficient for the occurrence of an effect. We consider three combinations of necessity and sufficiency of a causal factor and how these combinations affect the inferences people make about causal relations. First, consider the statement, ‘if the car ran out of petrol then it stalled’. In this scenario running out of petrol is sufficient to cause the car to stall. Therefore, if people were told ‘the car ran out of petrol’ they would be able to make the (modus ponens) inference ‘it stalled’. However, running out of petrol is not necessary for stalling a car as people can think of alternative instances where a car stalls, e.g., ‘not depressing the clutch when stopping’. As a consequence people are less likely to make the invalid affirmation of the consequent inference from ‘the car stalled’ to ‘the car ran out of petrol’. The cause is a weak cause.

Thompson (1994) reports a large effect of necessity on consistency judgements for conjunctions in which the antecedent of the conditional is negated (‘the car did not run out
of petrol’) and the consequent is present (‘the car stalled’), that is, items low in necessity were less frequently rated as inconsistent with the possibility ‘the car did not run out of petrol and it stalled’ than items that were high in necessity, because the availability of counterexamples in the form of alternative antecedents makes it possible to consider an alternative reason for the outcome (we examine the effect of counterexamples in more detail in the next section).

Second, there are instances where there are conditions that are necessary, but not sufficient for a cause. Consider the cause of a forest fire. Dry leaves (or other fuel) and oxygen are necessary for fire, but by themselves are not sufficient to cause a fire. A spark, such as lightning, is required to start the fire. The spark is likely to be attributed the role of cause as it is both necessary and sufficient to get the fire started. Events that are necessary but not sufficient to bring about an effect are the relations we call enabling conditions. So, if a person was told that there was oxygen they would not necessarily infer that there was a fire.

Third, some causes are both necessary and sufficient, such as, ‘if the water was heated to 100°C then it boiled’. In this case the antecedent is both necessary and sufficient, leading to a biconditional interpretation (‘if and only if the water was heated to 100°C it boiled’). Thompson (1995) reports that when a statement cues no alternative antecedents (and so it is a necessary relation) and no alternative consequents (and so it is a sufficient relation), then this should lead to a biconditional interpretation of the conditional. A biconditional interpretation is consistent with only two possibilities: ‘the water was heated to 100°C and it boiled’ and ‘the water was not heated to 100°C and it did not boil’. The cause is a strong cause. Our introduction to conditional reasoning demonstrated that the interpretation of a conditional influences the inferences people endorse.

Evaluation of necessity and sufficiency allows us to assess the strength of a causal relation. As can be seen above, when the antecedent is both necessary and sufficient the causal relation is strongest. Thompson (1995) views an evaluation of necessity and sufficiency as central in predicting peoples’ reasoning performance with conditionals. She tested the effect of necessity and sufficiency in a variety of tasks and domains (including causal, definitional and permission). She proposes that people’s inferences are based on a mental model that represents necessity and sufficiency relations. She further suggests that necessity and sufficiency information is cued by the availability of counterexamples and that the availability of counterexamples may be mediated by the content and context of the conditional relation. In the second part of this section we consider the effect of counterexamples on people’s understanding of causality.
Counterexamples

According to the mental model theory people's ability to distinguish between different sorts of causes depends on the possibilities they can think of for a particular causal relation (Johnson-Laird & Byrne, 1991). We discuss the mental model theory of causality in more detail in the fourth section of this chapter. First we consider how the possibilities people consider for a causal relation are related to the counterexamples they can think of.

A cause is considered not necessary for producing a particular effect when people can think of other possibilities in which a different cause produces the same effect. At the start of this section we suggested that a headache can be caused for a variety reasons, such as dehydration or being hit on the head. Now suppose a person was told 'if Peter had a brain tumour then he got a headache' and was then told 'he had a headache'. Would they infer 'he had a brain tumour'? If they can easily think of another reason for his headache then they might say 'he may or he may not have a brain tumour'. The fact that they can think of a counterexample for why Peter might have a headache allows only a weak link between a brain tumour and a headache. The counterexample prevents people from making the affirmation of the consequent inference. Similarly, if they were asked to suppose that 'Peter did not have a brain tumour', they might be reluctant to infer 'he did not have a headache', as again, their ability to think of a counterexample may lead them to doubt this inference. As a result they will be less likely to make the denial of the antecedent inference (Markovits, 1984, 1985). People are able to think of alternatives to weak causes.

The effect of additional requirements is quite different to that of alternatives. Suppose a person was told 'if the water was heated to 100°C then it boiled' and then told 'the water was boiling', then, because they cannot think of an alternative reason for the boiling water, they would infer 'the water was heated to 100°C'. This strong causal relation is both necessary and sufficient and no counterexamples exist for why the cause would not produce the effect. People tend not to be able to think of alternatives to strong causes.

However, if a person was told 'if the water was heated to 100°C then it boiled' and then told 'the water was boiling', then, because they cannot think of an alternative reason for the boiling water, they would infer 'the water was heated to 100°C'. This strong causal relation is both necessary and sufficient and no counterexamples exist for why the cause would not produce the effect. People tend not to be able to think of alternatives to strong causes.

The effect of additional requirements is quite different to that of alternatives. Suppose a person was told 'if there was oxygen then there was a fire' and then told 'there was no fire'. Would they infer that 'there was no oxygen'? Unless the statement was embedded in a description of a special chamber which typically contains no oxygen they would probably infer that 'oxygen could still be present', even if there was no fire. The reason people may make this inference is that oxygen is necessary for a fire, but in itself it is not sufficient. People can think of additional requirements for enabling conditions.

In this scenario a person's ability to think of an additional requirement (e.g., a spark) may block the modus tollens inference. Likewise, if a person was told 'there was
oxygen’ they may not necessarily infer that ‘there was a fire’, thereby blocking the *modus ponens* inference (Byrne, 1989). The *modus ponens* and *modus tollens* inferences can be blocked in two ways, either by an additional requirement, as the example above, or by a disabling condition. A disabling condition is something that blocks the effect of a cause. Suppose a person was told ‘if Jenny ate sweets then she got cavities’ and then told ‘she ate sweets but she did not get cavities’. It turns out that she brushes her teeth after eating sweets and therefore prevents cavities from forming. In this case ‘brushing her teeth’ is a disabling condition, as it disables the effects of the cause (‘eating sweets’). Disabling conditions are similar to enabling conditions and are understood in the same way as missing enablers (Byrne, 2005). In the example of the forest fire dry leaves are the enabling condition, and if the enabling condition is missing, that is, there are no dry leaves, then there is no fire. If the leaves were wet then there would also be no fire. Wet leaves would be a disabling condition and serve the same function as a missing enabling condition.

Similarly to the way in which necessity and sufficiency has an effect on the inferences people make, the number and the nature of the counterexamples a person is able to think of has an effect on the inferences they make from a conditional. Byrne (1989) demonstrated that additional requirements block *modus ponens* and *modus tollens* inferences, whereas alternative antecedents block denial of the antecedent and affirmation of the consequent inferences. However, when people can think of no counterexamples, that is, the relation is necessary and sufficient, they are more likely to make all four inferences (Cummins, Lubart, Alksnis, & Rist, 1991).

Some have suggested that the suppression of inferences reported by Byrne (1989) is not the result of the availability of counterexamples, but instead that the additional premise casts doubt on the first premise (e.g., Politzer & Braine, 1991) and therefore results in the suppression effect. Others have suggested that different additional requirements differ in their importance and inference suppression depends on how these additional requirements relate to memory schemas that are used to guide the reasoning process (Chan & Chua, 1994). Byrne et al. (1999) report a series of experiments in which they examined these differing accounts of the suppression effect. They demonstrated that premise doubt was not responsible for the suppression of inferences, as participants generated their own conclusions, few of which suggested doubt in the premises. They also demonstrated that the content of the additional requirements was not the only factor which could mediate the suppression effect. They expressed the additional premise as a biconditional which resulted in an even stronger suppression effect. This finding is inconsistent with the suggestion that
memory schemas are responsible for the suppression of inferences. Overall, Byrne et al. provide additional support for the idea that the availability of counterexamples results in the suppression of inferences.

Cummins et al. (1991) demonstrated that counterexamples need not be made explicit for them to exert their effects on the inferences people make. They report that a cause which is associated with few other causes (established by pre-testing with a separate group of participants) is more frequently interpreted as a biconditional than a material implication conditional. Cummins et al. inferred these interpretations from the pattern of responses to an inference task. Accordingly, for a conditional such as ‘if Joe cut his finger then it bled’ participants endorsed all four inferences. As mentioned previously, a biconditional is consistent with two possibilities: ‘cause and effect’ and ‘no cause and no effect’. People are therefore likely to make all four inferences (modus ponens, modus tollens, denial of the antecedent and affirmation of the consequent).

A conditional about a cause which is associated with few disabling conditions (e.g., ‘if Alvin read without his glasses then he got a headache’) is more frequently interpreted as a material implication conditional. A material implication conditional is consistent with three possibilities: ‘cause and effect’, ‘no cause and no effect’, and ‘no cause and effect’. These three possibilities lead to the typical (material implication) pattern of responses, that is, modus ponens and modus tollens inferences are endorsed whereas denial of the antecedent and affirmation of the consequent inferences tend not to be endorsed (Cummins et al., 1991).

De Neys, Schaeken and d’Ydewalle (2003) demonstrated that it is not only important whether or not there are counterexamples, but also how many counterexamples a person can retrieve. They report that modus ponens inferences linearly decrease with every additional retrievable disabler, whereas affirmation of the consequent inferences linearly decrease as a function of the number of retrieved alternatives.

The concept of counterexamples is closely linked to the concept of necessity and sufficiency. Thompson (1994) reports that responses to modus ponens and modus tollens inferences varied as a function of the sufficiency of the conditional relation. Whereas denial of the antecedent and affirmation of the consequent responses varied as a function of the necessity of the relation. A conditional whose antecedent is not sufficient for the consequent will have counterexamples in the form of additional requirements or disabling conditions, whereas a conditional whose antecedent is not necessary for the consequent will have counterexamples in the form of alternative antecedents. Thompson demonstrated these effects across four different pragmatic contents, including causal contents.
In the previous two sections we have suggested that the concepts of necessity and sufficiency and counterexamples are central to distinguishing between strong causes, weak causes and enabling conditions. We examine the distinction between causes and enabling conditions in more detail in the next section as there has been some disagreement over how the two sorts of causes are distinguished.

**Causes and enabling conditions**

What is an enabling condition and why is the distinction between causes and enabling conditions an important one? In answer to these questions consider the following scenario: A building proprietor negligently leaves open an unguarded lift shaft. Someone who knows the lift shaft is unguarded invites another person to step inside who is injured as a result (Johnson-Laird, 1999). The building proprietor is the enabling condition in this scenario as his actions enabled this incident. Is he therefore responsible for the injuries sustained? What about the person who designed the gas chambers used in the execution of millions of people during the Holocaust? The distinction between causes and enabling conditions is an important one which can have significant consequences for decisions in the domain of law.

The difference between causes and enabling conditions plays a central role in the research reported in this thesis. In Chapters 3 and 4 we examine the mental representation of enabling conditions together with other types of causes as well as counterfactual phrasings of causes. The experiments reported in Chapter 5 examine the distinction between causes and enabling conditions more closely.

According to the mental model theory causes and enabling conditions differ both in meaning and in logic (Goldvarg & Johnson-Laird, 2001). This distinction follows from the proposal that causes and enabling conditions are consistent with different possibilities. Being consistent with different possibilities entails that causes and enablers have different meanings and as a result are consistent with different logical inferences. Before we consider the mental model theory's account of the distinction between causes and enabling conditions we consider some of the proposals that were made prior to the mental model account and therefore provide a background to the mental model account.

Many researchers have proposed that causes and enabling conditions do not differ in terms of meaning or logic and instead have proposed a variety of characteristics with which to tell them apart (see Table 1.3 for an overview). These researchers follow Mill (1843/1973) who argued that no difference in meaning exists between causes and enablers, and these researchers have distinguished between them in other ways. Hart and Honoré (1959/1985), for example, propose that one of the criteria for distinguishing causes and
enabling conditions is the normality of the conditions in the set. According to this view an abnormal condition will be designated as the cause and any normal conditions are considered to be the enabling conditions. In the case of a typical fire oxygen would be regarded as normal and therefore the enabling condition. However, if the circumstances were different and people were considering a fire in an oxygen free chamber then the introduction of oxygen may be considered abnormal and therefore attributed the role of cause.

Table 1.3: Some proposed means of differentiating between causes and enablers

| Normal vs. abnormal conditions | Hart & Honoré, 1959/1985 |
| Conversational relevance       | Hilton & Erb, 1996       |
| Different possibilities brought to mind | Goldvarg & Johnson-Laird, 2001 |

According to another school of thought, the cause is the factor that is conversationally relevant in explanations. Hence, Hilton and Erb (1996) argue for a two stage process:

"explanations are first cognitively generated by building mental models of the causal structure of events, from which particular factors are identified in conversationally given explanations" (p. 275).

When there are a number of factors involved in producing an effect, then the why question, that is, the specific question about why the effect happened on this occasion, determines the focus of the mental model of the causal structure of events. If we consider the example of oxygen and fire then we can see that under normal circumstances oxygen would not be mentioned as its presence is taken for granted. However, if the circumstances were different and we were considering a fire in an oxygen free chamber then the answer to the why question would be the presence of oxygen. The event in focus will be identified as the cause whereas all other events, i.e. enabling conditions, form the causal background. Speakers therefore mention causes rather than enabling conditions (Hilton, 1990).

Hilton and Erb (1996) assert that within a particular causal scenario the various causal roles can change depending on the particular why question that is asked. Consider a
doctor who diagnoses a patient with mumps and recognises that he had not been eating enough fruit and was sharing a house with other infected people as the causes for this infection. A person inquiring why the patient was infected this year rather than the previous year would be told that it was because he was sharing a house with other infected people. Whereas a person inquiring why he was infected and another member of this household was not would be told that it is due to the lack of fruit in his diet (Hilton & Erb, 1996).

Cheng and Novick (1991) propose that a cause is established by computing the covariation between potential causes and the effect, with reference to a 'focal set', in other words the context in which the event takes place. The focal set is the set of events that are implied by the context.

"A cause is a factor the presence of which (relative to its absence) noticeably increases the likelihood of the effect" (p.95).

Cheng and Novick propose an equation for computing this covariation. They suggest that a cause is computed by calculating the proportion of cases in which the effect occurs when the factor is present subtracted by the proportion of cases in which the factor is absent. Factors that are always present (e.g., gravitational pull, oxygen) are not considered in the equation. Cheng and Novick report that 92% of participants perceived factors that covaried with the effect as causes. Cheng and Novick manipulated normality and conversational relevance of factors and found that these variables were not essential for distinguishing between causes and enabling conditions. Factors that remained constant, but were necessary for the effect, were identified as enabling conditions by 83% of the participants. Goldvarg and Johnson-Laird (2001) demonstrated that people can distinguish between causes and enabling conditions even when they do not differ in terms of constancy.

Goldvarg and Johnson-Laird report an experiment in which they gave participants descriptions about circumstances which did not contain causal expressions. Furthermore, the causes and the enabling conditions did not systematically vary in terms of constancy (cf. Cheng & Novick, 1991). Participants were asked to identify the cause and the enabling condition after reading each of these descriptions. The cause and the enabling condition could be identified by considering different possibilities suggested by the descriptions. On 85% of the trials Goldvarg and Johnson-Laird’s participants correctly identified the enabling condition and the cause (we examine this research in more detail in Chapter 5 where it forms the basis for our experiments). As a result, Goldvarg and Johnson-Laird
concluded that causes and enabling conditions differ in terms of meaning. They posit that while causes and enabling conditions can differ in terms of constancy, normality and conversational relevance, what is most important is that causes and enabling conditions differ in terms of meaning and, as a result, also differ in terms of their logical implications. Therefore, different possibilities should be considered consistent with causes and enabling conditions.

Goldvarg and Johnson-Laird (2001) also report differences between causes and enabling conditions in the inferences made from conditionals describing causes and enabling conditions. When participants were given the premises:

‘Eating protein will *cause* her to gain weight.’

‘She will eat protein.’

participants tended to draw the modus ponens conclusion: ‘she will gain weight’ (on 93% of trials). An enabling condition is consistent with the possibility ‘eating protein and not gaining weight’ therefore the mental model theory predicts that people will tend not to draw the modus ponens conclusion ‘she will gain weight’ from the premises:

‘Eating protein will *allow* her to gain weight.’

‘She will eat protein.’

Participants made the modus ponens inference on only 30% of trials for enabling conditions. Similarly participants made less modus tollens inferences from enabling conditions than they did from causes (47% versus 93%).

In this section (section 2) we have described differences between different types of causes and presented some evidence for these differences. In the third section we examine counterfactual thinking and how it is related to causal thinking. We begin with an overview of counterfactual thinking before we discuss the link between causal and counterfactual thinking.

**Counterfactual thinking**

Counterfactual thoughts are thoughts about how an event in the past could have turned out differently, *if only* one or more events had been different. Counterfactual conditionals are often phrased in the subjunctive mood (e.g., ‘if Joe had cut his finger it would have bled.’) and convey information about the truth of the statement (factual conditionals are typically phrased in the indicative mood). People generally think that the opposite is implied to what is actually stated (‘Joe did not cut his finger and it did not bleed’) (Thompson & Byrne, 2002). The possibility that ‘Joe did not cut his finger and it did not bleed’ is the presupposed fact, whereas ‘Joe cut his finger and it bled’ is the counterfactual conjecture.
When people are given an unexpected memory test after reading counterfactual statements they typically recall the presupposed facts (Fillenbaum, 1974a).

According to the mental model theory people understand a counterfactual by keeping in mind both the presupposed facts and the counterfactual conjecture, whereas they tend to understand a factual conditional ("if Joe cut his finger then it bled") by keeping in mind only one possibility ("he cut his finger and it bled") (Johnson-Laird & Byrne, 1991). As a result, they make inferences that require access to the negative possibility ("Joe did not cut his finger and it did not bleed") more readily from a counterfactual than from a factual conditional (Byrne & Tasso, 1999). For example, experimental evidence shows that when people are given the information that 'Joe did not cut his finger', they infer 'his finger did not bleed' much more readily from the counterfactual than from the factual conditional (Byrne & Tasso, 1999; Thompson & Byrne, 2002). Perhaps most revealingly, people are 'primed' to read a negative conjunction such as ‘there were no roses and there were no lilies’ reliably faster when it is preceded by a counterfactual conditional (such as, ‘if there had been roses then there would have been lilies’) rather than a factual conditional (such as, ‘if there were roses then there were lilies’). A conjunction such as, ‘there were roses and there lilies’ is read equally quickly following the two sorts of primes (Santamaria et al., 2005).

People tend to generate counterfactual thoughts in response to unexpected events in regular ways. A number of patterns have been identified in the counterfactuals people generate. Although people are able to generate a large variety of counterfactual thoughts, the typical mode of operation tends to be “very near to the Reality Channel” which results in the generation of counterfactuals that are close to what actually happened rather than dramatically different (Hofstadter, 1979, p. 639). Counterfactuals tend to focus on exceptional rather than routine events (Kahneman & Tversky, 1982). Someone who is involved in a car accident after taking a new route home from work is more likely to think ‘if only I had not taken a different route’ compared to a person who took their usual route home, who will tend to focus on something other than the route taken.

People’s counterfactual thoughts also tend to be about controllable rather than uncontrollable events, such as being home late due to the decision to go to a bar compared to being delayed due to having an asthma attack (Girotto, Legrenzi, & Rizzo, 1991). Socially undesirable actions, such as failing to pick up their child from school due to talking to someone, are more frequently ‘undone’ than socially acceptable actions, such as failing to pick up their child because they were helping someone (e.g., McCloy & Byrne, 2002; N'gbala & Branscombe, 1995). People generate more counterfactuals about actions
than inactions, such as choosing to switch to shares from a different company compared to sticking with the shares a person already has (Kahneman & Tversky, 1982).

Counterfactual thoughts also tend to be about the first event in a dependent causal sequence of events (Wells, Taylor, & Turtle, 1987). Wells et al. found that when a causally related sequence of events produces an undesirable outcome, people are more likely to want to alter the first event in that sequence rather than subsequent events. But in an independent sequence of events people tend to generate counterfactual thoughts about the last, most recent, event rather than earlier events (Byrne, Segura, Culhane, Tasso, & Berrocal, 2000; Miller & Gunasegaram, 1990). These last two examples of regularities in counterfactual thinking suggest that an understanding of causal relations has an effect on the counterfactual thoughts people generate. We now consider the relation between causal and counterfactual thoughts in more detail.

**Causal and counterfactual thoughts**

Causal and counterfactual thinking are closely linked as counterfactual thoughts about how events could have turned out differently are often of a causal nature. In order for counterfactual thoughts about how an outcome could have been different to make sense people must perceive a causal connection between the antecedent of the conditional and the consequent. For example a counterfactual such as ‘if the sky had not been blue Peter would not have broken the chair’ does not make sense unless people can perceive a causal link between the sky being blue and Peter breaking the chair. However, a counterfactual such as ‘if Mary had taken the shortcut then she would have arrived on time’ makes sense as people can immediately see the causal connection between the antecedent (‘Mary took the shortcut’) and the consequent (‘she arrived on time’).

Philosophers have long debated the relation between causal and counterfactual thinking. Hume (1748/1999) illustrated the relation between causal and counterfactual thought when he wrote:

```
“we may define a cause to be an object, followed by another, and where all objects, similar to the first, are followed by objects similar to the second. Or in other words, where, if the first object had not been, the second never had existed” (p. 146)
```

Similarly, Lewis (1973) suggests that a cause is something that makes a difference, a difference which would not have occurred had the cause not been present. Berofsky
(1973) cautions that a counterfactual analysis of causation results in every necessary condition (e.g., enabling conditions) being identified as a cause. Kim (1973) adds that counterfactuals can express many dependent relations other than causal relations. Consider the counterfactual ‘if George had not been born in 1950, then he would not have reached the age of 21 in 1971’. This counterfactual is not expressing a causal relation between being born in 1950 and being 21 in 1971. Our concern here is not with whether a counterfactual analysis of causation is satisfactory, but with the fact that causal and counterfactual thoughts are related.

Psychologists have recognised that the relation between causal and counterfactual thoughts is complex (Byrne, 2005). The relation between causal and counterfactual thoughts is in fact bidirectional. Causal relations imply certain counterfactuals and counterfactuals allow people to distinguish between correlation and causation by allowing them to assess whether an effect would have occurred had a particular event not happened (Sloman, 2005).

Developmental research has demonstrated that children are able to consider counterfactual thoughts in relation to causal reasoning. Harris, German and Mills (1996) report that children as young as 3 years were able to judge that a floor would still be clean had a doll taken her dirty shoes off before walking across it.

Causal beliefs, such as a belief in the effectiveness of nuclear deterrence, can influence judgements about the plausibility of counterfactuals, such as ‘if Kennedy had listened to his hawkish advisers the Cuban missile crisis would have become nuclear’ (Tetlock & Lebow, 2001). Counterfactual thoughts can also influence beliefs about causality. Consider a story in which a couple died when their car drove off a collapsed bridge. People attribute a causal role to a taxi driver who refused them a lift when they know he drove across the bridge safely (and so they can think, ‘if only he had given them a lift’) but not when they know he also drove off the collapsed bridge (Wells & Gavanski, 1989). But people focus on different events when they think about the cause of the outcome, the collapsed bridge, and when they think about counterfactual alternatives, ‘if only the taxi driver had given them a lift’ (Mandel & Lehman, 1996). Counterfactual thoughts may tend to focus on enabling relations and thus focus on how an event could have been prevented whereas causal thoughts focus on strong causes (Byrne, 2005).

Berofsky (1973) suggested that an analysis of causation must distinguish causes from enabling conditions. Research suggests that people distinguish between causes and enabling conditions in their causal and counterfactual thoughts. Are causes and enabling
conditions represented differently when they are factual (i.e., phrased in the indicative mood) or counterfactual (i.e., phrased in the subjunctive mood)? We have previously suggested that counterfactual conditionals are understood by keeping in mind two possibilities, the counterfactual conjecture and the presupposed facts. We have also suggested that different types of causes are consistent with different possibilities. How do people integrate causal and counterfactual information in their mental representations?

Research on deontic conditionals has demonstrated that content can override the typical mental representation of a counterfactual conditional. Deontic conditionals such as ‘if the nurse cleaned up the blood then she must have worn rubber gloves’ refer to permissions and obligations. Quelhas and Byrne (2003) found that deontic conditionals phrased in the subjunctive mood were understood by keeping different possibilities in mind compared to regular counterfactual conditionals about people in different places. A regular counterfactual conditional such as ‘if Anna had been in Dublin then Peter would have been in Limerick’ is understood by keeping in mind the presupposed facts and the counterfactual conjecture (‘Anna was not in Dublin and Peter was not in Limerick’ and ‘Anna was in Dublin and Peter was in Limerick’). A subjunctive deontic conditional such as ‘if the nurse had cleaned up the blood then she must have had to wear rubber gloves’ is understood by keeping in mind the same possibilities as an indicative deontic conditional, the conjecture ‘the nurse cleaned up the blood and she wore the rubber gloves’ and the possibility ruled out by the conditional ‘the nurse cleaned up the blood and she did not wear rubber gloves’.

Quelhas and Byrne have demonstrated how different content can affect the mental representation of counterfactual conditionals. Content effects have also been demonstrated in research on factual conditionals. For example, research on causal reasoning has demonstrated that the inferences people make from factual conditionals are affected by the suggestion of alternatives, be it through explicitly asking participants to generate alternative causes (Markovits & Potvin, 2001) or when the materials implicitly invite them to generate their own alternative causes (e.g., Cummins et al., 1991). One of the questions we address in this thesis is, how does context affect the mental representation and reasoning from causal counterfactual conditionals? There has been no research on how emphasising the facts or suggesting a counterfactual alternative affects the inferences people are willing to make from a causal counterfactual conditional.

In the last two sections we have considered causal relations and counterfactual thinking. In the next section we examine how the theories described in the first section of this chapter account for people’s causal and counterfactual thoughts.
Theoretical accounts of causal and counterfactual thinking

The mental model theory of causality

Goldvarg and Johnson-Laird (2001) provide a detailed outline of the mental model theory of causal meaning and reasoning (see also Johnson-Laird, 1999; Johnson-Laird & Byrne, 1991). They postulate five principles: the principles of truth, temporal constraint, causal modalities, circumstantial interpretation and causal deduction. The principle of truth applies to all deductive reasoning (Johnson-Laird and Byrne, 2002). People represent true possibilities (as described previously). Temporal constraint refers to the fact that in a causal relation the effect does not precede the cause. For example water cannot be boiling if it has not been heated to 100°C first. The principle of causal modalities is what must and what may or might have happened. The principle of causal modalities implies that when people consider causal relations they recognise that some things are possible and some are impossible (Goldvarg & Johnson-Laird, 2001). An assertion such as ‘turning on the sprinkler will cause the grass to be wet’ implies the possibilities ‘the sprinkler is turned on and the grass is wet’, ‘the sprinkler is not turned on and the grass is wet’ as well as the possibility ‘the sprinkler is not turned on and the grass is not wet’. The principle of causal modalities is an alternative to viewing everything within a probability framework, where there are degrees of possibility (Cheng, 1997). Goldvarg and Johnson-Laird acknowledge the role of probability in causal reasoning. However, rather than viewing the meaning of causal relations as probabilistic, they assert that it is the evidence supporting a causal relation that may be probabilistic.

The principle of circumstantial interpretation refers to the fact that people’s understanding of a causal relation is dependent on how they interpret the circumstances surrounding it. People’s general knowledge feeds into their interpretation of the circumstances and contributes to the construction of mental models. Goldvarg and Johnson-Laird provide examples where the mere changing of the circumstances results in a different interpretation of the causal relation. For example, if a patient was given an injection and then lost consciousness, there could be several interpretations of this relation, depending on the circumstances. The injection could have caused the loss of consciousness, failed to prevent it, or even had nothing to do with it. Only knowledge of the circumstances together with background knowledge will allow people to infer which of these possibilities is correct.

The principles of causal modality and circumstantial interpretation give rise to the assertion that causes and enabling conditions are distinct, both in meaning and in logic.
What Goldvarg and Johnson-Laird mean by this claim is that causes and enabling conditions give rise to different mental representations and consequently different inferences. We provided a detailed overview of the mental model theory's account of this distinction in our discussion of causes and enabling conditions in the previous section on causal relations.

The *principle of causal deduction* postulates that causal deductions are based on mental models and when the premises are complex, deductions will be based on initial models rather than on fully fleshed out models. Hence, we should be able to predict reasoning errors when they result from failure to consider all options.

**The mental model theory of counterfactual thinking**

The mental model account of reasoning with counterfactual conditionals (Byrne, 2005; Johnson-Laird & Byrne, 1991) proposes that reasoning about counterfactual conditionals uses the same reasoning procedures as reasoning from factual conditionals. A counterfactual such as 'if Joe had cut his finger then it would have bled' implies the fact that 'Joe did not cut his finger and it did not bleed', but it also suggests the counterfactual conjecture 'Joe cut his finger and it bled'. According to the mental model theory people keep track of both of these possibilities, together with a mental tag about the epistemic state of each of the possibilities. If necessary then people may also flesh out their model to consider the possibility 'Joe did not cut his finger and it bled', for example:

| not cut finger | not bleed          | presupposed fact |
|               | cut finger         | bleed            | counterfactual conjecture |

Research, reviewed in the previous section, supports the idea that counterfactual conditionals are understood by keeping two possibilities in mind whereas factual conditionals are understood by keeping only one possibility in mind (e.g., Byrne & Tasso, 1999; Santamaria et al., 2005; Thompson & Byrne, 2002).

**Criticism of the mental model theory of causal and counterfactual thinking**

Kuhnmünch and Beller (2005) criticise Goldvarg and Johnson-Laird's analysis of the distinction between causes and enabling conditions by suggesting that the differences found in one of their experiments were due to the linguistic cue 'given'. Consider the following scenario, 'given there is sunshine, if there is fertilizer then the plants grow'. Kuhnmünch and Beller argue that the word 'given' acts as a marker for the enabling condition and so people should identify 'sunshine' as the enabling condition. They provide some experimental evidence to support this claim. They suggest that causes and enabling
conditions cannot be distinguished through the mental models people generate. Their
criticism neglects the findings of Goldvarg and Johnson-Laird’s experiment in which they
compared inferences from causes and enabling conditions. Participants made fewer modus
ponens and fewer modus tollens inferences from an enabling relation than from a causal
relation. We address Kuhnmüntch and Beller’s criticism and their experimental results in
more detail in Chapter 5.

The mental model theory is the only theory to have developed a detailed account of
counterfactual thinking. Evans and Over (2004) criticise Johnson-Laird and Byrne’s
account of counterfactual thinking for not having sufficient representational content. For
example, the mental models proposed to represent a counterfactual do not represent
whether a counterfactual possibility is close or distant, perceived positively or negatively
(which would have a bearing on whether people feel regret or not).

We now consider how mental logic theories, domain specific rule theories and the
suppositional theory of if account for causal and counterfactual thinking.

Mental logic theories of causal and counterfactual thinking

Mental logic theories have not provided a detailed account for reasoning from causal or
counterfactual conditionals, despite the fact that there is evidence of differences for
reasoning with both causal and counterfactual conditionals. Proponents of mental logic
theories ascribe a very small role to the effects of content on the inferences people make.
As mentioned earlier, Braine and O’Brien (1991) suggest that there may be a role for a
pragmatic reasoning schema in the schema for ‘Conditional Proof’. However, they do not
elaborate any further on this.

“...there is nothing in the schema for Conditional Proof that requires that
the train of thought that leads from the antecedent to the consequent must
consist of a propositional-logic argument; the schema allows any kind of
argument – causal, psychological, based on a scenario or model, and so
on.” (p. 190).

Mental logic theories therefore do not appear to make any predictions about
differences in how different types of causes are understood.

Mental logic theories do not have a detailed account of counterfactual conditionals.
According to O’Brien, Dias, Roazzi, and Braine (1998) if a proposition is false then all
antecedents should be ignored. If an antecedent is not true then the proposition is not true and if a supposition leads to a contradiction then it is ignored. They assert:

“Any proposition that would not be true under a counterfactual supposition cannot be used in an argument leading to a conditional conclusion under that supposition unless it would still be true given that supposition.” (p. 248)

A counterfactual conditional by its very nature contains a false antecedent and consequent. Byrne (2005) suggests that Braine and O’Brien’s theory (1991) is ill equipped for explaining why people make the modus ponens inference from a counterfactual conditional. Braine and O’Brien propose that there is a rule for the modus ponens inference (given ‘if A then B’ and ‘A’, one can infer ‘B’). In addition they propose that there is a conditional proof rule: “To derive or evaluate if p then... first suppose p; for any proposition q that follows from the supposition of p taken together with other information assumes, one may assert if p then q” (Braine & O’Brien, 1991, p. 183). A constraint of the conditional proof rule is that suppositions must be consistent with prior assumptions. Byrne argues, that given these rules and constraints the modus ponens inference should not be made from a counterfactual conditional as an application of the rules results in a contradiction. Accordingly, a counterfactual conditional such as ‘if p had been q would have been’ should include the following formal derivation of a conclusion, the conditional ‘if p then q’ as well as the presupposed facts ‘not-p’ and not-q’. The minor premise ‘p’ contradicts the fact ‘not-p’, and so nothing can be concluded. We return to this theory in later chapters to examine whether it can be extended to account for our results.

**Domain specific theories of causal and counterfactual thinking**

Fiddick et al. (2000) focus on social contracts and have therefore not provided an account of causal reasoning. In this section we therefore focus on the pragmatic reasoning schema theory (Cheng & Holyoak, 1985). Cheng and Holyoak (1985) propose that people have causal schemas for reasoning about causal relations. According to their theory, when people only perceive a single cause they are likely to make a biconditional interpretation and therefore make fallacious inferences, such as the affirmation of the consequent. However, Cheng and Holyoak recognise that not all causal relations have a single cause. Furthermore, they state that some causal relations are deterministic whereas others are probabilistic. Therefore, they propose that there are likely to be several subtypes of causal schemas.
They also recognise the influence of background knowledge. For example, people's world knowledge allows them to judge temporal order, i.e. they know that causes precede effects. This knowledge takes precedence over which event is logically the antecedent or the consequent. This way they are able to account for Cummins' (1995) findings, where she reversed cause and effect, i.e., 'if effect then cause'. Cummins' participants made inferences from conditionals where either the cause preceded the effect ('if cause then effect') or where the effect preceded the cause ('if effect then cause'). In the first condition modus ponens and modus tollens inferences were influenced by the number of disabling conditions and denial of the antecedent and affirmation of the consequent inferences were influenced by the number of alternative causes. In the reverse condition ('if effect then cause') modus ponens and modus tollens inferences were influenced by the number of alternative causes and denial of the antecedent and affirmation of the consequent inferences were influenced by the number of disabling conditions. These results suggest that an understanding of the causal relation takes precedence over the logical form of the conditionals.

Cheng and Nisbett (1993) put forward the case for a causal reasoning schema instead of the notion of 'necessity' and 'sufficiency' or rules of natural logic. They assert that information on contingency rather than 'necessity' and 'sufficiency' is required for making causal predictions and propose a probabilistic equation for assessing contingency. Accordingly, people perceive a causal connection when the probability of the effect given the cause minus the probability of the effect given the absence of the cause is unequal to zero \[ P(e|c) - P(e|\neg c) \neq 0 \]. They report an experiment in which they compared conditionals describing abstract causal relations and non-causal relations. Cheng and Nisbett report that participants were more sensitive to the presence of a contingent relation for the causal conditionals than for the conditionals with arbitrary content and therefore conclude that contingency information is more important than necessity and sufficiency.

Participants were given both an inference task and a question about contingency when evaluating a causal scenario or an arbitrary scenario. The parameters of necessity and sufficiency were the same in both conditions. Accordingly, participants made the same frequency of all four inferences in both conditions. Cheng and Novick argue that the contingency judgement task demonstrates the difference between the causal and the arbitrary materials. However, a weakness of this task is that for the causal materials they asked participants to judge if event A and event B were causally related and for the arbitrary materials they asked if event A and event B were conditionally related, which could merely reflect a correlation. Thompson (1995) also provides evidence that necessity
and sufficiency account for variance in reasoning performance over and above that accounted for by reasoning schemas.

Cheng and Holyoak are able to account for many of the empirical findings in the causal reasoning literature by suggesting that people have multiple causal schemas. However, their account is ill-specified and it seems that they could account for any findings as they could always suggest another schema is at work. Furthermore, there is no explanation as to how these schemas come about, function and are applied or how many of them there are.

One finding domain specific theories do not appear to be able to account for is a cumulative effect of increasing number of counterexamples on people’s confidence in making certain inferences (De Neys et al., 2003). It is not clear how domain specific theories can account for these findings. As suggested previously, domain specific theories are very limited in scope. They do not provide an account of how mood (subjunctive versus indicative) affects people’s reasoning and have therefore not provided an account of counterfactual thinking.

**Suppositional theory of causal and counterfactual thinking**

Evans and Over (2004) make no proposals about how inferences are made from causal conditionals. The theory does not provide an account of how different types of causes are mentally represented and how causes and enabling conditions can be differentiated.

With regards to counterfactual thinking Evans and Over refer to Stalnaker’s extension of the Ramsey test to counterfactual conditionals. Stalnaker proposed that people assume the antecedent of a counterfactual while making minimal hypothetical changes to their beliefs to preserve consistency. As a result if a person believes a factual conditional has a high probability then they should apply the same probability to the counterfactual (Evans & Over, 2004). In addition Evans and Over advocate the ‘singularity principle’ according to which all conditionals are understood by keeping in mind only one possibility. This failure to distinguish between factual and counterfactual conditionals cannot explain the data that shows that a counterfactual leads to more of the negative inferences than a factual conditional. Evans and Over criticise Johnson-Laird and Byrne’s account of counterfactual thinking for not representing whether a counterfactual possibility is close or distant. However, they do not offer an account of how to represent close or distant counterfactuals in their account.

In this section we have described how the mental model theory, mental logic theories, domain specific theories and the suppositional theory of if account for causal and
counterfactual thinking. Throughout this thesis we test predictions from the mental model theory and consider how these other theories can account for our results.

**Thesis overview**

In this final section we provide an overview of the thesis. We first outline the research questions we examine and outline the different methodologies we employ to pursue answers to these questions. We will conclude this section and chapter by stating the aims of the thesis.

**Research Questions**

We examine two research questions in this thesis. The first research question is how do people mentally represent factual and counterfactual causal conditionals? Previous research has demonstrated that factual conditionals tend to be understood by keeping in mind one possibility, whereas counterfactual conditionals tend to be understood by keeping in mind two possibilities (e.g., Byrne & Tasso, 1999). We intend to add to this research in two ways. Firstly, we examine causal counterfactual conditionals. We suggest that causal conditionals are understood by keeping in mind different possibilities for different causal relations. We investigate how an understanding of different causal relations might be affected by a counterfactual phrasing of the relation. Secondly, we make use of a novel, paraphrasing, methodology to investigate differences between factual and counterfactual causal conditionals.

We also examine how context affects the way people reason from causal counterfactual conditionals. Previous research on reasoning from counterfactual conditionals has demonstrated that people make more of the negative inferences, modus tollens and denial of the antecedent, from counterfactual conditionals than from factual conditionals (Byrne & Egan, 2004; Byrne & Tasso, 1999; Egan, 2005; Quelhas & Byrne, 2003; Thompson & Byrne, 2002). Some of these studies have examined counterfactual conditionals with different content, including causal content. However, none of them have examined the effect of context on the inferences people make from causal counterfactual conditionals.

The second research question is how do people mentally represent different causes, namely strong causes, weak causes and enabling conditions? We examine the prediction made by the mental model theory that different causes are understood by keeping in mind different possibilities. We make use of two very different methodologies to investigate this question, a paraphrasing method and a priming method. We make use of different
methodologies with the aim of acquiring converging evidence to test the predictions made by the mental model theory.

As part of our investigation of the mental representation of different causes, we ask how do people understand causes and enabling conditions? The mental model theory predicts that causes and enabling conditions are understood by keeping in mind different possibilities and can therefore be distinguished by considering these possibilities. We examine people's ability to distinguish causes and enabling conditions and investigate the effect of inconsistent information on people's ability to distinguish between causes and enabling conditions.

**Methods**

We used a variety of methods to investigate our research questions regarding causal and counterfactual thoughts. We chose a variety of methods in order to address our research questions from different angles, with the aim of providing converging evidence for our predictions. In this section we provide a description of the different methods that were used in the research described in this thesis. We examined the effect of context on the inferences people make from counterfactual conditionals. We examined the mental representations people form of causal and counterfactual conditionals by using a paraphrasing and a priming paradigm. Finally, we examined the differences between causes and enabling conditions by asking participants to assign the roles of cause and enabling condition to two antecedent events. As part of this investigation we examined how information consistent and inconsistent with initial attributions was dealt with. We provide a brief overview of the different methods in turn.

**Inferences**

People's reasoning is investigated by presenting participants with a conditional assertion 'if Joe cut his finger then it bled' followed by a categorical assertion which either affirms the antecedent, 'Joe cut his finger' (modus ponens), denies the antecedent, 'Joe did not cut his finger' (denial of the antecedent), denies the consequent 'Joe's finger did not bleed' (modus tollens), or affirms the consequent, 'Joe's finger bled' (affirmation of the consequent). Participants are then either asked which inference, if any, can be made, or they are presented with a choice of three responses, e.g., 'Joe's finger bled', 'Joe's finger did not bleed', and 'Joe's finger may or may not have bled'. In Chapter 2 we report two experiments in which participants made inferences from counterfactual conditionals after reading stories which provided a context for the conditionals.
Paraphrases and the mental representation of conditionals

Paraphrases can act as an indicator of the mental representations people form of conditionals (Byrne & Johnson-Laird, 1992; Fillenbaum, 1978). Fillenbaum demonstrated that participants used different connectives to paraphrase promises and threats. Fillenbaum states:

"..., it seems quite clear that IF sentences may be differently paraphrased as a function of conceptual properties of the conditional that they embody. Insofar as the meaning of a sentence is revealed by the sentences that are produced as its equivalents or paraphrases, there is some evidence that IF may have different meanings or uses in the different contexts of the sort examined here." (p. 181)

In everyday life people convey conditional relations by using a variety of connectives (Byrne, 2006; Byrne & Johnson-Laird, 1992). These connectives may convey different nuances of meaning resulting in subtly different interpretations of a conditional relation (Byrne, 2006). Byrne and Johnson-Laird (1992) asked participants to combine three sentences, such as 'Joe hires a gardener', 'Joe does some gardening', 'Joe can get the grass cut', into one sentence. Some of the materials used in this experiment contained modal verbs ('Joe can get the grass cut') and some did not ('Joe gets the grass cut'). Participants used different connectives to combine these sentences depending on whether the sentences reflected an uncertainty (e.g., 'Joe may or may not have his grass cut') or not. Participants used the word 'if' when the outcome assertion described a possibility, e.g., 'if Joe hires a gardener or does some gardening his grass gets cut'. They used factual connectives, such as 'so' and 'as', when the outcome assertion was asserted categorically, e.g., 'as Joe hires a gardener or does some gardening his grass gets cut'.

The connectives people use to paraphrase an assertion may therefore reveal a person's understanding and interpretation of that assertion. This method provides a way in which people's mental representations can be examined. We make use of this methodology in Chapter 3 where we examine the paraphrases participants generated for factual and counterfactual conditionals describing different types of causes.

Priming paradigm

A conditional such as 'if Joe cut his finger then it bled' has four possibilities associated with it: 'he cut his finger and it bled', 'he cut his finger and it did not bleed', 'he did not
cut his finger and it bled' and 'he did not cut his finger and it did not bleed'. Depending on the interpretation people make of this assertion (biconditional or conditional) they will rate either two or three of the above possibilities as consistent. Which of the possibilities they rate as consistent or inconsistent depends on the mental representation they have formed of the conditional.

The mental representations people form of conditionals have typically been examined in two ways, either, indirectly, by inferring them from the inferences people make from conditionals, or by directly asking participants to rate the different possibilities as true or false or consistent or inconsistent (for a review see Evans et al., 1993). Others have asked participants to list both possible and impossible cases for conditional assertions (Goldvarg & Johnson-Laird, 2001).

A more subtle way of examining people’s mental representations of different conditionals has been devised by Santamaria et al. (Santamaria & Espino, 2002; Santamaria et al., 2005). They suggested that a person should read more quickly the possibilities they consider to be consistent with a conditional. Accordingly, they primed participants with different conditionals and then measured the time it took participants to read the various possibilities. The conditionals and associated possibilities (in the form of conjunctions, e.g., ‘Joe cut his finger and it bled’) were embedded in paragraphs consisting of 7 sentences (or sentence fragments) which were presented one by one on a computer screen. Presentation of the sentences was self-paced in that participants pressed the space bar when they were ready to read the next sentence. The paragraphs were about everyday scenarios in which two people encounter a situation such as:

‘Miguel was going to a flower shop with his sister.
She told him that in this shop
If there are roses then there are lilies.
When they arrived at the shop the salesman said to them
There were roses and there were lilies.
Miguel and his sister went to the cinema.
Did Miguel and his sister go to a flower shop?'

In this scenario participants were primed with a factual conditional (‘if there are roses then there are lilies’) and the reading time for the conjunction (‘there were roses and there were lilies’) was measured. Santamaria et al. (2005) compared reading times for the conjunctions following a prime with a factual conditional ‘if there are roses then there are lilies’ or a counterfactual conditional ‘if there had been roses then there would have been lilies’. They found that the negative conjunction (‘there were no roses and there were no
lilies') was read more quickly when it followed a counterfactual than a factual conditional. The affirmative conjunction ('there were roses and there were lilies') was read equally quickly in both conditions, indicating that participants were keeping in mind two possibilities to understand a counterfactual conditional and only one possibility to understand a factual conditional. As predicted there were no differences between the two conditions for reading times for the two possibilities ‘there were roses and there were no lilies’ and ‘there were no roses and there were lilies’. Santamaria et al. also used this paradigm to demonstrate differences in people’s mental representations of semifactual conditionals (‘even if there had been roses there would have been lilies’) compared to factual and counterfactual conditionals as well as to compare the mental representation of ‘if p then q’ conditionals to ‘p only if q’ conditionals (Santamaria & Espino, 2002; Santamaria et al., 2005).

We make use of this paradigm in order to compare the mental representation of different causes in Chapter 4. As we have suggested previously, different causes are consistent with different possibilities. As a consequence, we expect to find differences in reading times for the associated conjunctions for different types of causes.

Assigning causal roles and dealing with inconsistent information

In Chapter 5 we report two experiments in which participants were asked to identify the cause and the enabling condition for scenarios. For example they received the following information: ‘given that there is sunshine, if there is fertilizer, then the plants grow. However, if there is no sunshine then the plants do not grow even if there is fertilizer’. Participants were asked to identify the cause (‘fertilizer’ in the above description) and the enabling condition (‘sunshine’) (see Experiment 2 in Goldvarg & Johnson-Laird, 2001). In one experiment (Experiment 7) we broke these descriptions up into two sentences and presented participants with one sentence at a time and asked them to make causal judgements after each sentence. Breaking the descriptions up into two sentences allowed us to examine the effect of consistent and inconsistent information on participants’ initial identifications. In Experiment 8 we manipulated the wording of the scenarios and the order in which the cause and the enabling condition were presented in order to examine some of the factors which influence the assignment of causal roles.

Aims of the thesis

The primary aim of this thesis is to advance our understanding of the mental representations and cognitive processes that underpin thinking about and reasoning from causal and counterfactual conditionals. We examine the effect of context on reasoning
from causal counterfactual conditionals and we examine the mental representations and cognitive processes in thinking about different types of causes, in factual conditionals in the indicative mood and in counterfactual conditionals in the subjunctive mood. There has been little research on the mental representation of different types of causes and we derive our predictions from the mental model theory.
Chapter 2  Counterfactual Alternatives

The aim of this chapter is to examine the effect of context, in particular a context which emphasises the facts and suggests a counterfactual alternative, on the inferences people make from counterfactual conditionals. Research on factual conditionals has demonstrated that content can have a dramatic effect on the inferences people make from them. For example people make more denial of the antecedent and affirmation of the consequent inferences when they cannot think of counterexamples to these inferences, as for a strong cause such as ‘if water is heated to 100°C then it boils’, than when they can think of counterexamples, as is the case for weak causes such as ‘if the car runs out of petrol then it stalls’ (e.g., Markovits, 1984).

Content effects have also been demonstrated in studies examining reasoning from counterfactual conditionals. For example Quelhas and Byrne (2003) showed that participants reasoned differently from deontic counterfactuals than from regular counterfactuals. Reasoning from counterfactual conditionals has typically been studied by assessing inferences from counterfactuals presented in isolation (e.g. Byrne & Tasso, 1999). However, in everyday thinking counterfactuals arise from a context. Something unexpected happens, e.g. a person is involved in a car accident, and they think ‘if only I had not skipped the red light’. Does the background knowledge provided by the context that gave rise to a counterfactual have an effect on the inferences people make from it? The context from which a counterfactual arises provides two forms of information. First, people generate a counterfactual ‘if only I had stopped at the red light I would not have collided with the other car’ because they know the facts ‘I did crash the car’. Second, the context provides a person with one or more counterfactual alternatives, e.g., ‘if I had stopped at the red light’. We report two experiments in this chapter in which we investigated the effect of emphasising the presupposed facts as well as the suggestion of a counterfactual alternative on the inferences people make from counterfactual conditionals.

Conditional inferences

As we saw in Chapter 1, a view of reasoning is that people reason by envisaging possibilities (Johnson-Laird & Byrne, 1991, 2002). When they make inferences they tend to think of true possibilities and not false possibilities (Johnson-Laird & Byrne, 1991). They understand a conditional such as ‘if the couple got a taxi they arrived safely’ by thinking about true possibilities such as, ‘the couple took a taxi and they arrived safely’; they do not think about false possibilities, such as, ‘the couple took a taxi and they did not
arrive safely'. People also tend to think of few possibilities, because of the constraints of their limited working memories (Johnson-Laird & Byrne, 1991). They understand the conditional by thinking about just a single possibility initially, ‘the couple took a taxi and they arrived safely’ and they do not tend to think about the other possibilities that are consistent with it, such as ‘the couple did not take a taxi and they did not arrive safely’. But they can return to the other possibilities if need be.

Most people can readily make the modus ponens inference from ‘the couple took a taxi’ to ‘therefore they arrived safely’. They have more difficulty making the modus tollens inference from ‘the couple did not arrive safely’ to ‘they did not take a taxi’. Both inferences are logically valid, that is, there are no counterexamples to them on the usual conditional and biconditional interpretations. But they differ in the ease with which people can make them (see Chapter 1 for a more detailed discussion of the different sorts of inferences). The mental model theory explains this difference: the modus ponens inference is made by thinking about a single possibility, the modus tollens inference requires the reasoner to think about multiple possibilities.

We also saw in Chapter 1 that these same principles, of envisaging true possibilities and few possibilities, also explain the sorts of counterfactual alternatives to reality that people create (Byrne, 2005). A counterfactual conditional seems to be understood by forming a richer mental representation compared to a factual conditional. A counterfactual conditional, such as ‘if the runner had taken the newer drug she would have won the race’ may be understood by envisaging several possibilities, such as ‘the runner took the newer drug and she won the race’ (the imagined possibility) and ‘the runner did not take the newer drug and she did not win the race’ (the presupposed facts) (Johnson-Laird & Byrne, 1991).

Many people seem to keep in mind both possibilities, the conjecture and the presupposed facts, when they understand a counterfactual conditional. For example, they can readily make inferences that require access to either possibility, e.g., they can readily make the modus ponens inference from ‘the runner took the newer drug’ to ‘she won the race’, and they can also readily make the modus tollens inference from ‘the runner did not take the newer drug’ to ‘she did not win the race’ (Byrne & Tasso, 1999). They make the inferences that require access to the negative possibility more readily from the counterfactual conditional compared to a factual conditional. The result corroborates the proposal that people think about a single possibility to understand the factual conditional but two possibilities to understand the counterfactual conditional.
The proposal is also corroborated by the observation that people judge that someone who uttered the counterfactual meant to imply that 'the runner did not take the newer drug' and 'the runner did not win the race' (Thompson & Byrne, 2002). Moreover, people read the negative conjunction more quickly when it is preceded by a counterfactual conditional than when it is preceded by a factual conditional (Santamaria et al., 2005).

It is perhaps surprising that people are willing to make the affirmative inferences from a counterfactual conditional. They understand the counterfactual, e.g., 'if the runner had taken the newer drug she would have won the race' and they appreciate that it presupposes the facts, 'she did not take the newer drug and she did not win the race'. But they are then asked to suppose that the runner took the newer drug. The supposition may appear to contradict the presupposed facts. As described in Chapter 1, mental logic theories seem to suggest that people should not make the modus ponens inference from a counterfactual as it results in a contradiction (Byrne, 2005).

Our suggestion is that people are willing to make the supposition because they view the 'facts' as presuppositions. But when they understand a counterfactual in context they view the facts as real. We distinguish between (1) presuppositional counterfactuals for which participants do not know the facts but presuppose them to correspond to the negation of the antecedent and the negation of the consequent ('Jane did not take the newer drug and she did not win the race'), and (2) known counterfactuals for which participants know the facts. Studies of counterfactual inference have focussed on presuppositional counterfactuals. Our aim in this chapter is to examine inferences from known counterfactuals and compare them to presuppositional counterfactuals. We suggest that people may make different inferences from presuppositional and known counterfactuals.

The task of understanding known counterfactuals may be akin to revising beliefs. Belief revision experiments typically present participants with a conditional ('if Joe puts 50 cents in the machine, he gets a coke') and a categorical statement ('he put 50 cents in the machine'). Participants are then either invited to make an inference or are provided with an inference based on the conditional and the categorical ('therefore, he got a coke'). In the next step the inference is denied ('in fact Joe did not get a coke') and participants are asked to reconcile the new information with the earlier information (e.g., Elio & Pelletier, 1997). Elio and Pelletier reported that participants revise their belief in the conditional more than in the categorical statement. However, since their seminal studies, several experiments have shown that under some circumstances people revise their beliefs more in the categorical statement than in the conditional (e.g., Byrne & Walsh, 2005; Dieussaert, Schaeken, De Neys, & d'Ydewalle, 2000).
One of the important concepts for considering which belief is revised is epistemic entrenchment (Gärdenfors, 1988). Epistemic entrenchment refers to the fact that some beliefs may be more embedded in people’s belief system than others and are therefore more resistant to being revised. Studies of belief revision indicate that conditionals are more readily revised when participants are unfamiliar with their content and therefore have less reasons to hang on to their belief. However, when the conditionals refer to familiar beliefs then people are less willing to revise their beliefs in the conditional. For example, Byrne and Walsh (2005) demonstrated that participants tended to revise their belief in a conditional when the content of the problem was unfamiliar (life on an alien planet), whereas when the content of the problems described familiar causal relations (‘if water was poured on the campfire then the fire went out’) participants were more likely to revise the categorical.

A counterfactual (e.g., ‘if Jane had taken the newer drug then she would have won the race’) that is presented within a context that emphasises the facts may result in a reluctance to consider the counterfactual conjecture (e.g., ‘she took the newer drug and she won the race’) as people may remain focussed on the known facts. For example, imagine a story in which a girl, Jane, comes 4th in an Olympic 400 metre race because the drug she took to treat her sprained ankle resulted in side effects that impaired her performance. Suppose with this story as a backdrop, you were then given the counterfactual ‘if Jane had taken a different drug she would have won the race’, would you be willing to make the modus ponens inference from ‘she took a different drug’ to ‘she won the race’? Emphasising the facts of a situation by providing a context in which the facts occurred prior to providing the counterfactual may affect how people interpret counterfactual conditionals. As a result, emphasising the facts of a situation may lead to different patterns of inferences than a counterfactual conditional presented in isolation. When the counterfactual is given in a context participants may be more focussed on the facts from which the counterfactual arose (‘she did not win the race’) and be less willing to hypothesise about an alternative outcome in their reasoning.

To test this suggestion we asked participants to make inferences from factual and counterfactual conditionals. We presented them with a counterfactual such as ‘if Jane had taken the newer drug she would have won the race’ and asked them to suppose ‘she took the newer drug’ for the modus ponens inference, suppose ‘she did not take the newer drug’ for the denial of the antecedent inference, suppose ‘she did not win the race’ for the modus tollens inference, and suppose ‘she won the race’ for the affirmation of the consequent inference. We preceded the counterfactuals with stories which provided a context within
which to interpret them. We expected that participants would make different inferences from counterfactuals presented in isolation and counterfactuals that arise from stories of how events turned out and could have turned out differently.

**Experiment 1: Reasoning from Counterfactual Conditionals with a Context**

The aim of the experiment was to test the inferences people make from a counterfactual conditional when it is preceded by a story that describes the facts and suggests a counterfactual alternative to them. Most people readily make all four inferences from the counterfactual conditional ‘if the runner had taken the newer drug she would have won the race’. We suggest they have considered the two possibilities

- new drug won  *counterfactual conjecture*
- not new drug not won  *presupposed facts*

We call these counterfactuals presuppositional counterfactuals, people do not know that the facts actually occurred, but they are presupposed by the counterfactual. Experiments have shown that people tend to make the inferences that require access to the affirmative possibility, such as the modus ponens inference from ‘she took the newer drug’ to ‘she won the race’ and the affirmation of the consequent inference from ‘she won the race’ to ‘she took the newer drug’ (Byrne & Tasso, 1999; Thompson & Byrne, 2002). More importantly, they also make the inferences that require access to the negative possibility, such as the modus tollens inference from ‘she did not win the race’ to ‘she did not take the newer drug’ and the denial of the antecedent inference from ‘she did not take the newer drug’ to ‘she did not win the race’.

But suppose you first read the following story (adapted from Boninger, Gleicher, & Strathman, 1994; McCloy & Byrne, 2002).

"Jane is a runner and since the age of eight she has competed in the sprint races in local track and field events. Up through school she had won every race in which she had competed. It was at the age of 13 that she began to dream about the Olympics. At the age of 18, before starting college, she decides to give the Olympics one all out shot. She makes the Irish Olympic team for the 400 metre race.

On the day before the 400 metre race, in a freak accident during training, she sprains her left ankle. Although there is no break or fracture, when she tries to run, the pain is excruciating. Her trainer tells her about many advances in pain killing medications and assures her that she will still be able to participate. He recommends that she chooses between two drugs, both legal according to Olympic guidelines. One is a well-known
painkiller that has been proved effective but also has some serious side effects including temporary nausea and drowsiness. The other painkiller is a newer and less well-known drug. Although the research suggests that the newer drug might be a more effective painkiller, its side effects are not yet known because it has not been widely used.

After considerable thought, she elects to go with the more well-known drug. On the day of the race, although there is no pain in her ankle, she already begins to feel the nausea and finds herself fighting off fatigue. She finishes in fourth place, only 1 tenth of a second from a bronze medal, 4 tenths from a silver, and 5 tenths from a gold medal. After the event, she learns that some athletes in other events who were suffering from similar injuries used the other, newer drug. They felt no pain and experienced no side effects.”

The information in the story describes the facts, Jane took the well-known drug and she lost her race. But it also suggests an alternative to them, Jane could have taken the newer drug, and she could have won her race, especially in the light of the information that others took the newer drug and experienced no side effects. In fact, experiments have shown that people readily generate this counterfactual when they read the story (Boninger et al., 1994; McCloy & Byrne, 2002).

Suppose you read the story and you are then given the counterfactual, ‘if Jane had taken the newer drug she would have won the race’. You are told: Suppose Jane took the newer drug. What follows? Would you choose (a) Jane won the race, (b) Jane did not win the race, or (c) Jane may or may not have won the race? We hypothesise that people will have represented the conjecture and the facts

\[
\begin{align*}
\text{new drug} & \quad \text{won} \\
\text{not new drug} & \quad \text{not won}
\end{align*}
\]

We call these counterfactuals ‘known counterfactuals, reasoners know that the facts occurred (because of the information in the story) and we italicise the facts to emphasise that they may focus on them. We hypothesise that people will be less inclined to set aside their appreciation of the facts when they have read the story compared to when they have been given the counterfactual conditional in isolation. Hence, we expect they will make fewer affirmative inferences from the counterfactual in context than from the counterfactual by itself. In particular we expected participants who focus on the facts to make less of the affirmative inferences (modus ponens and affirmation of the consequent) as they require access to the counterfactual conjecture (‘she took the newer drug and she won the race’).
Suppose instead you are told: Suppose Jane did not win the race. What follows? Would you choose (a) Jane did not take the newer drug, (b) Jane took the newer drug, or (c) Jane may or may not have taken the newer drug? We suggest that the story makes particularly salient one of the two possibilities, the facts, ‘Jane did not take the newer drug and she did not win’. Participants may even be inclined to mentally represent the counterfactual by thinking about only the negative possibility in this instance. Hence, we expect that they will make the negative inferences from the known counterfactual as well as from the presuppositional counterfactual.

We examine whether people will make the affirmative inferences (modus ponens and affirmation of the consequent) as readily or not when they have read the story compared to when they have been given the counterfactual conditional in isolation. We also compare the inferences people make from the counterfactual conditional, without a story, to a factual conditional, without a story. Based on previous research we expect participants to make more of the negative inferences, modus tollens and denial of the antecedent, following a counterfactual compared to a factual conditional (Byrne & Tasso, 1999) because they have kept both possibilities in mind for the counterfactual and only one possibility for the factual conditional.

**Method**

**Materials and Design**

All participants were asked to evaluate four inferences, modus ponens (MP), modus tollens (MT), denial of the antecedent (DA), and affirmation of the consequent (AC), for three conditionals which differed in their content, that is, they completed 12 inferences. There were three groups of participants. The experimental (‘known counterfactual’) group of participants carried out the inferences for counterfactual conditionals, e.g., ‘if Jane had taken the newer drug she would have won the race’ after they first read a story (for each conditional) that described the situation surrounding the actual antecedent and outcome (‘Jane did not take the newer drug and she did not win the race’), as illustrated earlier, and that contained information that could enable the construction of a counterfactual alternative (information that another drug exists). We asked participants to imagine they were the protagonist who thought about how things could have turned out differently, and complete a sentence beginning ‘if only’. The ‘presuppositional counterfactual’ group of participants carried out the inferences for counterfactual conditionals but they did not receive a story. We tested a third group of participants (‘factual’ group) who received no story and carried out the inferences for factual conditionals, e.g., ‘if Jane took the newer drug she won the
race’. The participants were assigned to each condition consecutively. Participants for all conditions came from the same pool of participants, that is, Trinity College students.

We adapted three stories that have been used in previous studies on counterfactual thinking, one is about a runner who considers two alternative drugs to treat an injury and loses a race as a result of her choice of drug (McCloy & Byrne, 2002); one is about a man who dies in an airplane crash which could have been avoided had his wife pleaded with him to take the ferry instead (Mandel & Lehman, 1996), and one about a couple who are injured when they drive over a collapsed bridge after being refused a ride in a taxi (Wells & Gavanski, 1989). The conditionals were each presented on a page of a booklet, and the four inferences were presented on the same page. Each minor premise was followed by a choice of three responses, e.g., ‘she won the race’, ‘she did not win the race’ and ‘she may or may not have won the race’. Appendix A2 (p. 183) contains the full set of materials used in this experiment.

**Procedure**

Participants were tested in groups. They were given a booklet which contained the consent form, the instructions, the tasks and the debriefing sheet. The three stories were presented in six counterbalanced orders and the inferences for each story were also presented in different orders. In all conditions the conditional and four inferences were presented on a separate page to the stories. The conditional was followed by a request to consider each of the elements of the conditional in turn and indicate which conclusion could be drawn, e.g.,

> ‘Suppose Jane took the newer drug.  
> What can you conclude?  
> o Jane won the race  
> o Jane did not win the race  
> o Jane may or may not have won the race’

The instructions included the following information:

> This booklet contains three scenarios. [...] Each scenario is followed by a set of questions. Please read each scenario carefully and answer the questions that follow. Please answer the questions in the order in which they are presented and do not try to change your answers once you have written them. (see Appendix A1 for the full instructions, p. 183)

---

2 They were assigned consecutively for seven conditions, three reported in this experiment and four reported in the next experiment.
There was no time limit for completion of the task and completion took five minutes for the two groups which only received the inference task and approximately ten minutes for the group that received the stories. Participants were randomly assigned to the ‘presuppositional counterfactual’ or ‘known counterfactual’ group and then assigned to the ‘factual’ group.

**Participants**

The participants were 85 students from Trinity College, Dublin University, and one visiting transition year school pupil on work experience in the Psychology department, who all took part voluntarily. We excluded 23 participants as they had previously studied logic or reasoning or taken part in a similar experiment. The remaining 63 participants were assigned to the ‘known counterfactual’ group (n = 22), the ‘presuppositional counterfactual’ group (n = 21), and the ‘factual’ group (n = 20). Their mean age was 21 years with a range of 15 - 49 years (two participants did not disclose their age). There were 14 men and 49 women.

**Results and discussion**

We conducted a Kruskal Wallis H test to test our prediction that there would be reliable differences in the number of inferences participants made between the three groups. Participants’ responses were coded according to whether each of the particular inferences was made, that is when participants chose the determinate response, e.g. ‘Jane won the race’ rather than the indeterminate response of ‘Jane may or may not have won the race’. We found reliable differences in the frequency of MP inferences made, $H = 13.6$, df = 2, $p = .001$, in the frequency of MT inferences made, $H = 8.9$, df = 2, $p = .012$, and the frequency of DA inferences made, $H = 10.7$, df = 2, $p = .005$. However, there were no differences in the frequency of AC inferences made, $H = 1.5$, df = 2, $p = .474$. The frequency of inferences made for each of the three conditions can be seen in Table 2.1. We carried out planned comparisons to test our predictions.

First we compared the frequency of inferences between the ‘factual’ group and the ‘presuppositional counterfactual’ group. The comparison replicates previous studies which have shown increased frequencies of the negative, MT and DA, inferences, and equivalent frequencies of the affirmative inferences, MP and AC. Participants in the ‘presuppositional counterfactual’ group made more of the negative inferences from the counterfactual than the participants in the ‘factual’ group did from the factual conditional. This difference was observed for the MT inference, 81% versus 58% (Mann Whitney $U = 142.5$, n1 = 21, n2 =
20, \( p = .053 \), and the comparison had 80% power to detect a difference of .09) and there
was a marginal effect for DA inference (46% versus 20%, Mann Whitney \( U = 144.5, n_1 = 21, n_2 = 20, p = .068 \) and the comparison had 80% power to detect a difference of .09), as
Table 2.1 shows. Participants in both groups made the same frequency of the affirmative
inferences, for both the MP inference (86% versus 80%, Mann Whitney \( U = 195, n_1 = 21, n_2 = 20, p = .634 \)) and the AC inference (46% versus 40%, \( H = 1.5, df = 2, p = .474 \)).
These results replicate previous comparisons of factual and counterfactual conditionals
(Byrne & Tasso, 1999; Thompson & Byrne, 2002). They corroborate the proposal that
participants understand a factual conditional such as ‘if Jane took the newer drug then she
won the race’ by keeping in mind a single possibility, ‘Jane took the newer drug and she
won the race’; in contrast, they understand the counterfactual ‘if Jane had taken the newer
drug she would have won the race’ by keeping in mind two possibilities, ‘Jane took the
newer drug and she won the race (imagined)’ and ‘Jane did not take the newer drug and
she did not win the race (facts)’.

### Table 2.1: Percentages of each type of inference in the three conditions of Experiment

<table>
<thead>
<tr>
<th>Inference</th>
<th>MP</th>
<th>AC</th>
<th>MT</th>
<th>DA</th>
</tr>
</thead>
<tbody>
<tr>
<td>Factual</td>
<td>80</td>
<td>40</td>
<td>58</td>
<td>20</td>
</tr>
<tr>
<td>Presuppositional counterfactual</td>
<td>86</td>
<td>46</td>
<td>81</td>
<td>46</td>
</tr>
<tr>
<td>Known counterfactual</td>
<td>49</td>
<td>53</td>
<td>45</td>
<td>59</td>
</tr>
</tbody>
</table>

Our key set of comparisons is between the ‘presuppositional counterfactual’ and
the ‘known counterfactual’ group for the inferences from a counterfactual conditional. As
expected, the ‘known counterfactual’ group made fewer MP inferences than the
‘presuppositional counterfactual’ group, 49% versus 86% (Mann Whitney \( U = 102, n_1 = 22, n_2 = 21, p = .001 \)). However, they did not make fewer AC inferences (46% versus
53%, \( H = 1.5, df = 2, p = .474 \)). Participants in the ‘known counterfactual’ group also made
fewer MT inferences than the ‘presuppositional counterfactual’ group (45% versus 81%,
Mann Whitney \( U = 118, n_1 = 22, n_2 = 21, p = .003 \)). There were no differences for the DA
inferences (59% versus 46% %, Mann Whitney \( U = 190, n_1 = 22, n_2 = 21, p = .296 \)).

We predicted that the ‘known counterfactual’ condition, in which participants were
also asked to generate a counterfactual thought, would emphasise the facts ‘the runner did
not take the newer drug and did not win the race’. By emphasising the facts we expected that participants would have difficulty in accessing the counterfactual conjecture, ‘the runner took the newer drug and she won the race’, compared to reasoners who consider the counterfactual in isolation. We expected that a result of this difficulty would be that when reasoners are invited to ‘suppose the runner took the newer drug’ they would make fewer MP inferences, that is, judge that ‘the runner won the race’ as well as fewer AC inferences and they would make the same number of DA and MT inference. We observed that participants made fewer MP inferences and fewer MT inferences and the same frequency of AC and DA inferences.

If only thoughts

Participants in the ‘known counterfactual’ condition were asked to generate an ‘if only’ thought prior to completing the inference task. We examined the ‘if only’ thoughts participants generated to see which events they were most inclined to focus on. We classified the ‘if only’ thoughts as either focussing on the counterfactual alternative suggested by the story (‘taking the newer drug’) and as other (e.g., ‘had she not sprained her ankle’). Overall, participants predominantly identified the counterfactual alternative suggested by the story (on 67% of trials) in their ‘if only’ thoughts. The remaining 33% of ‘if only’ thoughts tended to focus on the event that led up to the counterfactual choice, e.g., ‘injuring her ankle’ (for the runner story), ‘having to go on a business trip’ (for the plane story) and ‘having to go into town’ (for the taxi story).

Interestingly, participants tended only to make assertions about the antecedent of the conditional (e.g., ‘if only she had taken the other drug’) and did not draw explicit conclusions by asserting a consequent. The ‘if only’ thoughts generated by participants validate the idea that the majority of participants produced the same counterfactual thought as the one participants were asked to evaluate in the inference task (or at least the same antecedent). Therefore, the conditional they were reasoning from was consistent with their beliefs about the facts of the story. It also confirms that they accepted the counterfactual alternative suggested by the story as a way in which the outcome could have been different.

Summary

The results of this experiment suggest that reading a story that emphasises the facts affects the inferences people make from counterfactuals. However, its influence is not confined to making people focus on the facts. Instead, the stories appear to have modulated participants’ interpretation of the conditional. Johnson-Laird and Byrne (2002) capture this
process with the principle of pragmatic modulation. According to this principle, knowledge of the specific circumstances surrounding the utterance of a conditional can affect the interpretation of that conditional, e.g. knowing that a soaking wet match will not light when struck (see Chapter 1 for a detailed description of this example). As a result, this additional knowledge may contribute to the construction of additional models.

The pattern of responses in this experiment suggests that the stories led participants to make an enabling interpretation of the conditionals (Johnson-Laird & Byrne, 2002). An enabling condition is consistent with the following three possibilities:

- new drug won
- new drug not won
- not new drug not won

An MP inference from this conditional ‘suppose she took the new drug’ would lead to an inconclusive answer ‘she may or may not have won the race’. The reason for this is that there are two models in which the new drug appears, in one of them she wins and in the other she does not win. Similarly, for an MT inference from this conditional ‘suppose she did not win’ the response would also be inconclusive, as again, there are two models in which she did not win with different values for the new drug. The DA and AC inferences can however, still be made as for each of these inferences there is only one consistent model.

Participants may have designated the event mentioned in the antecedent of the counterfactual conditional (‘had she taken the newer drug’) an enabling condition in this causal scenario. They may have felt that the counterfactual alternative only presented a possibility, rather than a guarantee, for changing the outcome of events. For example, in the runner story, participants may have reasoned that while the newer drug would not have entailed the same side effects as the drug Jane actually took, she still had an ankle injury which could have prevented her from performing at her best. Similarly, in the taxi driver story, participants may have reasoned that the couple could still have encountered the collapsed bridge even if the taxi driver had accepted them as passengers.

This experiment yielded two main results. Firstly, it corroborated previous findings of the difference between factual and counterfactual conditionals. Participants made more of the negative inferences, MT and DA, from a counterfactual conditional than from a factual conditional. A counterfactual conditional is understood by keeping two possibilities in mind, the conjecture and the presupposed facts, whereas a factual conditional is typically understood by just keeping one possibility in mind. This difference in representation means that it is easier to make the negative inferences from a counterfactual
conditional than from a factual conditional as the relevant model is already mentally represented for the counterfactual, whereas the representation of the factual conditional must be fleshed out before making the negative inferences.

Secondly, the experiment demonstrated that preceding a counterfactual conditional with a story which emphasises the facts has an effect on the inferences participants are willing to make. Contrary to our expectations the story did not merely lead to a reduction in the affirmative inferences, MP and AC. Instead, the story appeared to modulate participants' interpretation of the conditional.

In the next experiment our aim was to examine what aspect of the story was responsible for this modulation. We examined the effect of the story more closely by manipulating the amount of information contained in it. In particular we varied whether the story mentioned a counterfactual alternative, e.g., there was a choice between two drugs, and whether the story provided any further information about the counterfactual alternative, e.g., ‘other athletes used the other drug and experienced no side effects’. We investigated whether our findings resulted from the mere mention of a context, the suggestion of a counterfactual alternative or the suggestion of a counterfactual alternative which would have resulted in a better outcome.

**Experiment 2: Reasoning from Counterfactual Conditionals in Context – What Information Modulates the Interpretation?**

The aim of this experiment was to examine what aspects of the stories exerted their effect on the interpretation of the counterfactual conditionals. We investigated whether it was merely the existence of a context that modulated the interpretation. Thompson and Byrne (2002, Experiment 1) found that reasoners accepted more inferences from counterfactuals of all types in a no-context than in a context condition.

In this experiment we manipulated the amount of information contained in the story. We generated three story conditions. The first was an identical story to the one used in the previous experiment, but we omitted the request to generate an ‘if only’ thought. The second condition mentioned the counterfactual alternative (e.g., Jane had a choice between two drugs), it did not contain the information that the alternative would have led to a different outcome (e.g., the fact that other athletes took the alternative drug and suffered no side effects). The third story condition made no mention of an alternative (e.g., the story only suggested that she had the option of taking one drug).
Method

Materials and Design

As in the previous experiment participants made four inferences, MP, MT, DA, AC, from three counterfactual conditionals. There were four groups. The 'presuppositional counterfactual' group of participants did not receive a story. The 'known counterfactual' group of participants received the story with an explicit alternative and how this alternative would have led to a better outcome, as in the previous experiment. The 'suggested counterfactual' group of participants carried out the inference task after first reading the story without information on how the counterfactual alternative could have been better, that is, they did not receive the following information: 'After the event, she learns that some athletes in other events who were suffering from similar injuries used the other, newer drug. They felt no pain and experienced no side effects'. The 'known facts counterfactual' group received the story which merely mentioned the facts and had no mention of a counterfactual alternative, that is, they were not told that there was a choice between two drugs (instead of 'he recommends that she chooses between two drugs, both legal according to Olympic guidelines. One is a well-known painkiller that has been proved effective but also has some serious side effects including temporary nausea and drowsiness. The other painkiller is a newer and less well-known drug. Although the research suggests that the newer drug might be a more effective painkiller, its side effects are not yet known because it has not been widely used', participants received the following sentence 'He recommends that she takes a drug, legal according to Olympic guidelines'). The full set of materials is in Appendix A2 (p.183).

Procedure

The procedure for this experiment was identical to the previous experiment. Participants were tested in groups. They were given a booklet which contained the consent form, the instructions, the task and the debriefing sheet. The stories were presented in six counterbalanced orders and the inferences for each story were also presented in different orders. In all conditions the counterfactual conditional and four inferences were presented on a separate page to the stories. There was no time limit for completion of the task and completion took approximately ten minutes. Participants were assigned to the 'known counterfactual', the 'suggested counterfactual' condition, the 'presuppositional counterfactual', and the 'known facts counterfactual' conditions, in that order.
Participants

The participants were 97 students from Trinity College Dublin, and two visiting transition year school pupils on work experience in the Psychology department, who all took part voluntarily. We excluded 13 participants because they had either studied logic or reasoning or because they had taken part in a similar experiment. There were 25 men and 60 women. The mean age was 22 years (range 15-46 years). One participant did not provide their age and gender. The participants were assigned at random to the 'known counterfactual' group (n = 22) and 'suggested counterfactual' group (n = 23), and subsequent participants were assigned to the 'presuppositional counterfactual' group (n = 19) and the 'known facts counterfactual' group (n = 22).

Results and discussion

We conducted a Kruskal Wallis H test to test our prediction that there would be reliable differences in the frequency of inferences participants made between the four conditions. We found reliable differences in the number of MP inferences made, $H = 14.6$, df = 3, $p = .002$, and in the number of MT inferences made, $H = 13.8$, df = 3, $p = .003$. There were no differences in the number of DA inferences made, $H = 6.5$, df = 3, $p = .091$, and in the number of AC inferences made, $H = 5.5$, df = 3, $p = .141$. The frequency of inferences made for each of the four conditions can be seen in Table 2.2. We carried out planned comparisons to test our predictions.

Table 2.2: Percentages of each type of inference in the four conditions of Experiment 2

<table>
<thead>
<tr>
<th>Inference</th>
<th>MP</th>
<th>AC</th>
<th>MT</th>
<th>DA</th>
</tr>
</thead>
<tbody>
<tr>
<td>Presuppositional counterfactual</td>
<td>86</td>
<td>63</td>
<td>81</td>
<td>58</td>
</tr>
<tr>
<td>Known facts counterfactual</td>
<td>68</td>
<td>44</td>
<td>59</td>
<td>41</td>
</tr>
<tr>
<td>Suggested counterfactual</td>
<td>46</td>
<td>39</td>
<td>35</td>
<td>30</td>
</tr>
<tr>
<td>Known counterfactual</td>
<td>42</td>
<td>39</td>
<td>48</td>
<td>32</td>
</tr>
</tbody>
</table>

We first compared the three story conditions to the ‘presuppositional counterfactual’ condition. We carried out comparisons for the MP and MT inferences only as the Kuskal Wallis test indicated differences for these two sorts of inferences. The differences in the frequency of MP and MT inferences between the ‘presuppositional counterfactual’ and each of the other three conditions can be seen in Table 2.2.
counterfactual’ and the ‘known facts counterfactual’ conditions were marginally reliable, for MP inferences 86% versus 68%, Mann Whitney $U = 147$, $n_1 = 19$, $n_2 = 22$, $p = .068$, and the comparison had 80% power to detect a difference of .08; and for MT inferences 81% versus 59%, Mann Whitney $U = 142$, $n_1 = 19$, $n_2 = 22$, $p = .058$, and the comparison had 80% power to detect a difference of .09.

The difference in the frequency of MP inferences made between the ‘presuppositional counterfactual’ and the ‘suggested counterfactual’ conditions was reliable, 86% versus 46%, Mann Whitney $U = 122$, $n_1 = 19$, $n_2 = 23$, $p = .007$, as was the difference for the frequency of MT inferences made, 81% versus 35%, Mann Whitney $U = 92$, $n_1 = 19$, $n_2 = 23$, $p = .001$.

The comparison between the ‘presuppositional counterfactual’ and the ‘known counterfactual’ conditions yielded similar results. For MP inferences the difference was reliable, 86% versus 42%, Mann Whitney $U = 79$, $n_1 = 19$, $n_2 = 22$, $p = .001$, as well as for MT inferences, 81% versus 48%, Mann Whitney $U = 110$, $n_1 = 19$, $n_2 = 22$, $p = .006$.

The results suggest the inclusion of a counterfactual alternative has a particularly strong effect on the number of MP and MT inferences made. The ‘known facts counterfactual’ condition, which had no mention of an alternative, differed only marginally from the ‘presuppositional counterfactual’ condition, whereas the other two story conditions, which both mentioned a counterfactual alternative, both differed reliably from the ‘presuppositional counterfactual’ condition in the frequency of MP and MT inferences made. The additional information in the ‘known counterfactual’ condition did not have an additional effect over and above the information in the ‘suggested counterfactual’ condition, for MP inferences, 46% versus 42%, Mann Whitney $U = 242$, $n_1 = 23$, $n_2 = 22$, $p = .79$; for MT inferences, 35% versus 48%, Mann Whitney $U = 207$, $n_1 = 23$, $n_2 = 22$, $p = .27$.

The second comparison we made was between the ‘known facts counterfactual’ and the ‘suggested counterfactual’ conditions. The two conditions differed in that the ‘known facts counterfactual’ condition did not mention that there was an alternative to consider (e.g., the fact that there was a choice between two drugs). This comparison yielded a reliable result for the frequency of MT inferences made, 59% versus 35%, Mann-Whitney $U = 170$, $n_1 = 22$, $n_2 = 23$, $p = .047$, but no reliable difference for the frequency of MP inferences made, 68% versus 46%, Mann-Whitney $U = 192$, $n_1 = 22$, $n_2 = 23$, $p = .142$. The difference between the ‘known facts counterfactual’ and the ‘suggested counterfactual’ conditions suggests that including a counterfactual alternative in the story has an additional effect on the reduction of MT inferences made by participants.

59
Summary
The experiment replicates the results of the previous experiment in that preceding an inference task with a story which contained a counterfactual alternative led to a reduction in MP and MT inferences. The experiment demonstrated that providing a context for a counterfactual conditional which emphasises the facts has a small, statistically marginal, effect on the number of MP and MT inferences made, whereas suggesting a counterfactual alternative has a much larger effect on the number of MP and MT inferences made. The results reported here suggest that providing a counterfactual alternative is the key in modulating people’s interpretation of the counterfactual. In all of the conditions there were no reliable differences for the number of DA and AC inferences made.

General Discussion
The aim of this chapter was to examine the effect of providing a context for a counterfactual conditional such as, ‘if Jane had taken the newer drug she would have won the race’ on the inferences people make from it. We compared presuppositional counterfactuals and known counterfactuals. We preceded the known counterfactual conditionals with stories which emphasised the facts (‘she took the more well-known drug and lost the race’). We reported the difference between factual conditionals in the indicative mood and counterfactual conditionals in the subjunctive mood. The comparison of factual and counterfactual conditionals in Experiment 1 was consistent with previous research, in that participants made more of the negative inferences, MT and DA, from a counterfactual conditional than from a factual one (Byrne & Tasso, 1999; Thompson & Byrne, 2002).

Experiment 1 showed people make fewer inferences from known counterfactuals than from presuppositional counterfactuals. In particular they make fewer modus ponens and modus tollens inferences. Participants made MP inferences on 86% of trials following a presuppositional counterfactual conditional and only on 49% of trials for a known counterfactual. Similarly, they made MT inferences on 81% of trials following the presuppositional counterfactual and only 45% following the known counterfactual. There were no reliable differences between the two conditions for the number of AC and DA inferences. Experiment 2 replicated this effect and showed that the availability of a counterfactual alternative was primarily responsible for it.

In Experiment 2 we varied the amount of information provided in the stories that preceded the inference task. In the ‘known counterfactual’ condition participants read a story which suggested a counterfactual alternative (‘she had to choose between two drugs’).
and were told that the alternative would have been better (‘other athletes who took the newer drug felt no pain and suffered no side effects’). In the ‘suggested counterfactual’ condition participants were given the same stories, but we omitted information about how the counterfactual alternative would have been better (e.g., ‘others took the newer drug and suffered no side effects’). In the ‘known facts’ condition the stories merely stated the facts (‘Jane took the drug and lost the race’) and there was no mention of a counterfactual alternative (‘she had a choice between two drugs’).

We predicted that preceding a counterfactual conditional with a story that emphasises the facts would focus participants on the facts and therefore lead to a reduction in the affirmative inferences, MP and AC. The affirmative inferences require access to the counterfactual conjecture, ‘the runner took the newer drug and she won the race’. Reasoners are invited to ‘suppose the runner took the newer drug’. However, they appreciate fully from the story that the runner did not take the newer drug. We anticipated that participants who read the story would be less willing to set aside the facts and make inferences based on the counterfactual conjecture.

In Experiment 2 we examined what aspect of the story was required to lead to this reduction in MP and MT inferences. In the ‘presuppositional counterfactual’ condition participants made the MP inference on 86% and the MT inference on 81% of trials. In the ‘known facts counterfactual’ condition they made the MP inference on 68% and the MT inference on 59% of trials. In the two conditions that mentioned a counterfactual alternative (‘suggested-’ and ‘known counterfactual’) they made the MP inference on 46% and on 42% of trials and the MT inference on 35% and on 48% of trials.

There was only a marginal effect of presenting a story which contained the facts (e.g., ‘Jane only came in 4th due to the side effects of the pain killer she took’) but no counterfactual alternative (e.g., the fact that she chose between two drugs) on the frequency of making MP and MT inferences compared to the ‘presuppositional counterfactual’ condition, in which participants received the conditional without a story. Reading a story which suggested a counterfactual alternative (‘she had to choose between two drugs’) resulted in a clear reduction in the frequency of making MP and MT inferences, regardless of whether participants received more detailed information about this alternative (e.g., ‘other athletes who took the alternate drug suffered no adverse side effects’).

The ‘if only’ thoughts generated in Experiment 1 show that participants mostly, on 67% of trials, generated an ‘if only’ thought consistent with the counterfactual alternative suggested by the story. The majority of the other ‘if only’ thoughts focused on an event
that preceded the counterfactual alternative (e.g., ‘spraining the ankle’). It is striking that while participants were willing to generate the counterfactual thought expressed in the inference task, they were not willing to assert that this counterfactual alternative would definitely have led to a better outcome. Instead, participants tended to make indeterminate inferences, that is, they chose the option ‘she may or may not have won the race’. The stories, and in particular the suggestion of a counterfactual alternative, may have modulated participants’ interpretation of the conditional. The pattern of inferences made by participants is consistent with an enabling interpretation of the conditional (Johnson-Laird & Byrne, 2002).

An enabling condition makes an outcome possible, whereas a cause brings about an outcome. Participants in the two experiments tended to interpret the counterfactual conditional as an enabling condition when it was preceded by a story which included a counterfactual alternative. An enabling interpretation is consistent with a reduction in MP and MT inferences. In Chapter 1 we noted that the MP inference is made nearly all of the time (Schroyens et al., 2001a).

In the ‘runner’ story participants were told that Jane took the older drug and as a consequence of suffering side effects only finished in 4th place. They were also told that she could have chosen an alternative drug and this alternative drug would not have resulted in side effects. Participants were not willing to infer that taking the drug would have resulted in her winning the race. Participants were willing to consider that things would have been better if only she had taken the newer drug (as evidenced by their ‘if only’ thoughts). However, when they were told to imagine she took the newer drug, they did not conclude ‘she won the race’. They concluded she may or may not have won the race. Their ‘if only’ thoughts may be represented as

\[
\text{new drug won} \\
\text{not new drug won}
\]

but when they make the inference they appear also to consider the possibility

\[
\text{new drug not won}
\]

This representation is an enabling relation rather than a strong cause or weak cause relation.

Experiment 1 shows an intriguing difference between the counterfactual thoughts generated and the inferences made from the counterfactual. Participants stated that the protagonist would think ‘if only I had taken the newer drug’. However, the inferences they made from the same conditional reveal that they were not certain that the alternative would
have led to a better outcome. Providing participants with one counterfactual alternative may encourage them to consider other possibilities too.

**Implications of findings for other theories of conditional reasoning**

The difference between factual and counterfactual conditionals can readily be explained by the mental model theory. Participants in Experiment 1 made more MT and DA inferences following a counterfactual conditional than following a factual conditional. According to the mental model theory, counterfactual conditionals are understood by keeping in mind two possibilities (the counterfactual conjecture and the presupposed facts). Therefore, people find it easier to make the negative inferences, MT and DA, from a counterfactual conditional than from a factual conditional (Johnson-Laird & Byrne, 2002).

Theories based on formal rules of inference (e.g., Braine & O'Brien, 1998; Rips, 1994) suggest that people reason by constructing proofs using a set of abstract general purpose rules, as described in Chapter 1. Braine and O'Brien (1991) suggest that MP inferences are easier and therefore endorsed more frequently than MT inferences because people have a rule for MP and not for MT. They are therefore able to account for the finding that for factual conditionals in the indicative mood participants typically make more MP inferences than MT inferences. However, Braine and O'Brien do not have a detailed account for the effects of linguistic mood on the inferences people make and are therefore not able to account for the increase in MT inferences from a counterfactual conditional in the subjunctive mood, as we saw in Experiment 1. According to Braine and O'Brien's theory the logically fallacious inferences DA and AC are made because of comprehension errors or a misrepresentation of the task and are the result of large individual differences. As a result, they are not able to account for systematic 'errors' such as making more DA inferences from a counterfactual conditional than from a factual conditional. As outlined previously, Braine and O'Brien's theory seems to suggest that people should not make the modus ponens inference from a counterfactual conditional as an application of the rules suggested by Braine and O'Brien results in a contradiction from which no inference follows (Byrne, 2005).

The experiments reported in this chapter demonstrated that participants consistently make less MP and MT inferences when the counterfactual conditional is preceded with a story that contains a counterfactual alternative. Within the mental model framework we can account for this finding by referring to pragmatic modulation, as described previously. Braine and O'Brien’s (1991) theory is unable to account for context effects. However, context effects have been reported in many previous experiments, such as experiments on
causal conditionals as described in Chapter 1 (e.g., Cummins, 1995; Cummins et al., 1991).
Braine and O'Brien therefore propose a 'pragmatic comprehension process' which makes
use of pragmatic reasoning schemas such as those proposed by Cheng and Holyoak (1985).
We now turn our attention to domain specific theories, such as Cheng and Holyoak's to see
if they are able to account for the results of the experiments reported in this chapter.

Domain specific rule theories (e.g., Cheng & Holyoak, 1985; Fiddick et al., 2000)
were devised to account for context effects in reasoning, in particular in Wason's selection
task. We might expect these theories to be able to account for the findings of the
experiments reported here, given that they were particularly designed to account for
context effects. Cheng and Holyoak propose that people reason by applying appropriate
reasoning schemas (e.g., permissions and obligations, causality) which are sensitive to the
pragmatics of a situation, whereas Fiddick et al. (2000) focus on social contracts and
hazard management and therefore maintain that responses to reasoning problems are
determined by how the situation is interpreted with respect to social exchange. These
theories focus on very specific context effects and are able to account for perspective
effects found in domains such as permissions and obligations (Holyoak & Cheng, 1995).
Quelhas and Byrne (2003) provide a more generic, and arguably parsimonious, account of
counterexamples which in turn affects the way in which a conditional is mentally
represented.

It is not clear how domain specific theories could account for the context effect
found in the experiments reported here. Cheng and Holyoak assert that within a causal
context people possess a number of causal schemas. They could therefore invoke one of
these subtypes of the causal schema to explain these findings. The difficulty with Cheng
and Holyoak's theory is that their account is vague and it seems they could account for any
findings by suggesting another schema. Furthermore, there is no explanation as to how
these schemas come about, function and are applied.

Domain specific rule theories are also not able to account for the finding in
Experiment 1, where participants made more of the negative inferences from a
counterfactual conditional than from a factual conditional. The content of the two
conditionals was identical, therefore both sorts of conditional should invoke the same
schema or domain specific rule. Neither of the two theories makes any predictions about
the effect of mood on the inferences people make.

Evans and Over (2004) recognise the effects of pragmatics and believability on the
inferences people make. They may therefore argue that the stories which included a
counterfactual alternative had an effect on the believability of the conditional and as a result led to a reduction of MP and MT endorsements. According to Evans and Over prior knowledge and belief that is relevant in the context will be automatically added to premises. Uncertainty in the premises will be taken into account and as a result inference may be drawn on the basis of high probability or plausibility, rather than on the basis of what necessarily follows.

Evans et al. (2003) argue that people consider only one hypothetical possibility at a time (the singularity principle) and by only focusing on cases where the antecedent of the conditional is true. They are therefore not able to account for the finding that participants make the same number of affirmative inferences and more negative inferences from a counterfactual than from a factual conditional, given that these inferences require access to the negative possibility (‘she did not take the newer drug and she did not win the race’).

**Conclusion**

The experiments reported in this chapter provide two findings. Firstly, Experiment 1 corroborates previous research on the difference between factual and counterfactual conditionals. Accordingly, participants reasoning from counterfactual conditionals made more of the negative inferences, MT and DA, than participants reasoning from factual conditionals. Secondly, when a counterfactual conditional was preceded by a story suggesting a counterfactual alternative, participants consistently made less MP and MT inferences. This reduction in MP and MT inferences indicates that the counterfactual alternative suggested by the stories resulted in pragmatic modulation of the conditional.

The pattern of responses seen in the story conditions is consistent with an enabling interpretation of the conditional. This interpretation is consistent with three possibilities (‘she took the newer drug and won’; ‘she took the newer drug and did not win’; and ‘she did not take the newer drug and she did not win’) and leads to indeterminate responses to the MP and MT inferences. The pattern of inferences together with the ‘if only’ thoughts generated in Experiment 1 suggest that when people are given a counterfactual alternative, they are willing to accept that there is an alternative antecedent, but they are not certain that this alternative would have resulted in a better outcome.

In this chapter we examined the effect of context on the mental representation of and reasoning from counterfactual conditionals. In the next chapter we examine the effect of content on the mental representation of factual and counterfactual conditionals by describing different sorts of causal relations, including strong causes, weak causes and enabling conditions.
Chapter 3  Paraphrases of Causal and Counterfactual Conditionals

The aim of this chapter is to examine the mental representations people form of factual and counterfactual causal conditionals. In this chapter we examine how different content affects the mental representation of factual and counterfactual conditionals. Counterfactual conditionals are typically understood by keeping in mind two possibilities, the presupposed facts and the counterfactual conjecture. In the previous chapter we demonstrated that a context which suggests a counterfactual alternative affects the mental representation of counterfactual conditionals and thus the inferences people make from them. We suggested that the counterfactual alternative had modulated people’s interpretation of the conditional (‘if Jane had taken the newer drug she would have won the race’). The pattern of inferences we observed was consistent with an enabling interpretation, which is consistent with three possibilities (e.g., ‘she took the newer drug and won’, ‘she took the newer drug and did not win’, and ‘she did not take the newer drug and she did not win’). As described in Chapter 1, different types of causes can be distinguished by considering different possibilities and people make different inferences from factual conditionals describing different sorts of causal relations. In this chapter we examine how the counterfactual phrasing of different sorts of causal relations affects their mental representation.

The two experiments described in this chapter employ a paraphrasing paradigm (Fillenbaum, 1974b). Participants were asked to paraphrase conditional statements without using the word ‘if’. We measured their use of other connectives such as ‘because’, ‘so’, and ‘when’. We expected that differences in paraphrasings would reveal differences in people’s understanding of conditionals about different types of causes in both the indicative and subjunctive mood, that is, causal factual and counterfactual conditionals.

We examined causal counterfactual conditionals because a link between causal and counterfactual thinking has long been recognised in both philosophy and psychology (e.g., Hume, 1739/1978; Wells et al., 1987). In fact many philosophers have supposed that to think counterfactually is to think causally (Hume, 1739/1978; Mill, 1843/1973). A causal relation such as ‘water was heated to 100°C and it boiled’, and a counterfactual, ‘if the water had not been heated to 100°C it would not have boiled’, differ in their syntax, but their meaning seems the same. Thompson and Byrne (2002) investigated what people understand counterfactual conditionals to imply. Participants were asked what the speaker of a counterfactual, such as ‘if the butter had been heated then it would have melted’, meant to imply. Participants were given a choice of the following: ‘the butter was heated’, 
‘the butter was not heated’, it melted’ and ‘it did not melt’. Thompson and Byrne report that participants tended to identify ‘the butter was not heated’ or ‘the butter did not melt’, that is, the presupposed facts, for a counterfactual, particularly when it was describing a causal as opposed to a definitional relation. This research highlights the relationship between causal and counterfactual thoughts. Thompson and Byrne suggest that causal thinking and counterfactual thinking may serve a similar function, that is, to predict and prevent future outcomes.

We examined whether there are differences in the paraphrases of different sorts of causal relations, that is, strong causes, weak causes and enabling conditions. Different types of causes are consistent with different possibilities and we expected participants to use different connectives to distinguish between the different sorts of causal relations.

We also examined paraphrases of factual conditionals (‘if Joe cut his finger then it bled’) and counterfactual conditionals (‘if Joe had cut his finger it would have bled’). Research has shown that factual and counterfactual conditionals are understood by keeping in mind different possibilities. We therefore expect people’s paraphrases to reflect the different possibilities they are keeping in mind. In this chapter we examine the interrelationship between causal and counterfactual thoughts by examining how they are mentally represented by way of people’s paraphrases.

In the remainder of this section we briefly summarise the evidence on the difference between factual and counterfactual conditionals presented in Chapter 1. We then outline how we propose to examine these differences in relation to causal conditionals by means of a paraphrasing paradigm. The next section describes two experiments in which we examined paraphrases of factual and counterfactual causal conditionals.

**Counterfactuals**

As we saw in Chapter 1, people understand counterfactual conditionals such as ‘if Joe had cut his finger it would have bled’ differently from factual conditionals, such as ‘if Joe cut his finger it bled’. The mental model theory suggests that people understand factual conditionals such as ‘if Joe cut his finger it bled’ by thinking about true possibilities such as ‘Joe cut his finger and it bled’ but not false possibilities such as ‘Joe cut his finger and it did not bleed’ (Johnson-Laird & Byrne, 2002). The conditional is consistent with several true possibilities, but people tend to think about few possibilities and they may envisage just a single true possibility initially, ‘Joe cut his finger and it bled’ (Johnson-Laird & Byrne, 1991).
Counterfactual conditionals are different. People seem to understand a counterfactual such as ‘if Joe had cut his finger it would have bled’ by keeping in mind several possibilities (Johnson-Laird & Byrne, 1991). They think about the conjecture ‘Joe cut his finger and it bled’ and they also think about the presupposed facts, ‘Joe did not cut his finger and it did not bleed’. As a result they can make inferences that require access to the negative possibility, ‘Joe did not cut his finger and it did not bleed’ more readily from the counterfactual than from the factual (Byrne & Tasso, 1999).

Moreover, people judge that someone who uttered the counterfactual meant to imply that ‘Joe did not cut his finger’ and ‘his finger did not bleed’ (Thompson & Byrne, 2002). They rarely judge that someone who uttered the factual conditional meant to imply these propositions. Perhaps most revealingly, people are ‘primed’ to read the negative conjunction ‘Joe did not cut his finger and it did not bleed’ reliably faster when it is preceded by a counterfactual conditional (‘if Joe had cut his finger then it would have bled’) rather than a factual conditional (‘if Joe cut his finger then it bled’) (Santamaria et al., 2005).

In this chapter, we report the results of two experiments that examine the way in which people paraphrase factual and counterfactual conditionals when they are asked to rephrase them without using ‘if’. How would you rephrase ‘if Joe had cut his finger it would have bled’? How would you paraphrase ‘if Joe cut his finger it bled’? We hypothesise that people will use different sorts of connectives to paraphrase factual and counterfactual conditionals.

**Paraphrases and the mental representation of causal and counterfactual conditionals**

Paraphrases can act as an indicator of the mental representations people form of conditionals (Byrne & Johnson-Laird, 1992; Fillenbaum, 1974b). In everyday life people convey conditional relations by using a variety of connectives (Byrne, 2006; Byrne & Johnson-Laird, 1992). These connectives may convey different nuances of meaning resulting in subtly different interpretations of a conditional relation (Byrne, 2006).

When asked to paraphrase a factual conditional such as ‘if Joe cut his finger then it bled’ we expected people to rephrase the conditional by using a connective that reflected the single possibility they envisaged, for example by using a conjunction such as ‘and’: ‘Joe cut his finger and it bled’, or a temporal connective such as ‘when’: ‘when Joe cut his finger, it bled’. A conjunction is consistent with just one possibility (e.g., Barrouillet & Lecas, 2000). Likewise, a temporal connective such as ‘when’ is somewhat similar to ‘and’ but with additional information about the temporal sequence of events. People can
understand the temporal connective by keeping in mind just a single possibility (Byrne, 2006). Snitzer Reilly (1986) argues that a temporal such as ‘when’ implies certainty, unlike the word ‘if’ which implies the supposition, and hence uncertainty, of the event associated with it.

People understand a counterfactual conditional by keeping in mind more possibilities (Johnson-Laird & Byrne, 1991). Their initial representation of ‘if Joe had cut his finger it would have bled’ corresponds to the conjecture ‘Joe cut his finger and it bled’ and also the presupposed facts ‘Joe did not cut his finger and it did not bleed’. Accordingly, we expected that people would rephrase the counterfactual conditional differently from their paraphrases of the factual conditional. We expected that they would rephrase the counterfactual by using connectives that reflected the multiple possibilities they envisaged. We predicted that they would not use ‘and’ or ‘when’ as often as they do for factual conditionals. Instead, we predicted that they would use connectives that can capture the conditionality of the assertion, such as ‘provided’ or ‘suppose’, or its causality such as ‘because’. Assertions containing such connectives indicate that people are envisaging more than a single possibility. Goldvarg and Johnson-Laird (2001) report that participants listed a minimum of two possibilities as possible for an assertion of the form ‘A will cause B’.

In the two experiments reported in this chapter we compared factual and counterfactual causal conditionals, which contained different sorts of causes. As described in Chapter 1, different types of causes are consistent with different possibilities. Factual and counterfactual conditionals are also understood by keeping different possibilities in mind. Counterfactuals are understood by keeping in mind two possibilities whereas factual conditionals are understood by keeping only one possibility in mind. Our aim was to examine which aspect of the conditional people focus on in their paraphrases, its content or its mood.

People may keep in mind fewer possibilities to understand a strong cause, than they do to understand a weak causal relation or an enabling relation (Goldvarg & Johnson-Laird, 2001; Johnson-Laird, 1999; Johnson-Laird & Byrne, 2002). A strong causal relation such as ‘Joe’s cutting his finger caused it to bleed’ is consistent with the possibility ‘his finger was cut and it bled’ and a second possibility ‘his finger was not cut and it did not bleed’. The causal relation expressed is that the cause is necessary and sufficient for the outcome. People may tend to think initially about just one possibility, ‘his finger was cut and it bled’ (cf. Thompson & Byrne, 2002). As a result, we expected strong causes to be paraphrased using connectives that reflect a single possibility, such as ‘when’.

69
Weak causal relations allow a third possibility, in which the cause did not occur but the effect did, perhaps because some other cause occurred. A weak causal relation such as ‘the ripeness of the apples caused them to fall from the tree’ is consistent with the possibility ‘the apples were ripe and they fell from the tree’, and the possibility ‘the apples were not ripe and they did not fall from the tree’. It is also consistent with a third possibility ‘the apples were not ripe but they fell from the tree’, because the apples may fall from the tree for some other reason, for example, because of a windy storm. We therefore expected a weak cause to be paraphrased using connectives that reflect people are keeping multiple possibilities in mind, such as ‘should’.

A third sort of causal relation is an enabling relation. An enabler such as ‘turning the ignition key allows the car to start’ is consistent with the possibility ‘the ignition key was turned and the car started’ and the possibility ‘the ignition key was not turned and the car did not start’. It is also consistent with a third possibility, ‘the ignition key was turned but the car did not start’ because the car starting depends on other factors too, for example, the battery must not be flat. We therefore expected enabling conditions to be paraphrased using connectives that reflect people are keeping more than one possibility in mind, such as ‘provided’.

Experiment 3: Paraphrasing Counterfactuals

The aim of the experiment was to test whether people form different mental representations of factual conditionals, e.g., ‘if Joe cut his finger it bled’ compared to counterfactual assertions ‘if Joe had cut his finger it would have bled’. We included different sorts of causal assertions, including strong causal relations such as ‘if Joe cut his finger it bled’, weak causal relations, such as ‘if the apples were ripe they fell off the tree’, and enabling relations, ‘if the ignition key was turned the car started’. We expected that participants would construct different paraphrases of factual and counterfactual conditionals. We predicted that their paraphrases of factual conditionals would rely on connectives that refer to a single possibility, such as ‘and’ and ‘when’, whereas their paraphrases of counterfactual conditionals would rely on connectives that can encompass multiple possibilities, such as ‘provided’ and ‘because’. We predicted also that strong causes would be paraphrased using connectives that refer to a single possibility and weak causes and enabling conditions would be paraphrased using connectives which reflect that participants are keeping multiple possibilities in mind.
Method

Materials
We constructed twenty-four conditional statements, half were factual conditionals in the indicative mood in the past tense and half were counterfactual conditionals in the subjunctive mood in the past tense. Within these two blocks of twelve conditionals we had four strong causes, four weak causes and four enabling conditions. The materials were adapted from Cummins (1995). We identified conditionals from Cummins (1995) with few alternative causes and few disabling conditions as strong causes (e.g., if Joseph cut his finger then it bled), those with many alternative causes and few disabling conditions as weak causes (e.g., if Alvin read without his glasses then he got a headache) and those with few alternative causes and many disabling conditions as enabling conditions (e.g., if the trigger was pulled then the bullet was released). The full list of materials is in Appendix B2 (p.189).

Design
Participants were asked to paraphrase 24 conditionals without using the word “if”. We used a 2 (factual versus counterfactual) x 3 (strong causes, weak causes and enabling conditions) within participants design. Each conditional was presented on a new page in an A5 booklet. The conditionals were presented in counterbalanced blocks (factual versus counterfactual) and the types of causes were randomised within these blocks. The contents of the materials in the factual and counterfactual blocks were identical apart from the mood they were in, i.e., indicative mood for factual and subjunctive mood for counterfactual. We also included three conjunctions and disjunctions (either one conjunction and two disjunctions or two conjunctions and one disjunction) at fixed regular intervals as fillers.

Procedure
Participants were tested individually. They were given the A5 booklet with an instructions sheet attached to the front. We adapted the instructions from Fillenbaum (1976). The following is an extract of the instructions they received:

Your task will consist of rephrasing each sentence as accurately as you can. You should try to keep its meaning as much as possible, but without using the word ‘IF’. Imagine that you are rewording each sentence for someone else so that they can make sense of it as fully and exactly as possible. Your task is not to improve the
sentences or make them more sensible, but to paraphrase them, rewording each in a way that captures its meaning as accurately as possible.

(see Appendix B1 for the full set of instructions, p.189). There was no time limit and completion of the task took between 20 and 30 minutes.

Participants

Participants were recruited through newspaper adverts to become members of the Psychology School’s participant panel. Thirty people participated in the study, 23 women and 7 men, whose mean age was 53 years (range 21 - 72 years). Participants received 8 euro for taking part in the experiment. One participant was eliminated from the analysis because of failure to complete the task.

Results and discussion

Coding

There were 696 responses (29 participants x 24 paraphrases). 24 responses (3%) were eliminated because they used ‘if’ in the paraphrase contrary to the instructions, or they were assertions of ‘yes’, or they provided an explanation for the conditional rather than a paraphrase. The remaining 672 paraphrases were categorised according to the type of connective that was used in place of ‘if’, to convey the relationship between the antecedent and the consequent. The categories identified were conjunctive (e.g., ‘and’), conditional (e.g., ‘provided’, ‘to’), disjunctive (‘or’, ‘or else’), temporal (e.g., ‘when’, ‘following’, ‘once’, ‘after’), and causal (e.g., ‘because’, ‘in order’, ‘so’, ‘as’). Connectives were assigned to the categories based on their dictionary definitions. Table 3.1 provides a list of the categories and the connectives associated with each category. A major category of response is one we labelled ‘subjunctive’ (e.g., ‘had p happened q would have happened’). There were also some single-clause subjunctive responses (e.g., ‘cutting his finger would have led to it bleeding’) and single clause indicative responses (e.g., ‘Joseph’s cut finger bled’).

16% of responses (108) could not be assigned to a category readily (e.g., ‘reading without his glasses gave Alvin a headache’) and these were given to five judges who were asked to determine whether the sentences were ‘causal’, ‘conditional’, ‘temporal’ or ‘other’. The judges were given typical examples of ‘causal’, ‘conditional’ and ‘temporal’ sentences, which contained ‘because’, ‘provided’ and ‘when’ respectively. We assigned each of these responses to a category when over 50% of judgements corresponded to that
category. For example, the majority of judgements for sentences using the connective ‘by’ were ‘causal’. (This threshold was lowered to 40% in one case, for items such as ‘the sound of the gong means it has been struck’, for which 40% of judgements were ‘causal’ and 35% were ‘conditional’). Once all of the paraphrases had been categorised we gave 20% of the final overall set of paraphrases to an independent rater and there was 80% agreement on the assignments (with the exception of the subjunctive category which the independent rater had categorised as causal).

Table 3.1: Categories and connectives in Experiment 3

<table>
<thead>
<tr>
<th>Category</th>
<th>Connectives</th>
</tr>
</thead>
<tbody>
<tr>
<td>conjunctive</td>
<td>and, and therefore</td>
</tr>
<tr>
<td>indicative</td>
<td>e.g., ‘Joseph’s cut finger bled’</td>
</tr>
<tr>
<td>temporal</td>
<td>when, and then, then, after, as soon as, whenever, following, once, upon, always q each time p, on</td>
</tr>
<tr>
<td>disjunctive</td>
<td>or, or else, unless</td>
</tr>
<tr>
<td>conditional</td>
<td>provided, to, means, in the event of</td>
</tr>
<tr>
<td>causal</td>
<td>By, causes, because, in order, as, so, for, p-ing...q, indicates, shows, as a result of, as a consequence, usually produces</td>
</tr>
<tr>
<td>subjunctive</td>
<td>should (as in ‘should Joseph cut his finger, it would bleed’) should p then q, Had p would have q, had p then would have q, would have q had p (as in ‘the flame would have appeared had the match been struck’), were p would q (as in ‘were Alvin to read without his glasses, he would get a headache’)</td>
</tr>
<tr>
<td>single clause subjunctive</td>
<td>would be q from p-ing</td>
</tr>
<tr>
<td>other</td>
<td>had learned that p made q</td>
</tr>
</tbody>
</table>

Note: Some connectives may be considered to belong to more than one category, e.g., ‘unless’ can be considered to be conditional and disjunctive, ‘as a result of’ can be considered to be both temporal and causal; in these cases we have assigned the connective to the category on the basis of its primary use in the paraphrases.
**Analysis**

Most factual conditionals were paraphrased using temporal and causal connectives and most counterfactual conditionals were paraphrased using subjunctive and causal connectives, as Table 3.2 shows, and we report statistical comparisons for categories that contained more than 5% of responses.

**Table 3.2:** Percentages of each type of connective as a function of type of conditional, factual or counterfactual

<table>
<thead>
<tr>
<th>Connective</th>
<th>Factual</th>
<th>Counterfactual</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Single possibility</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Conjunctive</td>
<td>9</td>
<td>5</td>
</tr>
<tr>
<td>Indicative</td>
<td>3</td>
<td>1</td>
</tr>
<tr>
<td>Temporal</td>
<td>49</td>
<td>22</td>
</tr>
<tr>
<td>Total</td>
<td>61</td>
<td>28</td>
</tr>
<tr>
<td><strong>Multiple possibilities</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Disjunctive</td>
<td>0.3</td>
<td>1</td>
</tr>
<tr>
<td>Causal</td>
<td>28</td>
<td>28</td>
</tr>
<tr>
<td>Conditional</td>
<td>6</td>
<td>6</td>
</tr>
<tr>
<td>Subjunctive</td>
<td>4</td>
<td>36</td>
</tr>
<tr>
<td>Single clause</td>
<td>0.3</td>
<td>1</td>
</tr>
<tr>
<td>subjunctive</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Total</td>
<td>38.6</td>
<td>72</td>
</tr>
</tbody>
</table>

Participants used temporal connectives to paraphrase factual conditionals more often than to paraphrase counterfactuals (49% versus 22%), and this difference was reliable (Wilcoxon’s signed ranks $z = 3.58$, $N - Ties = 25$, $p < .001$, and the comparison had 80% power to detect a difference of .06), as Table 3.2 shows. The difference was reliable for strong causes (Wilcoxon’s $z = 3.07$, $N - Ties = 19$, $p = .002$), weak causes (Wilcoxon’s $z = 3.52$, $N - Ties = 21$, $p < .001$), and enablers (Wilcoxon’s $z = 2.49$, $N - Ties = 20$, $p = .013$), as Table 3.3 shows. Participants used the same amount of conjunctions for...
factual conditionals compared to counterfactuals (9% versus 5%, Wilcoxon’s $z = 1.39$, $N - Ties = 11$, $p = .16$, and the comparison had 80% power to detect a difference of .04). There were also no differences for the three sorts of causes. Overall, participants used these temporal and conjunctive connectives that capture a single possibility to paraphrase factual conditionals more than counterfactuals (61% versus 28%, Wilcoxon’s $z = 3.82$, $N - Ties = 26$, $p < .001$), as Table 3.2 shows. This difference was reliable for strong causes (56% versus 23%, Wilcoxon’s $z = 3.34$, $N - Ties = 21$, $p < .001$), weak causes (67% versus 25%, Wilcoxon’s $z = 4.03$, $N - Ties = 23$, $p < .001$) and enablers (60% versus 35%, Wilcoxon’s $z = 2.97$, $N - Ties = 23$, $p = .003$).

Table 3.3: Percentages of each type of connective as a function of type of cause, strong, weak, enabler

<table>
<thead>
<tr>
<th>Connective</th>
<th>Factual</th>
<th>Counterfactual</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Strong</td>
<td>Weak</td>
</tr>
<tr>
<td>Single possibilities</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Conjunctive</td>
<td>9</td>
<td>5</td>
</tr>
<tr>
<td>Indicative</td>
<td>3</td>
<td>7</td>
</tr>
<tr>
<td>Temporal</td>
<td>45</td>
<td>55</td>
</tr>
<tr>
<td>Multiple possibilities</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Disjunctive</td>
<td>0</td>
<td>1</td>
</tr>
<tr>
<td>Causal</td>
<td>30</td>
<td>23</td>
</tr>
<tr>
<td>Conditional</td>
<td>6</td>
<td>6</td>
</tr>
<tr>
<td>Subjunctive</td>
<td>7</td>
<td>2</td>
</tr>
<tr>
<td>Single clause</td>
<td>0</td>
<td>1</td>
</tr>
<tr>
<td>subjunctive</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Participants tended to paraphrase counterfactuals by using the ‘subjunctive’ construction. They used more subjunctive paraphrases for counterfactuals than factual conditionals (36% versus 4% Wilcoxon’s $z = 3.72$, $N - Ties = 20$, $p < .001$ and the comparison had 80% power to detect a difference of .05). The difference was reliable for
the three types of causes: strong causes ($z = 3.36, N - Ties = 18, p < .001$), weak causes ($z = 3.61, N - Ties = 18, p < .001$) and enablers ($z = 3.24, N - Ties = 17, p = .001$).

They used causal connectives to paraphrase factual and counterfactual conditionals equally often, 28% in each case (Wilcoxon’s $z = .25, N - Ties = 25, p > .05$ and the comparison had 80% power to detect a difference of .05). There was no difference for any of the three different types of causes. They also used conditional connectives equally often to paraphrase factual and counterfactual conditionals, 6% in each case ($z = .8, N - Ties = 12, p > .05$ and the comparison had 80% power to detect a difference of .06). There was no difference for the three different types of causes.

Overall, participants used connectives that capture multiple possibilities (subjunctive constructions, causal and conditional connectives) for counterfactual conditionals more than for factual ones (71% versus 39%, Wilcoxon’s $z = 3.66, N - Ties = 26, p < .001$), as Table 3.2 shows. The difference was reliable for strong causes (77% versus 44%, Wilcoxon’s $z = 3.23, N - Ties = 21, p < .001$), weak causes (74% versus 33%, Wilcoxon’s $z = 3.99, N - Ties = 24, p < .001$) and enablers (64% versus 40%, Wilcoxon’s $z = 2.5, N - Ties = 22, p = .013$).

**Presupposed facts**

Participants who are asked to rate what is implied by conditionals in the indicative and the subjunctive mood typically say that a conditional in the indicative mood either implies nothing or implies the affirmation of its components (i.e., ‘p and q’), whereas for a conditional in the subjunctive mood participants say 50% of the time that it implies the negation of at least one of its components (i.e., ‘not-p’ and ‘not-q’) (Thompson & Byrne, 2002). In this experiment we found that participants typically paraphrased all conditionals by affirming the components in the statements (e.g., ‘Joseph’s finger bled because he cut it’ or ‘For Joseph’s finger to bleed, he would have to cut it’). However, for 34 (10%) of the paraphrasings of counterfactual conditionals participants referred to the presupposed facts in their paraphrasings (e.g., ‘Joseph’s finger didn’t bleed because he hadn’t cut it’). The majority of these sorts of rephrasings were made by three participants (28 of the 34 paraphrasings of this sort were made by the three participants). The mention of the presupposed facts, that is, ‘not-p and not-q’ only occurred for counterfactual conditionals, consistent with Thompson and Byrne’s (2002) findings. This occurred for 8% of the strong cause counterfactuals, 14% of the weak cause counterfactuals and 9% of the enabling condition counterfactuals. Participants predominantly referred to the presupposed facts in conjunction with a causal connective, such as ‘because’ (26 out of 34 paraphrasings used
causal connectives). The results support the suggestion that counterfactuals convey their presupposed facts, at least for some individuals.

**Summary**

The experiment shows that people tend to paraphrase factual conditionals by using connectives that capture a single possibility: temporal connectives such as ‘when’. They used causal paraphrases such as ‘because’ equally often for factual and counterfactual conditionals. But, they tended to paraphrase counterfactual conditionals by using phrasings that capture multiple possibilities, such as subjunctive phrases. Subjunctive constructions such as ‘had Joseph cut his finger, it would have bled’ are little different from counterfactual conditionals, ‘if Joseph had cut his finger it would have bled’. The subjunctive construction does away with the ‘if’ connective but maintains the counterfactual reference to a presupposed possibility corresponding to the facts, ‘Joseph did not cut his finger and it did not bleed’, and to a counterfactual conjecture, ‘he cut his finger and it bled’.

The results corroborate the suggestion that people understand factual and counterfactual conditionals in different ways. Their initial representation of factual conditionals corresponds to a single possibility, whereas their initial representation of a counterfactual conditional corresponds to multiple possibilities. The experiment also shows that some participants focus on the presupposed facts (that is ‘not-p and not-q’) when considering a counterfactual conditional, but they do not think of this possibility when considering a conditional in the indicative mood. These results are consistent with previous experiments that have compared factual and counterfactual conditionals on measures of inferences, implications, and priming, and it adds paraphrases as a further converging measure on this phenomenon.

An alternative explanation for the differences found between factual and counterfactual conditionals is that participants responded to task demands by employing a superficial strategy. Subjunctive constructions are linguistically similar to the counterfactual and can be achieved by simply omitting the ‘if’. They are easier to construct than to generate an alternative connective. One explanation is that participants use this construction because they recognise that a subjunctive construction reflects two possibilities. Another explanation is that they use this construction simply as an easy way to fulfil the requirements of the task.

The experiment shows that the type of cause, strong causes, weak causes, or enablers does not affect the paraphrases used by participants. There were few differences
between strong, weak and enabling causal relations, as Table 3.3 illustrates. We anticipated that participants may keep in mind a single possibility to understand strong causal relations and so would paraphrase them by using connectives such as ‘and’ or ‘when’; we anticipated that they would keep in mind multiple possibilities to understand weak and enabling causal relations and so would paraphrase them by using connectives such as ‘because’ or ‘provided’. The results show that the mood of the conditional exerts the dominant influence and over-rides the type of cause: strong causes are paraphrased using single possibility connectives when they are in the indicative mood in a factual conditional but using multiple possibility connectives when they are in the subjunctive mood in a counterfactual conditional; likewise weak and enabling causes are paraphrased using single possibility connectives when they are indicative but using multiple possibility connectives when they are subjunctive.

The results for the different sorts of causes may arise because participants have not interpreted the three causes appropriately. In this experiment the different types of causes were conveyed implicitly, that is, participants were presented with only a conditional and no context. The materials were taken from Cummins (1995) who demonstrated that participants were able to distinguish the different causes when they were presented in this manner. In Cummins’ experiment participants made inferences from the different conditionals, a procedure which may encourage the search for counterexamples, and therefore participants may have been more sensitive to the different sorts of causal relations. The paraphrasing methodology used in this experiment may have a less facilitatory effect on generating counterexamples which help people to distinguish the different sorts of causes. The next experiment examines the relative influence of mood and type of cause further by providing a context for the different sorts of causal relations.

Experiment 4: Paraphrasing Different Causes

The aim of the experiment was to examine further the relative influence of mood and type of cause on the sorts of paraphrases that people construct. The previous experiment showed that the mood of the conditional, indicative or subjunctive had a major influence on the paraphrases that individuals constructed, but that the sort of cause, strong, weak, or enabling, did not. The aim of the second experiment was to replicate the first experiment, but also to emphasise the different types of causes. We constructed materials that attempt to make it clear to participants the different sorts of causal relations that are described. We provided a context for the conditionals, that is, we embedded the assertions in scenarios. In these scenarios we emphasized a weak cause by providing an alternative cause and we
emphasized an enabling condition by providing an additional requirement (Byrne, 1989; Byrne et al., 1999). The conditionals were embedded in seven-line scenarios, adapted from Santamaria et al. (2005), e.g.:

‘Peter was talking to Mary about his friend Joseph.
Peter told Mary that
If Joseph cut his finger, then it bled.
Peter also told Mary that Joseph stood by the kitchen sink when he bled.
When Mary went into the kitchen she saw that
Joseph was bleeding.
Mary went to welcome the new guests.’

The first line introduced two characters. The second line was about one character telling the other something. The third line contained the causal conditional, either factual or counterfactual. The fourth line was the crucial contextual information. It contained information about another antecedent. In the case of weak causes such as ‘if water was poured on the campfire, then the fire went out’ the antecedent was an alternative (‘Lisa also told Brian that the fire went out when sand was poured on it’), in the case of enablers, such as ‘if the ignition key was turned, then the car started’, the antecedent was an additional condition (‘Jason also told Nancy that the car started when the battery was charged’). In the case of strong causes, no other antecedent was mentioned and instead some filler information was included about the location of individuals when the consequent occurred (as in the example above). The fifth line was about the second character encountering the situation mentioned in the conditional. The sixth line affirmed the consequent. The last line contained some information about what the character did next.

Our aim was to examine the paraphrases that individuals construct of factual and counterfactual conditionals, and to test whether strong causes, weak causes, and enabling relations influence the paraphrases.

Method

Participants

The participants were psychology undergraduates, who received course credit for their participation. Forty-one individuals participated, 28 women and 13 men and their average age was 22 years, with a range from 17-51 years.
Materials

We used the same conditionals as in the first experiment, but they were embedded in scenarios. Each participant was given twelve scenarios, six containing a factual conditional and six containing a counterfactual conditional. Within these two blocks of six scenarios they received two strong causes, two weak causes and two enabling conditions (see Appendix B6 for a full list of the materials, p.192). We carried out a pre-test and a post-test of the materials to ensure that participants comprehended the additional or alternative condition in the enabling and weak causes scenarios.

Pre-test 4.1

In the pre-test we gave 10 participants who were not tested in the main experiment each scenario followed by a statement that the consequent happened (e.g., the bell rang) and asked participants to list the cause(s) of it. The ten participants were postgraduate students in the Psychology School. We categorised their responses into those that mentioned the antecedent only as the cause, and those that mentioned the antecedent and the extra antecedent. For strong causes all participants (100%) identified only the antecedent as the cause compared to 62% for weak causes ($z = 2.23, N - Ties = 6, p = .026$) and 40% for the enabling conditions ($z = 2.45, N - Ties = 6, p = .014$). There was no difference between weak causes and enabling conditions ($z = 1.38, N - Ties = 6, p = .167$).

In a second pre-test we tested a further 4 participants from the same pool, who had not taken part in the pre-test 4.1, and asked them what led to the consequent rather than what caused it. For strong causes 69% of the participants identified only the antecedent as the cause compared to 50% for weak causes ($z = 1, N - Ties = 1, p = .317$) and 19% for the enabling conditions ($z = 1.6, N - Ties = 3, p = .109$). The pre-tests confirmed the materials as distinguishing sufficiently between strong, weak, and enabling conditions.

Post-test

In the post-test the participants who took part in the main experiment were given a second booklet. The booklet contained a memory question for each of the scenarios used in the paraphrasing task. All the questions asked what led to the consequent of the conditional, e.g., ‘what led to the campfire going out?’. The questions were followed by four possible answers (presented in different random orders), the antecedent of the conditional (e.g., ‘water was poured on the campfire’), the additional or alternative requirement given (e.g., ‘sand was poured on the campfire’), and two other possibilities (e.g., ‘there was not enough wood’, ‘there was a strong wind’), and the full set of materials used for the post-test can be
found in Appendix B3 (p. 190). Participants were instructed to tick all the answers that applied. 89% of responses identified the antecedent as the sole cause for the consequent for strong causes, compared to 60% for weak causes ($z = 4.07, N - Ties = 21, p < .001$), and 63% for enabling conditions ($z = 3.83, N - Ties = 23, p < .001$). The post-test also confirms that the strong, weak, and enabling conditions were distinguishable in the materials.

**Design and procedure**

The design and procedure for the experiment was the same as for Experiment 3. Participants were asked to paraphrase twelve conditionals without using the word ‘if’. Each conditional was presented embedded in a scenario, followed by a request to paraphrase the conditional without using the word ‘if’, on a separate page in a booklet. The instructions were identical to the ones in the previous experiment.

**Results and discussion**

The same categories were used as in the previous experiment. An independent rater categorized 20% of the paraphrases and there was 75% agreement. The results corroborate those of the first experiment. Participants used temporal connectives to paraphrase factual conditionals more often compared to counterfactual ones (53% and 32%, Wilcoxon’s $z = 3.97, N - Ties = 34, p < .001$), and the comparison had 80% power to detect a difference of .06), as Table 3.4 shows. The difference occurred for strong causes (Wilcoxon’s $z = 2.17, N - Ties = 23, p = .03$), weak causes (Wilcoxon’s $z = 2.87, N - Ties = 23, p = .004$), and enablers (Wilcoxon’s $z = 3.25, N - Ties = 25, p < .001$), as Table 3.5 shows. There were few uses of conjunctions to paraphrase either factual or counterfactual conditionals. Overall, participants constructed more single possibility paraphrases (that is, in this case ‘when’ connectives) for factual than counterfactual conditionals and these results replicate those of the previous experiment.

Once again participants tended to use subjunctive constructions to paraphrase counterfactual conditionals, and they used them more often than they did for factual conditionals (39% versus 13%, Wilcoxon’s $z = 3.9, N - Ties = 24, p < .001$ and the comparison had 80% power to detect a difference of .06). The difference occurs for strong causes (Wilcoxon’s $z = 3, N - Ties = 21, p = .003$), weak causes (Wilcoxon’s $z = 3.42, N - Ties = 22, p < .001$), and enablers (Wilcoxon’s $z = 3.21, N - Ties = 15, p < .001$). These results also replicate those of the previous experiment.
Table 3.4: Percentages of each type of connective as a function of type of conditional, factual or counterfactual

<table>
<thead>
<tr>
<th>Connective</th>
<th>Factual</th>
<th>Counterfactual</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Single possibilities</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Conjunctive</td>
<td>0.4</td>
<td>0.4</td>
</tr>
<tr>
<td>Indicative</td>
<td>1</td>
<td>0</td>
</tr>
<tr>
<td>Temporal</td>
<td>53</td>
<td>32</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td>54.4</td>
<td>32.4</td>
</tr>
<tr>
<td><strong>Multiple possibilities</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Disjunctive</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>Causal</td>
<td>18</td>
<td>15</td>
</tr>
<tr>
<td>Conditional</td>
<td>10</td>
<td>9</td>
</tr>
<tr>
<td>Subjunctive</td>
<td>13</td>
<td>39</td>
</tr>
<tr>
<td>Single clause</td>
<td>4</td>
<td>4</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td>45</td>
<td>67</td>
</tr>
</tbody>
</table>

Once again, participants relied on causal connectives equally often for factual and counterfactual conditionals (18% versus 15%, Wilcoxon’s $z = .92$, $N - Ties = 21$, $p > .05$ and the comparison had 80% power to detect a difference of .03). The finding occurs for the three different types of causes. They also used conditional-type connectives such as ‘provided’ equally often for factual and counterfactual conditionals (10% and 9%, Wilcoxon’s $z = .52$, $N - Ties = 13$, $p > .05$ and the comparison had 80% power to detect a difference of .03). The result occurs for weak causes and strong causes but the pattern is different for enabling relations: they used marginally more of these connectives for counterfactual enablers compared to factual ones (13% versus 6%, Wilcoxon’s $z = 1.89$, $N - Ties = 7$, $p = .059$). Nonetheless, overall, participants constructed more multiple possibility paraphrases for counterfactual than factual conditionals (67% versus 45%, Wilcoxon’s $z = 3.62$, $N - Ties = 32$, $p < .001$). The results for counterfactual conditionals indicate that the subjunctive construction is used more readily than causal connectives, such as, ‘because’, or conditional-type constructions such as ‘provided’.
Table 3.5: Percentages of each type of connective as a function of type of cause, strong, weak, enabler

<table>
<thead>
<tr>
<th>Connective</th>
<th>Factual</th>
<th></th>
<th>Counterfactual</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Strong</td>
<td>Weak</td>
<td>Enabler</td>
<td>Strong</td>
</tr>
<tr>
<td>Single possibilities</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Conjunctive</td>
<td>0</td>
<td>1</td>
<td>0</td>
<td>1</td>
</tr>
<tr>
<td>Indicative</td>
<td>0</td>
<td>4</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>Temporal</td>
<td>49</td>
<td>49</td>
<td>61</td>
<td>35</td>
</tr>
<tr>
<td>Multiple possibilities</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Causal</td>
<td>19</td>
<td>16</td>
<td>18</td>
<td>17</td>
</tr>
<tr>
<td>Conditional</td>
<td>15</td>
<td>10</td>
<td>6</td>
<td>8</td>
</tr>
<tr>
<td>Subjunctive</td>
<td>14</td>
<td>18</td>
<td>9</td>
<td>37</td>
</tr>
<tr>
<td>Single clause subjunctive</td>
<td>4</td>
<td>1</td>
<td>6</td>
<td>3</td>
</tr>
</tbody>
</table>

As in the previous experiment, participants’ paraphrases did not distinguish between the different sorts of causes. In this experiment the two conditions (factual and counterfactual) were presented together. It is possible that participants focused on distinguishing factual and counterfactual conditionals thereby neglecting the content of these conditionals. Ormerod, Manktelow and Jones (1993) suggest that people may only focus on the initial mental models when they rephrase sentences. The initial mental models for the three sorts of causes described in this experiment are likely to be the same (e.g., ‘Joe cut his finger and it bled’). Paraphrases may thus tap into a level of information processing during which people are less likely to consider alternatives. According to the mental model theory, people tend to keep only few possibilities in mind and only flesh out their mental representations when the circumstances require it (Johnson-Laird & Byrne, 1991). Perhaps the paraphrasing task does not encourage people to flesh out their mental models. The pre-and post-tests demonstrate that participants were aware of the different causal relations, but this awareness is not reflected in their paraphrases.
Presupposed facts

In the previous experiment we reported that for a minority (10%) of the rephrasings of conditionals in the subjunctive mood participants had focused on the presupposed facts by asserting ‘not-p and not-q’ in their paraphrasings. In this experiment no paraphrasing focused on the presupposed facts. Instead, all paraphrasings described the relation between ‘p and q’. The conditionals in this experiment did not differ from the ones used in the previous experiment. What differed is that participants were given a context for the conditional in this experiment. Perhaps most importantly, the scenarios asserted that the consequent of the conditional had occurred (e.g., ‘Joseph’s finger bled’).

Summary

The experiment replicates the finding of the first experiment that factual conditionals are paraphrased by using temporal connectives that refer to a single possibility, whereas counterfactual conditionals are paraphrased by using subjunctive constructions that refer to multiple possibilities. The results also show that participants paraphrased conditionals that contain strong, weak, and enabling relations by using connectives guided by the mood of the conditional, whether indicative or subjunctive, rather than by the type of cause. In this experiment factual and counterfactual conditionals were presented together, rather than in separate blocks as in the previous experiment. It is possible that the mood of the conditional was more salient than the different sort of causal relation conveyed by it. As a result, participants may have focused on distinguishing between factual and counterfactual conditionals. An alternative explanation is that participants only considered the initial set of models and as a result did not distinguish between the different causes in their paraphrases.

General Discussion

The aim of this chapter was to examine people’s mental representations of factual and counterfactual conditionals as well as to examine people’s mental representations of different sorts of causes. We predicted that factual conditionals would be paraphrased using connectives that reflect a single possibility whereas counterfactual conditionals would be paraphrased using connectives that reflect multiple possibilities. We also expected to find differences in how the different sorts of causes are paraphrased. We expected strong causes to be paraphrased using connectives that reflect a single possibility and weak causes and enabling conditions to be paraphrased using connectives that reflect multiple possibilities.
The two experiments show that people paraphrase factual and counterfactual conditionals by using different sorts of connectives. Factual conditionals are paraphrased using connectives that capture a single possibility such as temporal, and to a lesser extent, conjunctive connectives; counterfactual conditionals are paraphrased using phrases that capture multiple possibilities such as subjunctive constructions. Individuals paraphrase factual conditionals by selecting another connective to replace ‘if’ that captures their meaning. Often the connective they select is a temporal one such as ‘when’. The temporal connective imbues the assertion with more certainty than the suppositional hypotheticality of ‘if’, and may reflect the tendency for individuals to keep in mind a single true possibility when they understand a factual conditional.

Individuals paraphrase counterfactual conditionals differently. They tend not to select another connective to replace ‘if’. Instead, they do away with any connective and rely instead on the subjunctive construction. Ormerod et al. (1993) suggest that people may sometimes not construct mental models but instead perform a linguistic transformation by omitting or adding a word. They asked participants to rephrase conditionals of the form ‘antecedent only if consequent’ into conditionals of the form ‘consequent if antecedent’ and found that participants’ rephrasings were logically incorrect, as they tended to merely add or omit the word ‘only’ without considering its meaning. Participants may be inclined to paraphrase counterfactuals by using subjunctive constructions because they appreciate that they are consistent with multiple possibilities or because it is a superficial strategy.

Previous research on counterfactual conditionals, which demonstrates that people understand counterfactuals by keeping in mind two possibilities, supports the suggestion that participants used subjunctive constructions because they appreciate that this phrasing is consistent with multiple possibilities. Participants could have used temporal connectives as part of their subjunctive construction, e.g., ‘Joe’s finger would have bled when he cut it’, but they chose not to include such a connective which would have hinted at only one possibility.

The two experiments show that there were no differences in the paraphrases individuals generated for strong causes, weak causes, and enabling conditions. Participants paraphrased these causes using connectives that were suited to the mood of the conditionals, indicative or subjunctive, rather than to the type of cause. There are two possible explanations for this lack of difference. First, it is possible that paraphrases are too crude a measure to pick up on the differences between different sorts of causes. Second, participants may have only constructed the initial models for this task and therefore not made the differences between different causes explicit. The pre- and post-tests of the
materials used in Experiment 4 demonstrate that the different sorts of causes were distinguishable. The mood of the conditional, indicative or subjunctive, exerts the major influence on the nature of the paraphrases that people construct.

**Implications of findings for other theories of conditional reasoning**

The differences between factual and counterfactual conditionals are readily explained according to the mental models account by the possibilities that people keep in mind to understand them, a single possibility initially for factual conditionals, and multiple possibilities for counterfactual conditionals (Johnson-Laird & Byrne, 2002). The findings are more difficult to explain for theories that suggest that people understand conditionals by recovering their logical form (e.g., Rips, 1994). The factual and counterfactual conditionals have the same form and so formal rules cannot account for the effects of mood. Mental logic theories make no predictions about the number of possibilities a factual or counterfactual conditional is consistent with. They cannot therefore explain why factual conditionals are paraphrased using connectives that reflect a single possibility and counterfactual conditionals are paraphrased using connectives and constructions that reflect that a person is keeping in mind multiple possibilities.

Likewise the findings are difficult to explain for theories that suggest that people understand conditionals by recovering a causal schema or module (Fiddick et al., 2000). These theories make no predictions about use of different linguistic mood or tense (Egan, 2005). According to domain specific theories, the content domain of a statement determines how it is understood. Accordingly, a factual conditional ‘if Joseph cut his finger then it bled’ should be understood in the same way as a counterfactual conditional ‘if Joseph had cut his finger then it would have bled’. The factual and counterfactual conditionals have the same content and so domain sensitive rules cannot account for the effects of mood.

The findings are also difficult to explain for theories that suggest that people understand a counterfactual such as ‘if Joe had cut his finger it would have bled’ by keeping in mind a single possibility corresponding to the facts, e.g., ‘Joe did not cut his finger and it did not bleed’ (e.g., Evans & Over, 2004). Only 10% of the paraphrases of counterfactual conditionals in Experiment 3 and none of the paraphrases in Experiment 4 made reference to the presupposed facts and instead they relied on subjunctive constructions to convey multiple possibilities.
Conclusion

These first studies of paraphrases of counterfactuals highlight the differences between factual and counterfactual conditionals. They provide further converging evidence, along with inference studies, implications studies, and priming studies, that people think about several possibilities when they understand a counterfactual conditional, the presupposed facts, and the counterfactual conjecture. In line with our findings in Chapter 2, the two experiments provide an indication of an effect of context on how people understand counterfactual conditionals. In particular we refer to the finding that some participants focused on the presupposed facts in Experiment 3, but did not do so when the conditionals were embedded in a causal scenario in Experiment 4.

The experiments reported in this chapter failed to show any differences between the different sorts of causes. We suggested that paraphrases may not be a measure sensitive enough to illustrate these differences. Alternatively, the paraphrasing task may not encourage people to consider multiple possibilities and as a result their paraphrases reflect this lack of consideration. In the next chapter we engage a different method to examine the possibilities people think about when they understand different sorts of causes.
Chapter 4 Priming Causal Relations

The aim of this chapter is to examine the mental representations people form of different sorts of causal assertions, that is, strong causes, weak causes and enabling conditions. According to the mental model theory the possibilities people are able to envisage have a profound effect on the way they reason from conditionals, such as ‘if the UK introduces ID cards then they can prevent terrorist attacks’ (Johnson-Laird & Byrne, 1991). When people consider only two possibilities, that is ‘the UK introduces ID cards and they can prevent terrorist attacks’ and ‘the UK does not introduce ID cards and they cannot prevent terrorist attacks’, they have come to a biconditional interpretation and are more likely to endorse all four inferences that can be made from such a conditional. For example, when informed of the absence of the antecedent (‘the UK does not introduce ID cards’) they make the inference that the consequent is also not present (‘terrorist attacks cannot be prevented’), the denial of the antecedent inference.

However, if a person can envisage a further possibility, such as ‘the UK does not introduce ID cards and terrorist attacks are prevented’ because they can think of alternative means of preventing terrorist attacks, they will come to a conditional interpretation and be less likely to make the denial of the antecedent and affirmation of the consequent inferences. Another person may be able to envisage the possibility of ID cards not preventing a terrorist attack (‘the UK introduces ID cards and cannot prevent a terrorist attack’) and therefore come to an enabling interpretation (or one of a number of other interpretations), thereby recognising that ID cards may not be sufficient to prevent terrorist attacks.

The inferences people are willing to make from a conditional can have consequences for their beliefs and actions. The current debate in the UK over whether ID cards should be introduced hinges on the possibilities people can envisage in relation to the conditional ‘if the UK introduces ID cards then they can prevent terrorist attacks’. A person who only considers the two possibilities consistent with a biconditional interpretation will be strongly in favour of an introduction of ID cards, whereas a person who can think of alternatives may be interested in pursuing these alternatives.

Causal relations are often thought of as conditional ‘if...then’ assertions and according to the mental model theory different sorts of causes are consistent with different possibilities (Johnson-Laird & Byrne, 1991). An understanding of how different causes are mentally represented may help further our knowledge of how people distinguish causal
conditionals and make predictions about how people reason when faced with different sorts of causal assertions.

**Different types of causal relations**

A strong cause such as ‘if Joe cut his finger then it bled’ is both necessary and sufficient and has no readily retrievable counterexamples associated with the inferences that can be made from it. As a result it is consistent with just two possibilities, ‘he cut his finger and it bled’ ‘he did not cut his finger and it did not bleed’.

We therefore expect a strong cause to be mentally represented by keeping these two possibilities in mind, see Table 4.1 for an overview (Johnson-Laird & Byrne, 1991).

A weak cause such as ‘if the apples were ripe then they fell from the tree’ is sufficient but not necessary for the outcome as people can readily think of alternative causes (e.g., a strong wind). As a result a weak cause is consistent with three possibilities, ‘the apples were ripe and they fell from the tree’, ‘the apples were not ripe and they fell from the tree’, ‘the apples were not ripe and they did not fall from the tree’.

We therefore expect the mental representation of a weak cause to consist of these three possibilities.

**Table 4.1:** Predicted mental representation for strong causes, weak causes and enabling conditions

<table>
<thead>
<tr>
<th>Strong cause:</th>
<th>Weak cause:</th>
<th>Enabling condition:</th>
</tr>
</thead>
<tbody>
<tr>
<td>p caused q</td>
<td>p caused q</td>
<td>p enabled q</td>
</tr>
<tr>
<td>p</td>
<td>p</td>
<td>p</td>
</tr>
<tr>
<td>q</td>
<td>q</td>
<td>q</td>
</tr>
<tr>
<td>not-p</td>
<td>not-q</td>
<td>not-p</td>
</tr>
<tr>
<td>not-q</td>
<td>p</td>
<td>not-q</td>
</tr>
</tbody>
</table>

An enabling condition such as ‘if the ignition key was turned then the car started’ is necessary but not sufficient as people can readily think of additional requirements (e.g., the battery must not be flat). As a result an enabling condition is consistent with three different possibilities, ‘the key was turned and the car started’, ‘the key was turned and the car did not start’.
the key was not turned and the car did not start’.

We therefore expect an enabling condition to be mentally represented by keeping these three possibilities in mind.

In this chapter we report two experiments in which we examine people’s mental representations of different causes by employing a priming paradigm. This priming paradigm has demonstrated differences between factual, semifactual, and counterfactual conditionals (Santamaria et al., 2005). The methodology exploits the fact that information consistent with people’s mental representation is processed more quickly than information inconsistent with it. Accordingly, possibilities consistent with a particular conditional are read more quickly than inconsistent possibilities.

Participants are presented with scenarios in which they first read a conditional, ‘if Joe cut his finger then it bled’, and are then presented with a conjunction describing one of the four possibilities associated with the conditional (e.g., ‘Joe cut his finger and it bled’). Conjunctions describing true possibilities are expected to be read more quickly than conjunctions describing false possibilities. We therefore expect different types of causes to prime different possibilities. We predict that strong causes will prime two possibilities, ‘p and q’
‘not-p and not-q’
weak causes will prime three possibilities,
‘p and q’
‘not-p and not-q’
‘not-p and q’
and enabling conditions will prime three different possibilities,
‘p and q’
‘not-p and not-q’
‘p and not-q’.

In Experiment 5 we tested our predictions for enabling conditions and in Experiment 6 we tested our predictions for strong causes and weak causes.

**Experiment 5: Priming Enabling Causal Relations**

The aim of this experiment was to examine the sorts of mental representations people form of causal assertions about enabling conditions. We examined the possibilities that people think about when they understand factual causal assertions by measuring the length of time it took them to read conjunctions (Santamaria & Espino, 2002; Santamaria et al., 2005).

We predicted that reading a factual conditional about an enabling condition, e.g. ‘if the lid
was twisted then the bottle opened’ would prime participants to read quickly the conjunctions that describe the true possibilities, that is, ‘the lid was twisted and the bottle opened’ (‘p and q’), ‘the lid was twisted and the bottle did not open’ (‘p and not-q’), and ‘the lid was not twisted and the bottle did not open’ (‘not-p and not-q’).

The conditionals about enabling relations and associated conjunctions were embedded in paragraphs similar to those used by Santamaria et al. (2005). The paragraphs consisted of 7 sentences or sentence fragments such as:

- Martin was telling Laura about his medicine bottle.
- He told her that the lid had to be squeezed for it to open.
- He also said
- If the lid was twisted then the bottle opened.
- When Martin showed Laura the bottle, she saw that
- The lid was twisted and the bottle opened.
- Laura went to get a drink.

The paragraphs were presented on a computer, one sentence at a time. Presentation of the paragraphs was self-paced in that participants pressed the space bar when they were ready to move on to the next sentence. We measured how long it took them to read the conjunctions, that is, the time between the space bar press for one sentence and the following sentence. The four conjunctions were ‘the lid was twisted and the bottle opened’ (‘p and q’), ‘the lid was twisted and the bottle did not open’ (‘p and not-q’), ‘the lid was not twisted and the bottle opened’ (‘not-p and q’), and ‘the lid was not twisted and the bottle did not open’ (‘not-p and not-q’).

We emphasised the enabling relation described in the conditional (‘if the lid was twisted then the bottle opened’) by introducing an additional requirement in the second line of the paragraph (‘he told her that the lid had to be squeezed for it to open’). We also pre-tested the materials to be used in the experiment to ensure they were understood as enabling conditions and we describe this pre-test shortly.

We compared the priming effects of the conditionals to a baseline condition. The paragraphs for the baseline condition were identical to the ones in the experimental condition with the exception of one sentence. In the baseline condition we replaced the conditional with an assertion that provided further information about the subject of the antecedent of the conditional, such as ‘the lid on the bottle was white’.

In summary, we presented participants with paragraphs about enabling conditions and measured their reading times of conjunctions about different possibilities. We compared these reading times to a baseline condition in which participants read a filler...
sentence instead of a conditional about an enabling condition. We generated 24 different contents and each participant saw each content paired with one of the four conjunctions. The different contents were rotated across all conditions.

**Method**

**Materials**

The experimental materials consisted of 24 different scenarios about causal relations. We examined the four conjunctions across two conditions (enabling condition and baseline) and each participant saw three items in each condition. The structure of the scenarios was based on the materials used by Santamaria et al. (2005), such as:

> ‘Martin was telling Laura about his medicine bottle. He told her that the lid had to be squeezed for it to open. He also said If the lid was twisted then the bottle opened. When Martin showed Laura the bottle, she saw that The lid was twisted and the bottle opened. Laura went to get a drink.’

The first sentence set the scene (‘Martin was telling his friend Laura about his medicine bottle’). The second sentence contained an additional requirement for the conditional (‘He told her that the lid had to be squeezed for it to open’). The information in sentence two was an additional requirement because the action needed to be carried out in conjunction with the action described in the conditional (e.g., squeezing the lid and twisting it). The third sentence was of the form, ‘He also said’ and the fourth sentence was either a conditional describing an enabling condition (‘If the lid was twisted then the bottle opened’) or a filler sentence for the baseline condition, which described an attribute of the antecedent of the conditional used in the experimental condition (‘The lid on the bottle was white’). We included information about the antecedent in the baseline condition to ensure that we were not merely priming the object ‘lid’ in the experimental condition and had no repeated reference to it in the baseline condition. The fifth sentence was a filler sentence (‘When Martin showed Laura the bottle, she saw that’). The sixth sentence was a conjunction describing a possibility derived from the conditional (e.g., ‘The lid was twisted and the bottle opened’). There were four different conjunctions, ‘the lid was twisted and the bottle opened’ (‘p and q’), ‘the lid was twisted and the bottle did not open (‘p and not-q’), ‘the lid was not twisted and the bottle opened’ (‘not-p and q’), and ‘the lid was not
twisted and the bottle did not open’ (‘not-p and not-q’). The seventh sentence was a filler sentence about what one of the characters did next (‘Laura went to get a drink’).

Each scenario was then followed by a question about one part of the scenario. 25% of the questions related to line one or two (e.g., ‘Was Martin telling Laura about his medicine bottle?’), 25% related to line four, the conditional (e.g., ‘Did Martin say if the lid was pushed then the bottle opened?’), or in the baseline condition ‘Did Martin say the lid on the bottle was green?’), 25% related to line five or six (e.g., ‘Was the lid twisted and the bottle did not open?’) and the remaining 25% related to line seven (‘Did Laura go to get a drink?’). Half of those questions required a ‘yes’ response and half a ‘no’ response. We included the questions to ensure that participants were reading the scenarios.

All scenarios had essentially the same syntactic structure, the same wording and the same number of words. The fourth sentence contained the conditional, ‘if p then q’. It was preceded in the second sentence by the additional requirement, ‘she told him that r for q’. We ensured that the structure of these sentences was the same for all scenarios. The fourth sentence had the detailed structure, ‘if P (a was b) then Q (cd)’ and the second sentence had the detailed structure, ‘R (e had to be f) for Q (c to d)’.

The materials for the baseline condition were identical to the experimental condition, apart from a change to line four of the scenario. In line four instead of a conditional, participants were presented with a filler sentence about the colour or location of the antecedent of the conditional used in the experimental condition. An example follows:

‘Martin was telling Laura about his medicine bottle.
He told her that the lid had to be squeezed for it to open.
He also said
The lid on the bottle was white.
When Martin showed Laura the bottle, she saw that
The lid was twisted and the bottle opened.
Laura went to get a drink.’

The full set of materials is in Appendix C4 (p.202). The 24 scenarios used in the experiment were selected from a pre-test in which we tested 38 scenarios in order to identify the most suitable scenarios.
We ensured the materials used in the experiment were describing enabling relations by pre-testing a set of 38 scenarios and selecting the 24 most suitable ones. For the pre-test we used only the first four lines of the scenarios used in the experiment, such as

‘Martin was telling his friend Laura about his medicine bottle
He told her that the lid had to be squeezed to open it
He also said
If the lid was twisted then the bottle opened.’

We also generated nine scenarios about strong causes and nine scenarios about weak causes to act as fillers. The items were placed in a booklet in a different random order, with the constraint that after every two scenarios about enabling conditions there was a filler (either a strong cause or a weak cause). Therefore, a total of 56 scenarios was generated for the pre-test (38 describing enabling conditions, 9 strong cause, and 9 weak causes).

Each participant received a random selection of half of the materials, 19 enabling conditions and a random selection of nine filler items (strong and weak causes). Each scenario was presented on a separate page together with a request to rate four conjunctions, presented in different random orders, as consistent or inconsistent with the information presented in the paragraph, as follows

<table>
<thead>
<tr>
<th></th>
<th>Consistent</th>
<th>Inconsistent</th>
</tr>
</thead>
<tbody>
<tr>
<td>The lid was not twisted and the bottle did not open</td>
<td>O</td>
<td>O</td>
</tr>
<tr>
<td>The lid was twisted and the bottle did not open</td>
<td>O</td>
<td>O</td>
</tr>
<tr>
<td>The lid was twisted and the bottle opened</td>
<td>O</td>
<td>O</td>
</tr>
<tr>
<td>The lid was not twisted and the bottle opened</td>
<td>O</td>
<td>O</td>
</tr>
</tbody>
</table>

(see Appendix C1 and C2 for the instructions as well as a full list of the materials used, p.196).

We tested 17 Trinify College students and one visiting transition year school pupil. There were 3 men and 15 women with a mean age of 20 (range 16-29 years). Participants were tested in groups and they took part voluntarily or received course credit for their participation.

As expected, participants interpreted the scenarios about different causal relations differently. Table 4.2 shows the percentages of consistency ratings for the three types of causes. The strong and weak causes were often interpreted as strong and weak causes (strong 59%, weak 62%). But there was considerably more variability in the interpretations of the enablers, as Table 4.2 shows.
We ranked the scenarios describing enabling conditions according to the frequency with which the pattern of responses consistent with enabling conditions was selected, that is, ‘the lid was twisted and the bottle opened’ (‘p and q’), ‘the lid was twisted and the bottle did not open’ (‘p and not-q’) and ‘the lid was not twisted and the bottle did not open’ (‘not-p and not-q’). We ranked the items according to the frequency of which this pattern of responses was chosen and selected the 24 items that were rated most often according to this pattern. The highest ranking items were rated according to this pattern on 44% of trials and the lowest ranking items were selected on 22% of trials.

The frequency of selecting the conjunction where the antecedent was present and the consequent was absent (e.g., ‘the lid was twisted and the bottle did not open’), which is the item that distinguishes an enabling condition from the other types of causes, was between 22% and 78%. We examined the frequency with which each conjunction was judged as consistent with the different types of causes. As expected, all three types of causes were rated as consistent with the conjunction where both items are present (e.g., ‘the lid was twisted and the bottle opened’) (93% - 97%, Friedman’s test, \( \chi^2 (2) = 1.2, p > .05 \)) and the conjunction where neither item was present (e.g., ‘the lid was not twisted and the bottle did not open’) (85% - 90% Friedman’s test, \( \chi^2 (2) = 5.2, p > .05 \)).

Table 4.2: Percentages of consistency ratings for the three types of causes

<table>
<thead>
<tr>
<th>%</th>
<th>Strong</th>
<th>Weak</th>
<th>Enabler all materials</th>
<th>Enabler selected materials</th>
</tr>
</thead>
<tbody>
<tr>
<td>p &amp; q</td>
<td>95</td>
<td>93</td>
<td>97</td>
<td>93</td>
</tr>
<tr>
<td>not p &amp; not q</td>
<td>90</td>
<td>85</td>
<td>88</td>
<td>89</td>
</tr>
<tr>
<td>not p &amp; q</td>
<td>27</td>
<td>79</td>
<td>43</td>
<td>34</td>
</tr>
<tr>
<td>p &amp; not q</td>
<td>4</td>
<td>2</td>
<td>36</td>
<td>44</td>
</tr>
<tr>
<td>only all consistent possibilities</td>
<td>59</td>
<td>62</td>
<td>23</td>
<td>32</td>
</tr>
</tbody>
</table>

Note: underlined are the possibilities consistent with the respective interpretations

As expected, the conjunction where the antecedent is absent and the consequent is present (e.g., ‘the lid was not twisted and the bottle opened’) was rated as consistent with the weak causes (79%) more than for strong causes (27%) and for enablers (43%),
(Friedman’s test, $\chi^2(2) = 18.1, p < .001$). In line with our predictions, the conjunction where the antecedent is present and the consequent is absent (e.g., ‘the lid was twisted and the bottled did not open’) was rated as consistent with the conditionals about enabling conditions (36% for all enablers and 44% for the enablers selected for the experiment) more than for strong causes (4%) and for weak causes (2%), (Friedman’s test, $\chi^2(2) = 22.8, p < .001$). Table 4.2 shows a breakdown for all enabling conditions compared to the ones that were selected for the priming experiment. The materials selected for the experiment were the ones most frequently rated in line with the pattern of consistent conjunctions for enabling conditions. In addition, as illustrated by Table 4.2, the materials selected were more frequently rated as consistent with the conjunction where the antecedent is present and the consequent is absent (‘p and not-q’) and less frequently rated as consistent with the conjunction where the antecedent is absent and the consequent present (‘not-p and q’), the possibility consistent with a weak cause. Appendix C4 (p.202) shows which materials were selected for the experiment.

**Design**

We examined two independent variables. The first independent variable was the condition, enabling conditional or baseline. The second independent variable was the sort of conjunction: ‘p and q’, ‘not-p and q’, ‘p and not-q’, ‘not-p and not-q’. The dependent measure was the reading times for the conjunctions (i.e., line 6 of the scenarios). The design was fully within participants and the 8 experimental conditions (2 conditions x 4 conjunctions) were given to participants for 3 different contents, making a total of 24 trials. Each individual participant was given the 24 trials with a different content assigned at random, that is, 24 distinct contents. We gave participants the 24 trials in a different random order.

**Procedure**

We tested participants in groups of 1-3 individuals. The materials were presented on Macintosh e-mac computers (with all extensions switched off and a CD in the CD-drive) using Superlab 1.75 software. Completion of the experiment took approximately 15 minutes.

The instructions included the following information:

The study consists of 24 short stories like the one below. Your task will consist of reading the stories quickly and accurately. The stories are about two people talking
in various situations. The stories will be presented to you sentence by sentence. When you finish reading a sentence and are ready to read the next sentence, please press the space bar. After reading each story, you must answer a question concerning a different part of the story. You will first be shown four practice problems so you can familiarise yourself with the procedure.

(Appendix C3 provides the full instructions, p.202)

Participants responded to the questions by pressing one of two keys on the keyboard (keys ‘V’ and ‘M’) which were labelled ‘no’ and ‘yes’. Participants completed the task in their own time, by pressing the space bar when they were ready to move on to the next sentence, that is, there was no time limit on how long each slide could be viewed for, although participants were instructed to read each sentence quickly and accurately. The two conditions were presented together and each participant saw the items in different random orders.

Participants
We tested 41 Trinity College students and 2 visiting transition year school pupils who participated for either course credit or 8 Euro. Based on Santamaria et al. (2005) we included participants in the analysis who contributed at least 83% of data points to the analysis. Data points were omitted when participants answered the questions at the end of the scenarios incorrectly or when their reading times were outliers (see results section for further details). As a result we excluded 21 participants. The mean age of the remaining 22 participants was 20 years (range 15-27 years) and there were 9 men and 13 women.

Results and discussion
Based on Santamaria et al. (2005), before any data analysis we identified outliers as any latency that was less than the mean latency divided by two or greater than the mean latency plus 3 times the standard deviation. Each outlier was replaced with a missing value code and removed from the analysis. Only latencies for correct responses were analysed. We therefore had to exclude 21 participants from the analysis, 12 for answering 4 or more questions incorrectly and a further 9 for having a combination of 4 or more outliers and incorrect responses. In addition to the 21 participants who were excluded from the analysis, 51 (10%) of 528 reaction times were not included in the analysis, 41(8%) due to incorrect responses and 10 (2%) due to outliers.

We carried out a 2 (conditional, baseline) by 4 (conjunction: ‘p and q’, ‘p and not-q’, ‘not-p and q’, ‘not-p and not-q’) ANOVA with repeated measures on both factors,
using log transformed data. There was a main effect of condition (conditional versus baseline), $F(1, 21) = 32.48$, $MSe = 0.027$, $p < .001$, indicating that some conjunctions were read more quickly when they were primed by a conditional compared to the baseline condition. There was also a main effect of conjunction, $F(3, 63) = 9.45$, $MSe = 0.051$, $p < .001$, showing that some conjunction were read more quickly than others. This effect is not surprising given that the conjunctions differ in the number of words they contain because of the negations. There was no reliable interaction, $F(3, 63) = 0.61$, $MSe = 0.042$, $p = .612$. Nonetheless, we carried out planned comparisons to test our predictions (see Winer, 1971 for a justification for carrying out planned comparisons on a non significant interaction).

![Figure 4.1: The mean reading times (in milliseconds) for the baseline and after the conditional. Bars are standard error.](image)

We compared the priming effects of the conditional describing an enabling relation to the baseline condition on reading times of the conjunctions (see Figure 4.1). We expected reading times for ‘p and q’, ‘p and not-q’, and ‘not-p and not-q’, the three true possibilities for the enablers, to be faster following the conditional prime. The ‘p and q’ conjunction was read 465 milliseconds faster following a conditional prime than in the baseline condition, $t(21) = 4.14$, $p < .001$. The conjunction ‘p & not-q’ was read 404 milliseconds faster and this difference was reliable, $t(21) = 2.82$, $p < .01$. However, the difference in reading times for the ‘not-p and not q’ conjunction was 227 milliseconds and it was not reliable, $t(21) = 1.47$, $p = .166$. We predicted no difference in reading time for the ‘not-p and q’ conjunction, the false possibility for the enabler, and consistent with this prediction, the difference of 332 milliseconds was not reliable, $t(21) = 1.86$, $p = .077$. 

98
The reliable main effect of conjunction showed that in both conditions the ‘p and q’ conjunction was read more quickly than the ‘p and not-q’ conjunction (141 milliseconds faster for the enablers and 350 milliseconds faster for the baseline) which in turn seemed to be read somewhat more quickly than the ‘not-p and not-q’ conjunction (179 milliseconds faster for the enablers and 2 milliseconds faster for the baseline) which appeared to be read somewhat more quickly than the ‘not-p and q’ conjunction (139 milliseconds faster for the enablers and 244 milliseconds faster for the baseline). We did not analyse these differences as the conjunctions differed in their number of words and also because negations are more difficult to process and should therefore take longer to read (Schroyens, Schaeken, & D'Ydewalle, 2001b). Furthermore, in everyday conversations people do not typically begin a sentence by first saying what is not present and then what is, e.g. ‘there were no bananas and there were oranges’. As a result the not-p and q conjunction is likely to be processed more slowly than the ‘not-p and not-q’ conjunction.

An enabling condition is consistent with three possibilities, ‘p and q’, ‘p and not-q’, and ‘not-p and not-q’. In this experiment we found a priming effect for two of the three conjunctions consistent with an enabling interpretation, ‘p and q’ and ‘p and not-q’, compared to a baseline condition. The initial possibility a person is likely to think of when they read a conditional is ‘p and q’. If the context requires it a person will flesh out their mental representation and consider other possibilities (Johnson-Laird & Byrne, 2002). In this experiment the scenarios suggested an additional requirement which should prompt participants to keep in mind the possibility where the antecedent occurs but the consequent does not occur (‘the lid was twisted and the bottle did not open’), as the additional requirement may not be satisfied (e.g., ‘the lid had to be squeezed’). Participants may have also kept a third possibility in mind, that is ‘not-p and not-q’. However, due to limited working memory capacity some participants may have only kept the two most salient possibilities in mind, that is, ‘p and q’ and ‘p and not-q’ (Johnson-Laird & Byrne, 2002). Only participants with high working memory capacity may have kept all three consistent possibilities in mind.

Summary
Consistent with our prediction this experiment demonstrated a priming effect of a conditional describing an enabling condition compared to a baseline condition. Participants read two of the three possibilities consistent with an enabling condition reliably faster after reading a conditional about the enabling relation than in the baseline condition. The results indicate that participants were not able to keep all three consistent possibilities in mind, but
instead kept two possibilities in mind. The two possibilities that were primed can perhaps be described as the most salient possibilities. The mental model theory predicts that the initial representation of a conditional consists of ‘p’ and ‘q’ which is consistent with priming of the ‘p and q’ conjunction. The additional requirement mentioned in the scenarios may be responsible for priming of the ‘p and not-q’ conjunction. The ‘p and not-q’ conjunction is typically not rated as consistent with a conditional, but the presence of an additional requirement explains why ‘p’ may not have been sufficient for ‘q’.

An alternative interpretation of our data is that people interpret enabling conditions as just consistent with two possibilities (i.e., ‘p and q’ and ‘p and not-q’) and consider the other possibilities to be false (i.e., ‘not-p and q’ and ‘not-p and not-q’). However, such an interpretation of our data is inconsistent with the finding from our pre-test where the ‘not-p and not-q’ conjunction was rated as consistent on 89% of trials.

The experiment demonstrates that the methodology is useful to identify the possibilities people keep in mind when they understand an enabling relation. A further test of our predictions is to compare the priming effect of conditionals describing different types of causes.

**Experiment 6: Priming Strong and Weak Causes**

The aim of Experiment 6 was to compare the sorts of mental representations people form of causal assertions about strong causes and weak causes. As in the previous experiment we examined the possibilities that people think about when they understand factual causal assertions by measuring the length of time it took them to read conjunctions (Santamaria & Espino, 2002; Santamaria et al., 2005). In Experiment 5 we reported a priming effect for two of the predicted three consistent possibilities. An examination of strong causes and weak causes allows us to examine two questions raised by the first experiment. Firstly, do people routinely keep in mind only two of the set of consistent possibilities? Secondly, if people only keep in mind two consistent possibilities, do they keep in mind the same possibilities or do they keep in mind possibilities that allow them to distinguish different types of causes?

Strong causes are consistent with only two possibilities whereas weak causes are consistent with three possibilities. We predicted that reading a causal factual conditional about a strong cause, such as ‘if Joe cut his finger then it bled’ would prime participants to quickly read two conjunctions, that is, ‘p and q’ (‘Joe cut his finger and it bled’), and ‘not-p and not-q’ (‘Joe did not cut his finger and it did not bleed’).
If people are able to keep in mind three possibilities then we expect that reading a causal factual conditional about a weak cause such as ‘if the apples were ripe then they fell from the tree’ would prime participants to read quickly three conjunctions, that is, ‘the apples were ripe and fell from the tree’ (‘p and q’), ‘the apples were not ripe and they fell from the tree’ (‘not-p and q’), and ‘the apples were not ripe and they did not fall from the tree’ (‘not-p and not-q’). However, if people tend to keep in mind only two consistent possibilities (as we found in Experiment 5), then there are three combinations of possibilities they could keep in mind:

1. ‘p and q’ and ‘not-p and not-q’
2. ‘p and q’ and ‘not-p and q’
3. ‘not-p and q’ and ‘not-p and not-q’

The first set of possibilities (1) do not distinguish a weak cause from a strong cause. If participants kept these two possibilities in mind then that is evidence against the suggestion that people understand different types of causes by keeping in mind different possibilities. The second (2) and third (3) set of possibilities allow people to distinguish a weak cause from a strong cause as well as an enabling condition. According to the mental model theory the possibility where both the antecedent and the consequent are present (‘p and q’) is part of people’s initial representation of a conditional we therefore predict that the second set of possibilities will be observed rather than the third set of possibilities.

As in the previous experiment, we also included a baseline condition. There were two reasons for including the baseline condition. First, the baseline condition allows us to compare the pattern of results from this experiment to the previous experiment. Second, given that strong and weak causes share two consistent possibilities, a mere comparison of strong and weak causes may not reveal information about the number of possibilities primed by the different causes as they may only differ for one of the possibilities.

We therefore made a set of predictions about the priming effect for the different types of causes compared to the baseline condition and a set of predictions about the comparison between strong causes and weak causes. Compared to the baseline condition a strong cause is expected to prime two possibilities (‘p and q’ and ‘not-p and not-q’). A weak cause is expected to prime at least two of the three consistent possibilities compared to the baseline condition (‘p and q’, ‘not-p and q’, and ‘not p and not-q’). A comparison of strong causes and weak causes is expected to reveal no differences for the two consistent possibilities shared by the two types of causes, that is, ‘p and q’ and ‘not-p and not-q’. However, we expected that the conjunction ‘not-p and q’ would be read more quickly following a prime by a weak cause compared to a prime by a strong cause.
Method

Materials
As in the previous experiment we generated 24 scenarios describing causal relations. The materials were informed by a pre-test, described below. The scenarios described strong causes and weak causes and again we included a baseline condition. We used the same causal conditionals for strong and weak causes by adjusting the information provided in the second sentence of the scenario. For a weak cause scenario the second sentence described an alternative cause to the one mentioned in the conditional (e.g., throwing the bottle on the floor instead of twisting the lid to open it), whereas for the strong cause the second sentence included further information about the colour or location of the antecedent of the conditional. The information contained in the second sentence of the strong cause materials was used in the baseline condition as further information to replace the conditional. As in the previous experiment we ensured that the materials all followed the same structure. Examples of the three conditions are as follows:

Strong cause:

Martin was telling Laura about his medicine bottle.
He told her that the lid on the bottle was white.
He also said
If the lid was twisted then the bottle opened.
When Martin showed Laura the bottle, she saw that
The lid was twisted and the bottle opened.
Laura went to get a drink.

Weak cause:

Martin was telling Laura about his medicine bottle.
He told her that the bottle opened when the bottle was thrown on the floor
He also said
If the lid was twisted then the bottle opened.
When Martin showed Laura the bottle, she saw that
The lid was twisted and the bottle opened.
Laura went to get a drink.

Baseline:

Martin was telling Laura about his medicine bottle.
He told her that the bottle opened when the bottle was thrown on the floor
He also said
The lid on the bottle was white.
When Martin showed Laura the bottle, she saw that
The lid was twisted and the bottle opened.
Laura went to get a drink.

As in the previous experiment each scenario was then followed by a question about one part of the scenario. We also ensured that all of the materials followed the same structure and contained the same number of words. The full set of materials is in Appendix C7 (p.216).

The 24 scenarios used in the experiment were selected from a pre-test in which we tested 48 scenarios in order to identify the most suitable scenarios. The pre-test was designed to distinguish weak causes and enabling conditions. The pre-test raised several problems with using the same materials to describe weak causes and enabling condition and as a result we focussed on a comparison of weak causes and strong causes in the main experiment. The materials used in Experiment 6 were informed by the pre-test.

Materials pre-test 6.1

We conducted a materials pre-test in order to adapt the materials used in Experiment 5 for enabling conditions for weak causes. We developed 48 scenarios describing weak causes and enabling conditions to be used in this pre-test. For this purpose we adapted 30 items from the pre-test from the previous experiment and generated a further 18 scenarios. The materials for weak causes and enabling conditions were identical apart from the second line in each paragraph. For the weak causes the second line described an alternative cause whereas for the enabling conditions the second line described an additional requirement. As in the previous pre-test the materials consisted of four sentences or sentence fragments. The paragraphs all followed the same structure and the weak causes and enabling conditions only differed in the information provided in the second sentence, such as

Weak cause:
‘Martin was telling his friend Laura about his medicine bottle
He told her the bottle opened when it was thrown on the floor
He also said
If the lid was twisted then the bottle opened’

Enabling condition:
‘Martin was telling his friend Laura about his medicine bottle
He told her the bottle opened when the lid was squeezed
He also said
If the lid was twisted then the bottle opened'  

We changed the wording of the second sentence from the previous pre-test. Instead of stating ‘the lid had to be squeezed for the bottle to open.’ the sentence was phrased ‘the bottle opened when the lid was squeezed’. We made this change in order to match the phrase used in the enabling and weak causes, and to ensure the phrase was suitable for weak causes. We also generated 12 paragraphs about strong causes to act as fillers.

The items were placed in a booklet in a different random order, with the constraint that after every two paragraphs about enabling conditions and weak causes there was a filler (a strong cause). The presentation of the materials and the task was identical to the pre-test for the previous experiment (see Appendix C6 for a full set of the materials, p.208).

Each participant received a random selection of 12 weak causes and a random selection of 12 enabling conditions with the constraint that they did not receive the same content for the two conditions. In addition each participant received the 12 strong causes. Therefore, each participant completed a booklet containing 36 scenarios, 12 weak causes, 12 enabling conditions and 12 strong causes.

We tested 59 Trinity College students who received 5 euro for their participation. We excluded 11 participants, eight for being non-native English speakers, two for having studied logic and one because of an administrative error. Of the remaining 48 participants there were 20 men and 28 women. Their mean age was 23 years (range 17 - 65 years). Participants were tested in groups and testing took approximately 30 minutes.

As in pre-test 5.1, participants interpreted the scenarios about different causal relations differently, though the effect was less pronounced for the enabling conditions compared to the previous pre-test. We examined the frequency with which each conjunction was judged as consistent with the different types of causes. In line with our findings from pre-test 5.1 and our predictions, all three types of causes were rated as consistent with the ‘p and q’ conjunction, ‘the lid was twisted and the bottle opened’ (96% to 97%, Friedman’s test $\chi^2 (2) = 3.4, p = .185$). Contrary to our predictions the ‘not-p and not-q’ conjunction, ‘the lid was not twisted and the bottle did not open’, was more frequently rated as consistent with the strong causes (80%) than with the weak causes (72%), Friedman’s test $\chi^2 (2) = 6.3, p < .05$ (we expected them to be rated as consistent equally often). Consistent with our predictions the ‘not-p and q’ conjunction, ‘the lid was not twisted and the bottle opened’, was rated as consistent with the weak causes (74%), more than for strong causes (35%) and for enabling conditions (57%), Friedman’s test $\chi^2 (2) = 73.4, p < .001$. The ‘p and not-q’ conjunction, ‘the lid was twisted and the bottle did
not open’, was rated as consistent only for scenarios about enabling conditions (14%), more than for strong causes (3%) and for weak causes (5%), Friedman’s test $\chi^2 (2) = 26.6$, $p < .001$. Table 4.3 shows the percentages of consistency ratings for the three types of causes.

**Table 4.3:** Percentage of consistency ratings for the three types of causes

<table>
<thead>
<tr>
<th></th>
<th>strong</th>
<th>weak</th>
<th>enabler</th>
</tr>
</thead>
<tbody>
<tr>
<td>p &amp; q</td>
<td>97</td>
<td>96</td>
<td>97</td>
</tr>
<tr>
<td>not-p &amp; not-q</td>
<td>80</td>
<td>72</td>
<td>78</td>
</tr>
<tr>
<td>not-p &amp; q</td>
<td>35</td>
<td>74</td>
<td>57</td>
</tr>
<tr>
<td>p &amp; not-q</td>
<td>3</td>
<td>5</td>
<td>14</td>
</tr>
</tbody>
</table>

Note: underlined are the possibilities consistent with the respective interpretations

The results were satisfactory for the weak causes. However, the consistency ratings for the ‘p and not-q’ conjunction for enabling conditions were substantially lower in this pre-test compared to the previous one. We had changed the wording of sentence 2, instead of saying ‘the cause had to happen for the effect to occur’ we said ‘the effect happened when the cause happened’, and this change appears to have had a detrimental effect on consistency ratings for ‘p and not-q’.

The materials pre-test highlights the difficulty in finding materials suitable for testing weak causes and enabling conditions at the same time. A requirement of the priming methodology is that the sentences in each condition follow the same wording. We therefore needed to ensure that weak causes as well as enabling conditions were conveyed in the same way. However, altering the wording of the second sentence in favour of weak causes (‘He told her the bottle opened *when* it was thrown on the floor’) led to a reduction in consistency ratings of the ‘p and not-q’ conjunction for enabling conditions. In addition, the low consistency ratings for ‘p and not-q’ for enabling conditions indicate that materials capable of being adapted for weak causes (by way of identifying an alternative condition) are not suitable for enabling conditions.

The pre-test was suggestive of an alternative comparison. There was a large difference in consistency ratings for the ‘not-p and q’ conjunction. As expected weak causes were more frequently judged to be consistent with this conjunction than strong
causes. We therefore expected strong causes and weak causes to have a differing priming effect on the 'not-p and q' conjunction. In addition, the results of the pre-test suggested a difference for the 'not-p and not-q' conjunction. Strong causes were more frequently judged consistent with this conjunction than weak causes. Strong causes and weak causes are both consistent with this conjunction; therefore an investigation of this difference is warranted.

We selected the top 24 materials from the pre-test for this experiment, that is, we selected the 24 materials for which participants most frequently identified the three conjunctions consistent with a weak cause. For the materials we selected the conjunctions consistent with a weak cause were selected on 42% to 77% of trials.

**Design**

We examined two independent variables. The first independent variable was the condition, strong cause, weak cause or baseline. The second independent variable was the sort of conjunction: 'p and q', 'not-p and q', 'p and not-q', 'not-p and not-q'. The dependent measure was the reading times for the conjunctions. The design was fully within participants and the 12 experimental conditions (3 conditions x 4 conjunctions) were given to participants for 2 different contents, making a total of 24 trials. Each individual participant was given the 24 trials with a different content assigned at random, that is, 24 distinct contents. We gave participants the 24 trials in a different random order.

**Procedure**

The procedure and instructions were identical to the previous experiment.

**Participants**

We tested 48 Trinity College students and 1 visiting transition year school pupil who participated for either course credit or 4 Euro. As in the previous experiment we included participants in the analysis who contributed at least 83% of data points to the analysis. We therefore excluded 11 participants (8 for having too many incorrect responses and 3 for having too many outliers). We excluded a further 4 for having previously taken part in a similar experiment and excluded another 5 due to an administrative error in the presentation of the stimuli. In total we excluded 20 participants. The mean age of the remaining 29 participants was 22 years (range 15-43 years) and there were 10 men and 19 women.
Results and discussion

Before any data analysis we identified outliers as any latency that was less than the mean latency of the group divided by two or greater than the mean latency plus 3 times the standard deviation. The outliers were replaced with missing value codes and removed from the analysis. Only latencies for correct responses were analysed. Therefore, in addition to the participants excluded from the analysis, 61 (9%) out of 696 reaction times could not be included in the analysis, 34 (5%) due to incorrect responses and 27 (4%) due to outliers.

We carried out a 3 (strong cause, weak cause, baseline) by 4 (conjunction: ‘p and q’, ‘p and not-q’, ‘not-p and q’, ‘not-p and not-q’) ANOVA with repeated measures on both factors, using log transformed data. There was a main effect of condition (strong, weak, baseline), \( F(2,56) = 19.83, MSe = .061, p < .001 \), showing that some conjunctions were read more quickly when they were primed by a conditional than in the baseline condition. There was also a main effect of conjunction, \( F(3,84) = 21.35, MSe = .063, p < .001 \), showing that across all conditions some conjunctions were read more quickly than other conjunctions.

There was no reliable interaction, \( F(6,168) = .41, MSe = .075, p = .87 \). Nonetheless, we carried out planned comparisons to test our predictions (see Winer, 1971 for a justification for carrying out planned comparisons on a non significant interaction).

We first compared strong causes with the baseline condition (see Figure 4.2). We expected the ‘p and q’ and the ‘not-p and not-q’ conjunctions, corresponding to true possibilities, to be read faster following the conditional prime by a strong cause than in the baseline condition. The ‘p and q’ conjunction was read 508 milliseconds faster, \( t(28) = 2.84, p = .008 \), as was the ‘not-p and not-q’ conjunction which was read 548 milliseconds faster: \( t(28) = 2.57, p = .016 \). As expected the ‘not-p and q’ conjunction, corresponding to a false possibility, was not primed by a strong cause, \( t(28) = 1.68, p = .105 \). Unexpectedly, the ‘p and not-q’ conjunction, also corresponding to a false possibility, was read 523 milliseconds faster \( t(28) = 2.84, p = .008 \).

Next we compared the weak causes with the baseline condition. Again, we expected the true possibilities ‘p and q’ and ‘not-p and not-q’ to be read faster following the conditional prime by a weak cause. We also expected the ‘not-p and q’ conjunction, corresponding to a true possibility, to be read more quickly. Consistent with our predictions the ‘p and q’ conjunction was read 378 milliseconds faster when it was primed by a weak cause compared to the baseline condition, \( t(28) = 2.16, p = .039 \), as was the ‘not-p and q’ conjunction, which was read 708 milliseconds faster: \( t(28) = 2.57, p = .016 \). The ‘not-p and not-q’ conjunction was also read marginally faster (393 milliseconds) when it was primed by a weak cause compared to the baseline condition, \( t(28) = 1.91, p = .066 \).
Unexpectedly the weak causes, similar to the strong causes, primed the false possibility ‘p and not-q’, which was read 550 milliseconds faster: \( t(28) = 3.24, p = .003 \).

Figure 4.2: The mean reading times (in milliseconds) for the baseline and after the strong and weak cause conditionals. The bars are standard error.

Finally, we compared the priming effects of the strong causes to the weak causes. We expected reading times for the ‘p and q’ and the ‘not-p and not-q’ conjunctions to be similar for the two sorts of causes. However, we expected the ‘not-p and q’ conjunction to be read more quickly following a prime by a weak cause compared to a prime by a strong cause. The results show no reliable differences between strong causes and weak causes. Consistent with our predictions the ‘p and q’ conjunction was read equally quickly following a prime by a weak cause or a strong cause (130 milliseconds difference), \( t(28) = .51, p = .61 \). Consistent with our predictions there was no reliable difference for the ‘not-p and not-q’ conjunction, the difference was 155 milliseconds, \( t(28) = 1, p = .328 \).

The main difference we expected to find between strong causes and weak causes was for the ‘not-p and q’ conjunction. We expected the conjunction to be primed by a weak cause but not by a strong cause. In fact there was a 256 milliseconds difference for the ‘not-p and q’ conjunction, however, this difference was not reliable, \( t(28) = 1.1, p = .278 \), and the comparison had 80% power to detect a difference of .03. As expected, there were no differences between strong causes and weak causes on the reading times for the false possibility ‘p and not-q’ (27 milliseconds difference), \( t(28) = .19, p = .86 \), (see Appendix C8 for power calculations on all pairwise comparisons, p.221).
A strong cause is consistent with just two possibilities, ‘p and q’ and ‘not-p and not-q’ whereas a weak cause is consistent with three possibilities, ‘p and q’, ‘not-p and q’, and ‘not-p and not-q’. In this experiment we found reliable differences for reading the conjunctions consistent with a strong cause when compared to the baseline condition. We also found reliable differences for two of the three possibilities consistent with a weak cause when compared to the baseline condition, ‘p and q’ and ‘not-p and q’. As in the previous experiment, participants tended to keep in mind just two of the three consistent possibilities.

All three sorts of causes were understood by keeping in mind two true possibilities. Strong causes primed the two true possibilities ‘p and q’ and ‘not-p and not-q’, weak causes also primed two true possibilities, ‘p and q’ and ‘not-p and q’, and enabling conditions (in Experiment 5) also primed two true possibilities, ‘p and q’ and ‘p and not-q’. These findings demonstrate that even though people may only keep two out of three consistent possibilities in mind for different types of causes, they tend to keep in mind possibilities which allow them to distinguish between different types of causes.

Unexpectedly, the false possibility ‘p and not-q’ was also read reliably faster following both a strong cause and a weak cause. This conjunction is the possibility which is consistent with an enabling condition and should be ruled out by both a strong cause and a weak cause. A conditional is typically not consistent with this possibility. One option is that participants did not interpret the weak and strong causal scenarios as weak and strong causes and instead interpreted the weak causes as disabling relations and strong causes as enabling relations. The patterns of responses we found for weak cause and strong causes are consistent with a disabling and an enabling interpretation respectively (Johnson-Laird & Byrne, 2002). The disabling interpretation implies that the outcome is bound to happen but it may be prevented if the antecedent occurs (Even if A then C may still occur). As a result, the possibility in which neither the antecedent nor the consequent occurs (‘not-p and not-q’) is blocked. The enabling interpretation implies that the antecedent of the conditional is necessary but not sufficient for the consequent and is therefore consistent with three possibilities, ‘p and q’, ‘p and not q’, and ‘not-p and not-q’. However, such interpretations are inconsistent with the pre-test findings where participants tended not to rate the ‘p and not-q’ conjunction as consistent with strong and weak causes.

The priming of the ‘p and not-q’ conjunction is consistent with Evans and Over’s (2004) assertion that conditionals are evaluated by considering only possibilities in which the antecedent of the conditional is present. However, the fact that possibilities where the
The antecedent is absent (‘not-p and q’ and ‘not-p and not-q’) were primed is inconsistent with this viewpoint. Evans and Over are therefore not able to account for all of our findings.

The comparison of strong causes and weak causes yielded no reliable differences. The ‘not-p and q’ conjunction was read more quickly when it followed a weak cause than when it followed a strong cause. However, this difference was not reliable. A possible explanation for this lack of difference is that for the strong causes the ‘not-p and q’ conjunction was represented implicitly, not because of the content of the conditional but because of the logical form, that is, participants may have come to a conditional rather than a biconditional interpretation of the conditional. The ‘not-p and q’ conjunction was more accessible for weak causes, as evidenced by its priming compared to the baseline condition. But because the conjunction is not inconsistent with a conditional interpretation, participants may have been able to retrieve it for strong causes, albeit slightly more slowly than for weak causes, which is reflected in the finding that the possibility was not primed compared to the baseline condition.

This experiment lends support to the idea that people understand different causes by keeping different possibilities in mind, as evidenced by the different possibilities primed by the two sorts of causes, compared to the baseline condition.

**Summary**

This experiment demonstrated a priming effect of a conditional describing a strong cause compared to a baseline condition as well as a priming effect of a weak cause compared to a baseline condition. Participants read the two true possibilities consistent with a strong cause reliably faster after reading a conditional about a strong cause than in the baseline condition. Participants also read two of the three conjunctions consistent with a weak cause reliably faster following a conditional describing a weak cause compared to the baseline condition. These results support the suggestion that people tend to keep in mind at most two possibilities rather than three; and that the possibilities distinguish different sorts of causes.

The experiment did not demonstrate reliable differences in a direct comparison between strong causes and weak causes, although the trend of the differences is compatible with the mental model theory. The main difference we expected to find between strong and weak causes was for the ‘not-p and q’ conjunction.

The experiment also, unexpectedly, showed a reliable difference for reading the conjunction ‘p and not-q’ following both a strong and a weak cause when compared to the baseline condition. The priming of this possibility may be linked to the order of processing.
The processing of negated components of a conditional is more effortful than of non-negated components (Schroyens et al., 2001b).

**General Discussion**

The aim of this chapter was to examine people’s mental representations for different sorts of causes by means of a priming paradigm. Different sorts of causes are consistent with different possibilities and we expected people’s mental representations of the different sorts of causes to reflect this. The priming paradigm allows a more direct access to the possibilities people keep in mind compared to other methods (e.g., inference tasks). The rationale behind the priming paradigm is that possibilities that are consistent with a conditional are read more quickly than possibilities that are inconsistent because people tend to think of true and not false possibilities (Johnson-Laird and Byrne, 2002).

In Experiment 5 we examined the priming of conjunctions corresponding to true possibilities by conditionals describing enabling causal relations compared to a baseline condition. The experiment supported our main predictions. We predicted that a conditional such as ‘if the lid was twisted then the bottle opened’ would prime three true possibilities, e.g., ‘the lid was twisted and the bottle opened’, ‘the lid was twisted and the bottle did not open’, and ‘the lid was not twisted and the bottle did not open’. Participants read two of the three true possibilities consistent with an enabling condition more quickly when they were primed by an enabling conditional than when they read a baseline sentence. Participants read the possibility in which both antecedent and consequent were present (e.g., ‘the lid was twisted and the bottle opened’) reliably faster (465 milliseconds) when they were primed by an enabling condition than in the baseline condition. They read the possibility in which the antecedent was present and the consequent was absent (e.g., ‘the lid was twisted and the bottle did not open’) reliably faster (404 milliseconds) when they were primed by an enabling condition than in the baseline condition. Contrary to our predictions the ‘not-p and not-q’ conjunction (‘the lid was not twisted and the bottle did not open’) was not primed by an enabling conditional.

According to the mental model theory people think about few possibilities because of working memory constrains, unless the circumstances require otherwise (Johnson-Laird & Byrne, 2002). The first possibility a person is likely to consider is ‘p and q’. In the scenarios we gave to participants, the most salient second possibility is the one where the antecedent (‘p’) occurs but the consequent (‘q’) fails to happen. This is the most salient possibility because the scenarios mention an additional requirement that must be satisfied
in order for the antecedent to exert its effect. Due to working memory limitations people may have only kept two of the three consistent possibilities in mind (Barrouillet & Lecas, 1999; also see De Neys, Schaeken, & d'Ydewalle, 2005 for evidence for the effect of working memory capacity on the retrieval of counterexamples).

As expected there was no reliable difference for the reading times of the ‘not-p and q’ conjunction (‘the lid was not twisted and the bottle opened’). According to the mental model theory, people think only of true possibilities, not false possibilities, and this result supports that prediction.

In Experiment 6 we examined the priming effects of both strong causes and weak causes and again compared them to a baseline condition. In this experiment we also found that two consistent possibilities were primed for the two sorts of causes when compared to the baseline condition. Strong causes primed the two true consistent possibilities as predicted, ‘p and q’ and ‘not-p and not-q’. The ‘p and q’ conjunction (‘the lid was twisted and the bottle opened’) was read reliably faster (508 milliseconds) when it was primed by a strong cause compared to the baseline condition. The ‘not-p and not-q’ conjunction (‘the lid was not twisted and the bottle did not open’) was read reliably faster (548 milliseconds) when it was primed by a strong cause.

Weak causes also primed two of the three true consistent possibilities. As expected, the ‘p and q’ conjunction was read reliably faster (378 milliseconds) when it was primed by a weak cause compared to the baseline condition. Also as expected, the ‘not-p and q’ conjunction was read reliably faster (708 milliseconds) when it was primed by a weak cause. The ‘not-p and not-q’ conjunction, though consistent with a weak cause interpretation, was not primed by a weak cause. These findings also are consistent with the results of the pre-tests, where participants tended to rate the ‘not-p and not-q’ conjunction as consistent with weak causes less often than they did for strong causes. These findings are consistent with the findings of Experiment 5 where enabling conditions also primed two out of the three consistent possibilities (in that case, ‘p and q’ and ‘p and note-q’). Working memory limitations may account for participants’ ability to keep in mind only two consistent possibilities. Alternatively, the task may not encourage participants to flesh out their mental representations as the two possibilities they represent are sufficient to distinguish the different sorts of causes and complete the task.

Unexpectedly, the strong causes primed one of the false possibilities. The ‘p and not-q’ conjunction was read reliably faster (523 milliseconds) when it was primed by a strong cause. However, the other false possibility, the ‘not-p and q’ conjunction, was not
primed by a strong cause. Also unexpectedly, the weak causes, like strong causes, primed the false possibility ‘p and not-q’.

A possible explanation for the pattern of results observed for weak causes is that participants interpreted the weak causal scenarios not as weak causes but as disabling relations. Johnson-Laird and Byrne (2002) suggest that the pattern of responses observed for weak causes is consistent with a disabling interpretation. A disabling interpretation would suggest that participants acknowledged that the cause was necessary but considered the cause (e.g., twisting the lid) may not produce the effect. However, this explanation is inconsistent with results of the pre-test of the materials where the ‘p and not-q’ conjunction was rated as consistent on only 5% of trials. Thus, we can rule out this explanation.

A possible explanation for the pattern of results observed for strong causes is that they were interpreted not as strong causes but as enabling conditions, that is, the cause may or may not produce the effect. Again, as with the weak causes, such an interpretation is inconsistent with the pre-test findings where strong causes were judged consistent with the ‘p and not-q’ conjunction on only 3% of trials. Again, we can rule out this explanation.

Although the direct comparison between strong causes and weak causes did not produce reliable effects, the trend of these differences was in the expected direction. In particular, the ‘not-p and q’ conjunction was read somewhat more quickly when it followed a weak cause than when it followed a strong cause. Although participants may not have had a particular alternative cause in mind when they considered the strong causes, they may still have interpreted the conditional conditionally rather than biconditionally. The ‘not-p and q’ conjunction may have been represented implicitly and therefore not been as accessible for the strong causes as it was for the weak causes, and as a result only weak causes primed it in comparison to the baseline condition. The weak cause content strengthened the conditional interpretation in the weak cause condition and in the strong cause condition the content, whilst not eliminating it, weakened it.

Unexpectedly, the strong causes and weak causes primed the false possibility ‘p and not-q’. Espino, Santamaria, and Byrne (2006) report that biconditionals (with non-causal content) do not prime the false possibility ‘not-p and q’. It is also striking that in the pre-test participants rated this possibility as inconsistent for both strong and weak causes. The specific content used in this experiment should therefore not be responsible for this priming effect. So, how can we explain this priming effect?

One possibility is that the priming effects are related to the order of processing. The processing of negated components of a conditional is more effortful than of non-negated components (Schroyens et al., 2001b). Accordingly, following a conditional, a conjunction
of the two non-negated components should be read more quickly ("the lid was twisted and the bottle opened") than any of the other conjunctions. The possibility where the antecedent is present and the consequent is absent ("the lid was twisted and the bottle did not open") should be processed more quickly than a conjunction where the antecedent of the conditional is absent/negated. The priming of this possibility in the two experimental conditions in Experiment 6 may thus be explained by the order of processing. But of course, this explanation cannot explain the priming of 'p and not-q' for enablers (in Experiment 5), and 'not-p and not-q' for strong causes (in Experiment 6), and 'not-p and q' for weak causes (in Experiment 6). Two mechanisms may be at work. A basic order of processing mechanism which accounts for priming difference between 'p and q' and 'p and not-q' for example, and a further interpretation mechanism which depends on the causal relation.

In both experiments we excluded a substantial proportion of participants from the analysis. The majority of these exclusions resulted from participants answering the question at the end of the scenarios incorrectly\(^3\). The questions were in place to ensure that participants were reading the scenarios for comprehension. The questions were simple and a person reading the scenarios for comprehension should have been able to answer them correctly. The scenarios consisted of only 7 lines and were all about different topics and different people. The memory load of the task should not have been a problem, particularly as previous studies which have used the same methodology have not reported such problems. One possibility is that the participants who were excluded lacked the motivation to complete the task conscientiously. The task is quite boring and artificial and some of the participants may have found it difficult to sustain attention. However, the positive aspect of this procedure is that we are able to gain an insight into the possibilities people keep in mind without them explicitly knowing that this is what they are being tested for.

**Implications of findings for other theories of causal reasoning**

The experiments in this chapter were guided by the predictions made by the mental model theory. The findings of the experiments are consistent with the view that people understand

---

\(^3\) In Experiment 5 we excluded 21 of the 43 participants, 12 for having too many incorrect answers and a further 9 for a combination of incorrect answers and outliers. In Experiment 6 we excluded 20 of the 49 participants. We excluded 9 because they had previously taken part in a similar experiment or due to an administrative error in the presentation of the stimuli. Of the remaining 11 excluded participants 8 were excluded for having too many incorrect responses.
different sorts of causes by keeping in mind different possibilities. We now consider the implications of these findings for other theories of causal reasoning.

Proponents of mental logic theories have not developed a theory of reasoning about causal relations (Braine & O'Brien, 1991; Rips, 1994). Indeed, they ascribe a very small role to the effects of content on the inferences people make. Rule theorists make no predictions about the different possibilities people may keep in mind and are therefore not able to account for the results of Experiments 5 and 6 where different types of causes primed different possibilities.

Cheng and Nisbett (1993) propose that causal reasoning schemas are responsible for people’s reasoning performance about causal relations. In particular, they argue that the notion of *contingency* overrides any information on necessity and sufficiency. They suggest that the evaluation of a causal relation involves assessing the cases in which the effect is present. This implies that people should consider two possibilities, ‘Joe cut his finger and it bled’ and ‘Joe did not cut his finger and it bled’. According to the mental model theory these are two of the possibilities consistent with a weak cause. However, according to Cheng and Nisbett, if the second possibility (‘Joe did not cut his finger and it bled’) is consistent with the state of affairs then a person should not perceive a causal relation at all. Cheng and Nisbett propose that people compute the contrast between these two cases in order to evaluate an event’s causal role.

The possibility that ‘Joe did not cut his finger and it bled’ implies that cutting his finger is not necessary for it to bleed, and according to Cheng and Nisbett people would not perceive a causal link between cutting his finger and it bleeding. If people understand and assess strong causes in the way suggested by Cheng and Nisbett, then participants in Experiment 6 should have read the possibility ‘Joe did not cut his finger and it bled’ after being primed by a strong cause more quickly than in the baseline condition. However, strong causes did not prime this possibility.

When considering alternative causes, what we have termed a weak cause, Cheng and Novick (1992) propose that people carry out multiple contrasts. That is, for each potential cause under consideration people carry out a contrast, comparing the probability of the effect given that the cause is present or absent. This implies that considering alternative causes poses greater cognitive processing demands. Accordingly, we may expect the possibility where the cause is not present and the effect is present (e.g., ‘the apples were not ripe and they fell from the tree’) to be read more slowly for a weak cause than for a strong cause. This prediction is inconsistent with the results of Experiment 6.
Cheng and Novick (1992) suggest that enabling conditions are events that are constant and do not vary within the focal set under consideration for a particular effect. A potential enabling condition is evaluated by assessing covariation of the event in other focal sets. If the potential enabling condition covaries in an alternative focal set, then it is identified as an enabling condition and if it does not covary in any other focal set then it is regarded as an irrelevant factor. The fact that Cheng and Novick view enabling conditions as constant may account for priming of the possibility where the enabling condition is present and the effect is absent (e.g., ‘the ignition key was turned and the car did not start’). However, they are unable to account for the finding that other possibilities were also primed.

According to the suppositional theory, conditionals are assessed by considering the cases in which the antecedent is present (e.g., ‘Joe cut his finger and it bled’ and ‘Joe cut his finger and it did not bleed’). The suppositional theory cannot therefore account for priming of possibilities in which the antecedent is absent (e.g., ‘Joe did not cut his finger and it bled’ and ‘Joe did not cut his finger and it did not bleed’). However, in their discussion of the role of counterfactuals in causation, Evans and Over (2004) suggest that a cause is inferred by applying the Ramsey test\(^4\) to an affirmative counterfactual (‘if Joe were to cut his finger then it would bleed’), that is, the probability of Joe’s finger bleeding given that he cut it, and by applying the Ramsey test to a negative counterfactual (‘if Joe were not to cut his finger then it would not bleed’), that is the probability of Joe’s finger not bleeding given that he did not cut it. In fact, this conclusion suggests that people keep the affirmative and the negative possibility in mind when they understand a cause. However, Evans and Over explicitly rule out such a conclusion by their claim that conditionals are evaluated by only considering the cases in which the antecedent is present.

The finding that strong and weak causes primed the possibility in which the antecedent is present and the consequent is absent (e.g., ‘Joe cut his finger and it did not bleed’) is consistent with Evans and Over’s account. They propose that conditionals are understood by keeping in mind possibilities in which the antecedent is present. However, in both priming experiments two possibilities were primed for each causal relation, including ones where the antecedent was absent (‘p and q’ and ‘not-p and not-q’ for strong causes, ‘p and q’ and ‘p and not-q’ for enablers, ‘p and q’ and ‘not-p and q’ for weak causes). This finding rules out Evans and Over’s “singularity” principle, the claim that people keep only one relevant possibility in mind.

\(^4\) According to the Ramsey test p is added hypothetically to a person’s stock of knowledge and they will argue on that basis about q (Evans & Over, 2004).
Conclusion

Overall the experiments in this chapter provide evidence for the idea that people keep in mind different possibilities for different sorts of causes. These two experiments have added to our knowledge about different types of causes by demonstrating that participants in both experiments tended to keep in mind only two consistent possibilities, even when the conditional was consistent with three possibilities (as for weak causes and enabling conditions). Strong causes primed ‘p and q’ and ‘not-p and not-q’, weak causes primed ‘p and q’ and ‘not-p and q’, and enabling conditions primed ‘p and q’ and ‘p and not-q’. The experiment corroborates the idea that people represent few possibilities, at most two consistent possibilities were primed. The experiment provides some support for the idea that people represent true possibilities but in some cases false possibilities were primed. However, the priming of ‘p and not-q’ may result from a basic order of processing mechanism. In the experiments reported in the previous two chapters we examined how people represent different types of causes by making the different types of causal relations explicit by suggesting alternative causes and additional requirements. In the experiments reported in the next chapter we examine the distinction between causes and enabling conditions in more detail by examining people’s ability to identify causes and enabling conditions by considering different possibilities.
Chapter 5  Causes and Enabling Conditions

“A pure enabler is an event the occurrence of which makes it causally possible for a certain effect to occur, but which does not itself bring about that effect; it is an event that merely causes a thing to acquire a primary capacity, but does not also activate that capacity.” (Lombard, 1990, p. 204)

In this chapter we examine the distinction between causes and enabling conditions. One aim of this chapter is to uncover how people make the distinction between causes and enabling conditions. A second aim is to examine how people deal with inconsistent information about causes and enabling conditions. In this chapter we report an experiment in which we examined how people deal with inconsistent information about causes and enabling conditions (Experiment 7). We also report an experiment in which we examined some of the factors that influence the way in which people distinguish a cause from an enabling condition (Experiment 8).

We reported in Chapter 1 that the distinction between causes and enabling conditions is of interest when considering the counterfactual thoughts people generate in response to unexpected events. Thoughts about how an event could have been prevented tend to be about enabling conditions whereas thoughts about why the event happened may focus on causes (Mandel, 2005). An example of this can be seen in a recent headline in the Guardian newspaper “More resources ‘could have stopped July 7 attacks’” (Guardian Unlimited, 11/5/06). The headline refers to the fact that had the security services had more resources, they would have been able to identify and stop the terrorists before they were able to carry out their attacks. How do people distinguish between causes and enabling conditions?

As we suggested in Chapter 1 there is some debate over how causes and enabling conditions can be distinguished. The distinction between causes and enabling conditions is not always obvious. If you were told that diet and exercise result in weight loss, which preceding event would you identify as the cause and which as the enabling condition? As we saw in Chapter 1, some argue that it is a particular characteristic that distinguishes causes and enabling conditions, such as normality, relevance to conversation or constancy (e.g., Buehner & Cheng, 2005; Einhorn & Hogarth, 1986; Hilton & Erb, 1996). Others
have argued that they differ in terms of meaning and therefore also differ in terms of their logical implications (e.g., Johnson-Laird, 1999).

In this chapter we examine the difference between causes and enabling conditions further. A question we address in this chapter is how information which is inconsistent with people’s identification of causes and enabling conditions affects the way in which people view their original identification. Furthermore we ask, what determines how a person decides what is the cause and what is the enabling condition?

The way in which people deal with inconsistent information about causes and enabling conditions may be affected by the difference between causes and enabling conditions. Consider the following causal relation: ‘pulling the trigger causes the gun to fire’. Initially a person is likely to keep only one possibility in mind, possibly interpreting it as a strong cause:

\[ \text{trigger} \quad \text{fire} \]

However, if a person now encounters additional information they are forced to consider other possibilities. Imagine that someone pulled the trigger, but the gun did not fire. How do you explain this? This causal relation can be revised by considering a missing enabling condition, such as a missing bullet in the chamber, or a faulty mechanism within the gun. Now imagine that someone did not pull the trigger, but the gun fired. The causal relation can now be revised by considering this as a weak causal relation and thinking of an alternative cause for the firing of the gun, such as the gun being dropped on the floor. This example illustrates two things. First, new information can lead people to re-evaluate the nature of a causal relation. Second, different causes are consistent with different possibilities and people may not appreciate different types of causes at the outset, when they are considering an initial possibility. When additional information requires them to consider other possibilities they are able to distinguish different types of causes.

In the remainder of this section we briefly summarise the differing views on how causes and enabling conditions can be distinguished. The next section will describe an experiment in which we examined the effect of inconsistent information on the assignment of the roles of cause and enabling condition. We then describe an experiment in which we examined some of the factors that influence the distinction between causes and enabling conditions.
Causes and enabling conditions

Recall that the explanations for how people distinguish between causes and enabling conditions typically imply that enabling conditions are preconditions which tend to exist prior to the occurrence of the cause. A number of criteria have been suggested for identifying these preconditions as enabling conditions. Some have proposed that causes and enabling conditions differ in terms of normality (Hart & Honoré, 1959/1985). This view is related to the idea that causes and enabling conditions differ in terms of constancy (Cheng & Novick, 1991). The concepts of normality and constancy of course differ, a constant event may not always be normal. Conversational relevance refers to the view that people mention causes rather than enabling conditions (Hilton & Erb, 1996). Kuhnmünch and Beller (2005) suggested that the word ‘given’ acts as a linguistic cue for an enabling condition.

These different criteria are not mutually exclusive and in many circumstances all of these criteria can be applied to a particular situation. So for example, in the case of a forest fire, oxygen would be regarded as normal and constant and conversationally irrelevant, whereas the lightning that started the fire would be abnormal, inconstant and relevant to conversation. As reported in Chapter 1, researchers have developed examples in which these different criteria make differing predictions and have also demonstrated that none of the above criteria are necessary for making the distinction between causes and enabling conditions (Cheng & Novick, 1991; Goldvarg & Johnson-Laird, 2001).

We test the idea proposed by Goldvarg and Johnson-Laird (2001) that causes and enabling conditions differ in terms of the possibilities each of them are consistent with and as a result differ in meaning. This difference results in differences in the inferences people are willing to make from causes and enabling conditions. They report that participants made fewer modus ponens and fewer modus tollens inferences from ‘A will cause B’ than from ‘A will allow B’.

Goldvarg and Johnson-Laird also demonstrated that people are able to consider different possibilities when they identify the cause and the enabling condition for a particular outcome. We provide a detailed description of this task as it forms the basis of the two experiments reported here.

Participants were given scenarios such as,

'Given that there is good sunlight, if a certain new fertilizer is used on poor flowers, then they grow remarkably well. However, if there is not
good sunlight, poor flowers do not grow well even if the fertilizer is used on them.’

and asked to identify the cause and the enabling condition for flower growth. The first part of the description introduces the two causal factors, however, it does not distinguish the cause from the enabling condition. The initial representation for this causal relation is:

sunlight fertilizer grow

Based on the first sentence a person could assign either of these two events the role of cause and of enabling condition. The ambiguity regarding the causal roles results from the fact that the first sentence merely asserts that the two factors ‘sunlight’ and ‘fertilizer’ play a causal role in the growth of the flowers, but does not provide information on the necessity of each of the two factors. People are likely to use their background knowledge to come to a decision, or as Kühnmünch and Beller (2005) suggest, may be guided by the word ‘given’ when they identify the enabling condition. The second sentence unambiguously identifies ‘good sunlight’ as the enabling condition. An enabling condition makes it possible for the cause to exert its effect. Below is the full set of models consistent with this scenario:

sunlight fertilizer grow
sunlight not fertilizer grow
sunlight not fertilizer not grow
not sunlight fertilizer not grow
not sunlight fertilizer not grow
not sunlight not fertilizer not grow

The following three models are inconsistent with the description in this scenario:

sunlight fertilizer not grow
not sunlight fertilizer grow
not sunlight not fertilizer grow

It is inconsistent with the scenario that there is sunlight and fertilizer and the plants do not grow. It is also inconsistent that the plants grow in the absence of sunlight.
The full set of models consistent with this scenario demonstrate that sunlight is a necessary factor, as the flowers do not grow whenever there is no sunlight (as shown by the last two consistent models). However, the appearance of sunlight in itself is not a guarantee that the flowers will grow. The enabling condition, in this case sunlight, merely makes it possible for a cause to exert its effect. As can be seen from the models above that are consistent with the scenario, fertilizer is not the only cause that can interact with sunlight to produce the effect of the flowers growing. The second model

sunlight not fertilizer grow

allows the possibility for an alternative cause to act with the enabling condition to cause the flowers to grow.

The difference between causes and enabling conditions depends on the fully explicit possibilities compatible with assertions. However, individuals tend to consider one possibility at a time, and represent it in a mental model, which does not make explicit what is false in a possibility (Johnson-Laird & Byrne, 1991). One consequence is that individuals tend to focus on the possibility in which the cause (or enabler) and the effect both occur, and so people may find it difficult to distinguish between causes and enabling conditions (Goldvarg and Johnson-Laird, 2001). This difficulty in distinguishing causes and enabling conditions may explain the tendency for theorists to argue that they do not differ in meaning. People need to consider multiple possibilities within a context in order to distinguish them. Nonetheless, on 85% of the trials Goldvarg and Johnson-Laird’s participants correctly identified the event highlighted in the second statement (in the above case ‘sunlight’) as the enabling condition.

Goldvarg and Johnson-Laird conclude that causes and enabling conditions differ in terms of meaning. They posit that while causes and enabling conditions can differ in terms of constancy, normality and conversational relevance, what is most important is that causes and enabling conditions differ in terms of meaning and, as a result, also differ in terms of their logical implications. Therefore, different possibilities should be considered consistent with causes and enabling conditions.

We tested the prediction that people are able to distinguish causes and enabling conditions by considering possibilities in two experiments. In the first experiment we examined people’s ability to deal with inconsistent information about causes and enabling conditions. In the second experiment we examined some of the factors that affect how

---

5 In the experiments reported in Chapter 4 we provided additional information, in the form of alternative causes for weak causes and additional requirements for enabling conditions, to facilitate the differentiation of the different types of causes.
people identify causes and enabling conditions, including the claim that the word ‘given’ serves as a linguistic cue, in a modified version of Goldvarg and Johnson-Laird’s Experiment 2.

**Experiment 7: Inconsistent Information about Causes and Enabling Conditions**

The aim of the experiment was to examine how people distinguish between causes and enabling conditions when their initial view is either confirmed or contradicted. The mental model theory suggests that when people encounter a conditional they tend to consider only one true possibility (Johnson-Laird & Byrne, 1991). We have previously demonstrated that different types of causes are consistent with different possibilities. However, the initial possibility people are likely to consider for strong causes, weak causes and enabling conditions is the same, that is, the possibility where both antecedent and consequent are present (‘the trigger was pulled and the gun fired’). Only when people consider other possibilities are they able to tell different types of causes apart. The consideration of other possibilities may be prompted by subsequent information or the context of the situation, as demonstrated in the previous chapter.

Imagine you are presented with information that does not contain clues about the specific causal roles played by different events, e.g., ‘if Sarah follows this diet then given that she exercises she will lose weight’, and are then asked to identify the cause and the enabling condition of her weight loss, what would you say? You might use your background knowledge and decide that one of the events is the cause and the other the enabling condition. The information contained in the statement is not sufficient to make a clear distinction between cause and enabling condition. We would therefore expect half of a group of people to identify exercise as the cause and diet as the enabling condition and the other half to identify diet as the cause and exercise as the enabling condition.

Imagine now being told ‘if Sarah does not exercise then whether or not she follows this diet she does not lose weight’, and again being asked what causes and what enables Sarah’s weight loss. This second statement, together with the previous statement, identifies exercise as the enabling condition and diet as the cause of Sarah’s weight loss. If this evaluation of the circumstances is consistent with a person’s initial identification of causal roles then their response to the question about causal roles for the second statement should be identical to their first response. However, if this state of affairs, that is, diet is the cause and exercise the enabling condition, is inconsistent with a person’s initial assignment of causal roles, then they need to re-evaluate their initial assessment of the situation. People have two options, they can recognise that their initial evaluation of the situation was
incorrect and therefore switch their assignment of causal roles, or else they can maintain their assignment of causal roles but be less confident in their evaluation of the situation. We examined which of these two options people employ when they deal with inconsistent information about causes and enabling conditions. We were also interested in whether contradictory information is integrated differently into people’s identification of causes and enabling conditions.

The materials for this experiment were based on the ones used by Goldvarg and Johnson-Laird (2001), such as

‘Given that there is fertilizer, if the sun shines then the plants grow. However, if there is no fertilizer then whether or not the sun shines the plants do not grow’.

Goldvarg and Johnson-Laird demonstrated that participants are able to distinguish causes and enabling conditions from these descriptions (on 85% of trials). We presented these descriptions one sentence at a time and asked participants to identify the cause and the enabling condition after each sentence. The first sentence by itself is ambiguous as to the different causal roles and as a result we predicted that participants would have some difficulty identifying a cause and an enabling condition after reading the first sentence. We expected that once they were presented with the disambiguating information in the second sentence they would be able to identify the cause and the enabling condition based on the different possibilities implied in the descriptions.

Asking participants to identify the cause and the enabling condition after reading the first sentence in the descriptions means that the second sentence will sometimes be consistent and sometimes inconsistent with this initial identification. As a result, trials will be categorised as consistent or inconsistent depending on how a person’s initial identification relates to the information presented in the second sentence.

We expected different responses for consistent and inconsistent trials. On a consistent trial we expected participants to maintain their belief in the causal assignments they had made after reading the first sentence. On inconsistent trials we expected participants to switch their identifications of cause and enabling condition. An alternative to switching identifications is to reduce their confidence in their belief that a particular event is a cause or an enabling condition.

In summary this experiment examined people’s ability to distinguish causes and enabling conditions based on the different possibilities implied in the descriptions as well as how contradictory information is dealt with for the identification of causes and enabling conditions.
**Method**

*Materials and Design*

The materials were causal scenarios derived from a study in Goldvarg and Johnson-Laird (2001) such as:

\[
\text{Given that there is fertilizer, if the sun shines then the plants grow.}
\]

\[
\text{If there is no fertilizer then whether or not the sun shines the plants do not grow.}
\]

Goldvarg and Johnson-Laird demonstrated that participants could reliably identify the enabling condition ('fertilizer') from these descriptions. We divided these scenarios into two sentences: the first sentence was ambiguous, and the second sentence, in principle, resolved the ambiguity. The first statement in each pair introduced two antecedent events and an effect, e.g.: ‘given that there is fertilizer, if the sun shines then the plants grow’. Participants were then asked to answer a question about the cause of the outcome, ‘What causes the plants to grow (i.e. brings about the event)’ and to rate their confidence in their belief on a scale of 1-7.

They were also asked a question about the enabling condition of the outcome, ‘What allows the plants to grow (i.e. makes the event possible)’ and again they were asked to rate their confidence in their belief. The order of the questions was randomized across all the trials. The second statement in each pair provided participants with new information about the causal relation and it made clear, unambiguously, which event was the cause and which was the enabling condition. For instance they were told, ‘if there is no fertilizer then whether or not the sun shines the plants do not grow’. In this case the sentence makes clear that fertilizer is the enabling condition. Again participants were asked to say what causes the event and what allows the event to happen, together with confidence ratings of their beliefs.

In line with Cheng and Novick (1991) and Goldvarg and Johnson-Laird (2001), we only gave minimal instruction about the difference between causes and enabling conditions. We relied on people’s intuitive understanding of the difference between causes and enabling conditions and did not want to bias their responses by providing examples. Accordingly, a cause was described as something that brings about the event and an enabling condition was described as something that makes the event possible. An example of the materials and task can be seen in Table 5.1.
Table 5.1: Sample of the materials and task for Experiment 7

Statement:
*Given that the sun shines, if there is fertilizer then the plants grow.*

What causes the plants to grow (i.e. brings about the event)?

Rate your confidence in this belief:
not at all confident 1 2 3 4 5 6 7 very confident

What allows the plants to grow (i.e. makes the event possible)?

Rate your confidence in this belief:
not at all confident 1 2 3 4 5 6 7 very confident

You now learn that:
Statement:
*If there is no fertilizer then whether or not the sun shines the plants do not grow.*

In the light of this new information, please answer the following questions:

What causes the plants to grow (i.e. brings about the event)?

Rate your confidence in this belief:
not at all confident 1 2 3 4 5 6 7 very confident

What allows the plants to grow (i.e. makes the event possible)?

Rate your confidence in this belief:
not at all confident 1 2 3 4 5 6 7 very confident

Participants made judgments on five different contents and each content consisted of two sentences (as above). The different contents were presented to each participant in a different random order. The materials also counterbalanced whether the cause or the
enabler was introduced using the word ‘given’ or ‘if’ (cf. Kuhnmünch & Beller, 2005), and whether the cause or the enabler was in the first or second clause of the initial sentence. This yielded four different versions of the first statement:

‘Given that there is fertilizer, if the sun shines then the plants grow.’
‘If there is fertilizer, then given that the sun shines the plants grow.’
‘Given that the sun shines, if there is fertilizer then the plants grow.’
‘If the sun shines, then given that there is fertilizer the plants grow.’

We counterbalanced the order of the two questions about cause and enabler for both sentences. And we counterbalanced which of the two events was identified as the enabler in the second sentence. There were accordingly two versions of the second sentence and associated questions. Below are examples of the second sentence:

‘If there is no fertilizer then whether or not the sun shines the plants do not grow’
‘If there is no sun shine then whether or not there is fertilizer the plants do not grow.’

To recap, the first statement introduced the two antecedent events required for the effect (‘Given that there is x, if there is y then there is z’) and the second statement essentially made clear that if a certain precondition was not met (e.g., ‘if there is no fertilizer’) then whether or not the other event occurred did not matter for the outcome. Therefore, the antecedent of the second sentence (e.g., ‘if there is no fertilizer’) identified one of the events as the enabling condition (‘if there is no x, then whether or not there is y there is no z’). The contents of the materials concerned five different domains: psychological, socio-economic, physiological, mechanical, and biological (see Appendix D2 for a full list of the materials, p.222). The different contents were assigned to the forms of item in a different random way for each participant.

Participants

We tested 8 Princeton undergraduates and 20 Trinity College undergraduates, and we excluded 10 of the latter (see the procedure). The results are accordingly based on 18 participants (seven men and eleven women, their mean age was 20, ranging from 17 to 30 years). All participants took part for course credit.
Procedure

Participants were tested individually. Eight participants from Princeton University completed the task after completing an experiment on reverse engineering Boolean systems. The remaining 20 participants were tested at Trinity College, Dublin. The first twenty participants received the following instructions (see Appendix D1 for the full instructions, p.222):

This booklet contains ten statements. Each statement is followed by a set of questions [...] Please read each statement carefully and answer the questions that follow with reference to the information you have been given in the statement that preceded it. For this task we would like you to ignore any other knowledge you have about the topics referred to in the statements.

The reason for asking participants to ignore their other knowledge of the topics referred to in the statements was to avoid the introduction of other factors as causes or enabling conditions.

Eight of the first 20 participants failed to distinguish between causes and enabling conditions in more than half of the first sentences, and instead identified both events as joint enabling conditions. We predicted that participants may find it difficult to distinguish causes and enabling conditions based on the first sentence as this sentence was intentionally ambiguous as to the respective causal roles. However, as our classification of trials into consistent and inconsistent hinged on a comparison between participants' identification of causal roles after the first sentence and the information contained in the second sentence, we had to exclude these participants, and so we replaced these participants with eight new participants.

In order to avoid having to exclude further participants, these eight new participants received amended instructions. We added a sentence to the instructions which emphasized that one event was the cause and one the enabling condition, ‘Please note that an event is either the cause or else it allows the outcome to happen’. However, despite these revised instructions we had to exclude two of these eight participants, as they failed to distinguish between causes and enabling conditions following the first sentence. As a result of these exclusions the results are based on 18 participants, 12 of which received the initial instructions and 6 received the amended instructions. There was no time limit and completion of the task took between 10 and 15 minutes.
Results and discussion

Examination of the materials

The 18 participants who were included in the analysis carried out a total of 90 trials. We excluded six of these trials from the analysis as participants had identified a combination of both events as the enabling condition. Five of the excluded trials were from the physiological content and one from the biological content. On an additional 39 trials, participants identified the same event as both the cause and the enabler, that is, they said one event (e.g., ‘sunshine’) was both the cause and the enabling condition. We anticipated that participants would choose one event as the cause and the other as the enabling condition. However, as participants did not always follow this expected pattern we analysed causes and enabling conditions separately, ignoring the fact that they sometimes identified the same event as the cause and the enabling condition.

The first statement participants read was meant to be ambiguous and the second statement in each pairing unambiguously identified one of the events as the enabling condition. Before any data analysis we investigated whether the first statement was perceived to be ambiguous by our participants. For this purpose we first examined whether the wording of the first statement affected which event was identified as the cause and the enabling condition. We wanted to ensure that participants were not merely relying on linguistic cues to guide their choices when distinguishing between causes and enabling conditions, e.g., some participants may have been tempted to call the event paired with the word ‘given’ the enabling condition (as suggested by Kuhnmünch & Beller, 2005). We therefore analyzed the assignment of events as enabling conditions as a function of the word it was paired with in the first statement. Although participants chose the event paired with the word ‘given’ as the enabling condition more frequently (a mean of 2.8, 60% of all trials) than the event paired with the word ‘if’ (mean of 1.8, 39% of all trials), this difference was not reliable, Wilcoxon test, $z = 1.42, p > .1$ (pace Kuhnmünch & Beller, 2005). Hence, the statements were sufficiently ambiguous.

Analysis

We deal first with enabling conditions and then with causes because classification of the trials into consistent or inconsistent was based on participants’ identification of the enabling condition in sentence 1 and the event disambiguated in sentence 2. And because participants did not always identify the event not identified as the enabling condition as the cause we analyse them separately.
Enabling Conditions

We classified the 5 trials each participant completed into consistent and inconsistent trials. The trials were categorised as consistent or inconsistent based on each participant’s responses. A trial was consistent if the event a participant judged to be the enabler after the first sentence was disambiguated as the enabler in the second sentence; otherwise, the trial was inconsistent. Although we could not determine in advance the distribution of the two sorts of trial, of the 84 trials in the analysis, 42 were consistent and 42 were inconsistent.

Table 5.2: The percentages of trials on which participants maintained their belief about the *enabler* after disambiguating sentences that were consistent or inconsistent with this identification.

<table>
<thead>
<tr>
<th></th>
<th>Maintain belief in enabler</th>
<th>Switch belief to cause</th>
</tr>
</thead>
<tbody>
<tr>
<td>Consistent trial</td>
<td>88</td>
<td>12</td>
</tr>
<tr>
<td>Inconsistent trial</td>
<td>43</td>
<td>57</td>
</tr>
</tbody>
</table>

Table 5.2 provides a summary of the data. The overall prediction was that for consistent trials participants should maintain their judgment, but for inconsistent trials participants would change their judgment. A mean of 3.4 (standard deviation, 1.1) trials fitted the prediction and a mean of 1.2 (standard deviation, 1.1) trials went against it (the means do not sum to 5 because not all the participants provided relevant data on every trial). Table 5.2 shows that on consistent trials participants tended to identify the same event as the enabling condition after the second sentence, whereas they tended to switch identifications on inconsistent trials, e.g. they were given the sentence ‘given that there is fertilizer, if the sun shines then the plants grow’, and they identified ‘fertilizer’ as the enabler, on a consistent trial they were then given ‘if there is no fertilizer then whether or not the sun shines the plants do not grow’ and they again identified ‘fertilizer’ as the enabler, on an inconsistent trial they were given ‘if there is no sun shine then whether or not there is fertilizer the plants do not grow’ and they switched and identified ‘sun shine’ as the enabling condition. This interaction was reliable (Wilcoxon test, \( z = 2.1, p < .05 \)). As the Table shows, on consistent trials, only 12% switched the identity of the enabler to being the cause (88% maintained versus 12% switched, Wilcoxon test, \( z = 3.43, p < .001 \)).
On inconsistent trials 57% correctly switched their identification, whereas on 43% of trials participants incorrectly maintained their belief in the enabling condition. This difference was not reliable (43% versus 57%, Wilcoxon test, $z = .74, p = .462$). For the participants who maintained their belief, 22% reduced their confidence in their belief and 17% increased their confidence in their belief, Wilcoxon test, $z = 0.45, p = .655$.

**Causes**

For the analysis of the causal assignments we maintained the classification of trials into consistent and inconsistent from the analysis of the enabling conditions. Table 5.3 provides a summary of the data for the causal assignments. Participants predominantly identified the event not identified as the enabling condition as the cause after reading the first sentence. Although on 21% of the consistent trials and 23% of the inconsistent trials they chose the same event as the cause as they did for the enabling condition. For example, they identified 'fertilizer' as the cause and as the enabling condition for plant growth. The pattern of responses following the second sentence was quite different for the causes compared to the enabling conditions.

Table 5.3: The percentages of trials on which the participants maintained their belief about the *cause* after disambiguating sentences that were consistent or inconsistent with this identification.

<table>
<thead>
<tr>
<th></th>
<th>Maintain belief in cause</th>
<th>Switch belief to enabler</th>
</tr>
</thead>
<tbody>
<tr>
<td>Consistent trial</td>
<td>58</td>
<td>42</td>
</tr>
<tr>
<td>Inconsistent trial</td>
<td>82</td>
<td>18</td>
</tr>
</tbody>
</table>

On consistent trials participants tended to show a slight bias to identify the same event as the cause after the second sentence, but, strikingly, on inconsistent trials they showed an even greater tendency to maintain their identification. On a mean of 1.9 trials (standard deviation, 1.3) participants maintained their belief in a particular cause on a consistent trial and switched their belief on an inconsistent trial. But, a mean of 2.9 trials (standard deviation, 1.6) went against this pattern. The interaction was in the opposite direction to the interaction found for the enabling conditions (Wilcoxon test, $z = 2.6, p <$
.01). Planned comparisons showed that on consistent trials, no reliable difference occurred between trials on which the participants maintained their belief in the cause or switched their identification of it to the enabler (58% versus 42%, Wilcoxon test, $z = .89, p = .374$).

On inconsistent trials, however, the majority of participants maintained their identification of the event as the cause even though it had been disambiguated as the enabling condition (82% versus 18%, Wilcoxon test, $z = 3.11, p < .002$), e.g., participants were given the statement ‘given that there is fertilizer, if the sun shines then the plants grow’, and they identified ‘fertilizer’ as the cause, on a consistent trial they were then given ‘if there is no sun shine then whether or not there is fertilizer the plants do not grow’ and half again identified ‘fertilizer’ as the cause, on an inconsistent trial they were given ‘if there is no fertilizer then whether or not the sun shines the plants do not grow’ and they were expected to switch and identify ‘sun shine’ as the cause, but instead they continued to identify ‘fertilizer’ as the cause.

**Analysis of content effects**

We examined whether the unexpected results found for the identification of the causes could be attributed to content effects. We therefore first examined whether there were any systematic patterns for the assignment of causal roles following the first sentence. Recall that the first sentence was intended to be ambiguous as to which event was the cause and which the enabling condition. We investigated how frequently a particular pairing of cause and enabling condition was identified. If the materials were ambiguous then each cause and enabling condition should be chosen on approximately 50% of the trials. The majority of the materials were reasonably ambiguous, as can be seen in Table 5.4. However, the psychological and the mechanical materials were not ambiguous, with approximately 90% of participants choosing the same pairing of cause and enabling condition.

We carried out an analysis for the different contents. We examined the five different contents for deviations from the pattern of responses found for the combined materials. Table 5.5 presents a breakdown for the different contents compared to the overall pattern. We carried out Friedman non-parametric tests to check whether the contents led to different patterns of revision for causes and for enabling conditions. Neither test yielded reliable results: for enablers $N_r^2 = 3.1, df = 4, p = .5$; and for causes $N_r^2 = 3.8, df = 4, p = .4$. We also examined whether there were any differences in the frequency with which participants followed the overall pattern of results. Again the two Friedman tests failed to yield reliable results: for enablers $N_r^2 = 1.7, df = 4, p = .8$; and for causes $N_r^2 = 2.7, df = 4, p = .6$. We can therefore conclude that the content effects observed after
reading the first statement did not exert a systematic effect on responses following the second sentence.

**Table 5.4:** Percentage of trials on which a particular cause and/or a particular enabling condition were selected for the different contents

<table>
<thead>
<tr>
<th>%</th>
<th>Cause</th>
<th>Enabler</th>
</tr>
</thead>
<tbody>
<tr>
<td>Biological</td>
<td>47</td>
<td>52</td>
</tr>
<tr>
<td>Cause = sun</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Enabler = fertilizer</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Psychological</td>
<td>94</td>
<td>89</td>
</tr>
<tr>
<td>Cause = insult</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Enabler = sensitive</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Socioeconomic</td>
<td>61</td>
<td>61</td>
</tr>
<tr>
<td>Cause = interest rates</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Enabler = unemployment</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Physiological</td>
<td>31</td>
<td>46</td>
</tr>
<tr>
<td>Cause = diet</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Enabler = exercise</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Mechanical</td>
<td>89</td>
<td>67</td>
</tr>
<tr>
<td>Cause = trigger</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Enabler = bullet</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Note: some participants identified the same event as cause and enabling condition on some of the trials, therefore the percentages in each row are not always equal
Table 5.5: Comparison of the five different contents on rates (in percentages) of switching causal assignments.

<table>
<thead>
<tr>
<th>%</th>
<th>Enablers</th>
<th>Causes</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>switch belief to cause</td>
<td>switch belief to enabler</td>
</tr>
<tr>
<td><strong>Consistent trial</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>psychological</td>
<td>0</td>
<td>21</td>
</tr>
<tr>
<td>socio-economic</td>
<td>9</td>
<td>59</td>
</tr>
<tr>
<td>physiological</td>
<td>17</td>
<td>58</td>
</tr>
<tr>
<td>mechanical</td>
<td>20</td>
<td>35</td>
</tr>
<tr>
<td>physical</td>
<td>13</td>
<td>31</td>
</tr>
<tr>
<td>Overall</td>
<td>12</td>
<td>42</td>
</tr>
<tr>
<td><strong>Inconsistent trial</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>psychological</td>
<td>45</td>
<td>32</td>
</tr>
<tr>
<td>socio-economic</td>
<td>57</td>
<td>29</td>
</tr>
<tr>
<td>physiological</td>
<td>71</td>
<td>0</td>
</tr>
<tr>
<td>mechanical</td>
<td>50</td>
<td>13</td>
</tr>
<tr>
<td>physical</td>
<td>67</td>
<td>11</td>
</tr>
<tr>
<td>Overall</td>
<td>57</td>
<td>18</td>
</tr>
</tbody>
</table>

Summary

Our main prediction that participants would maintain their belief for enabling conditions on consistent trials and switch their belief on inconsistent trials was supported. On 88% of the consistent trials participants maintained their belief and chose the same event as the enabling condition after reading the second sentence as they did after reading the first sentence. On 57% of the inconsistent trials participants correctly identified the other event as the enabling condition. However, on 43% of the inconsistent trials participants did not switch and instead incorrectly identified the cause as the enabling condition. On only 22% of these trials participants’ confidence in their belief was reduced, on 56% of the trials their confidence in their belief was maintained and on 17% of the trials their confidence rating increased. The pattern of responses for the causes was very different to that for the enabling conditions. For consistent trials only a marginal majority correctly identified the
cause by maintaining their belief. Whereas for inconsistent trials the majority of participants (80% of trials) incorrectly identified the event disambiguated as the enabling condition as the cause by maintaining their belief.

The results for the enabling conditions suggest that participants were able to identify enabling conditions based on the different possibilities implied by the descriptions participants were asked to consider. However, several aspects of the experiment cast doubt on such a firm conclusion.

Firstly, the fact that a number of participants had to be excluded from the analysis suggests that at least some of the participants in this experiment had difficulty in distinguishing between causes and enabling conditions. However, these exclusions were a result of responses to the first sentence in each of the descriptions. The first sentence participants had to consider was deliberately ambiguous because no semantic difference was available to guide judgment. As a result some difficulties in differentiating between causes and enabling conditions were expected. In order to resolve this ambiguity some participants made use of linguistic cues, such as the word ‘given’, and some made use of relevant general knowledge when it was available. Thus, our participants knew that in the case of the psychological contents: ‘given a person is sensitive, if they are insulted then they get angry’, sensitivity is an enabling condition, not a cause. Likewise, in the case of the mechanical contents: ‘given that there is a bullet in the chamber, if the trigger is pulled then the gun fires’, they knew that a bullet in the chamber is an enabling condition for the gun to fire, not its cause.

Secondly, the responses to the second, disambiguating, sentence also indicate that some participants had difficulty in distinguishing causes and enabling conditions as evidenced by some participants’ tendency to identify the same event as the cause and the enabling condition. This particular tendency may be responsible for our failure to find the same pattern of results for the identification of the causes as we did for the enabling conditions. There are two possible explanations for this failure. One possibility is that participants did not distinguish between causes and enablers and instead focused on the one event they considered to be causally most relevant (i.e., the first event mentioned in the second sentence). Another possibility is that there are indeed differences between causes and enabling conditions, but that the results of this experiment do not allow us to fully appreciate the nature of these differences.

In the next experiment we went back to the descriptions used in the previous experiment in order to examine people’s ability to differentiate between causes and
enabling conditions and to examine some of the factors that influence a person’s identification of causes and enabling conditions.

**Experiment 8: Distinguishing Between Causes and Enabling Conditions**

The aim of this experiment was to examine some of the factors that guide people’s identification of causes and enabling conditions. Kuhnmünch and Beller (2005) questioned people’s ability to distinguish causes and enabling conditions based on possibilities. They suggested that the findings reported by Goldvarg and Johnson-Laird (2001) were due to a confound in the materials. Kuhnmünch and Beller argue that the word ‘given’ acted as a linguistic cue for the enabling condition. The results of Experiment 7 reported in this chapter demonstrate that the word ‘given’ may sometimes guide participants’ choices, but it did not do so reliably. Furthermore, the word ‘given’ did not have an influence on the assignment of causal roles participants made after reading the second sentence.

We had two objectives for this experiment. First, we systematically investigated the effect of the word ‘given’ on the assignment of causal roles. Second, we tested people’s ability to distinguish causes and enabling conditions based on different possibilities. As described in the previous experiment, Goldvarg and Johnson-Laird showed that participants were able to distinguish causes and enabling conditions by reading descriptions such as the one that follows:

> ‘Given that there is good sunlight, if a certain new fertilizer is used on poor flowers, then they grow remarkably well. However, if there is not good sunlight, poor flowers do not grow well even if the fertilizer is used on them.’

In their experiment they counterbalanced the order of mention of the causes and enabling conditions over the experiment, and also swapped the causal roles in the descriptions from one participant to another. Participants were able to consider the different possibilities and correctly identified the cause and the enabling condition from each of the descriptions. Goldvarg and Johnson-Laird concluded that contrary to the view held by many (e.g., Cheng & Novick, 1991; Einhorn & Hogarth, 1986; Mill, 1843/1973) causes and enabling conditions do differ in meaning and logic because they are consistent with different possibilities. However, the event paired with the word ‘given’ was always the event disambiguated as the enabling condition in the second sentence.

Kuhnmünch and Beller (2005) tested their hypothesis that the word ‘given’ was acting as a linguistic cue by giving participants scenarios of the following sort:
‘Given that a particular new fertilizer is added to the ground: If poor flowers get enough sunlight then poor flowers grow well. If poor flowers grow well then they have got enough sunlight.’

This description yields exactly the same fully explicit possibilities as the scenario used by Goldvarg and Johnson-Laird. The cause in those possibilities is the fertilizer and the enabling condition is the sunlight. Yet, the majority of the participants interpreted the fertilizer as the enabling condition, and Kuhnmünnch and Beller argue that this switch occurred because the fertilizer is referred to in the ‘given that’ clause.

The results of their experiment seem to indicate that the phrase ‘given that’ was responsible for participants’ identification of causes and enablers. However, the wording of the scenarios used by Kuhnmünnch and Beller differs from the ones used by Goldvarg and Johnson-Laird and as a result the mental models people construct may differ for the two sorts of scenarios.

Given this difference between the two sets of scenarios used, we set out to test Kuhnmünnch and Beller’s prediction that the term ‘given’ was guiding participants choices in assigning the roles of cause and enabling condition by making much smaller changes to the original materials than Kuhnmünnch and Beller did. Our prediction was that participants choices would be guided by the possibilities each event is consistent with rather than by a linguistic marker such as ‘given’. We examined this prediction in two pre-tests reported below.

We used materials which were free from a person’s background knowledge. In addition, all materials described two antecedent actions. We chose two actions, such as pushing a yellow button and pushing a blue button, as opposed to an action and a state, such as pushing the button and holding the gadget vertical. The reason for choosing two actions is that two actions are less likely to be interpreted as constant, normal, or conversationally relevant, thereby biasing participants to select one event as the enabling condition due to one of these characteristics. The materials used in the experiment were informed by the results of two materials pre-tests. We report the materials pre-tests first as we made some important changes to our materials as a result of these pre-tests.
Method

Materials

We report two pre-tests in which we examined the effect of the word ‘given’ on people’s ability to identify causes and enabling conditions.

Materials pre-test 8.1

In order to avoid any biases in the selection of causes and enabling conditions we inoculated the materials from participants’ general knowledge. In addition we chose two antecedent actions. We constructed eight scenarios, e.g.,

‘If the yellow button is pressed then, given that the blue button is pressed, the lamp flashes. However, if the yellow button is not pressed, the lamp does not flash even given that the blue button is pressed.’

We manipulated two independent variables. The first independent variable was whether the enabling condition was paired with the word ‘given’, e.g., ‘Given that the yellow button is pressed then, if the blue button is pressed, the lamp flashes. However, given that the yellow button is not pressed, the lamp does not flash even if the blue button is pressed’. The second independent variable was whether the enabling condition was mentioned first or last in the first sentence of the scenario, e.g., ‘If the blue button is pressed then, given that the yellow button is pressed, the lamp flashes. However, given that the yellow button is not pressed, the lamp does not flash even if the blue button is pressed’. There were therefore four different versions of each content and there were eight different contents (a full list of the different contents can be seen in Appendix D5, p.223).

Participants were asked to identify the cause and the enabling condition for eight scenarios. We used a 2 (enabler paired with ‘given’ or ‘if’) x 2 (enabler mentioned first or second) within participants design. Each participant saw eight scenarios, one of each content and two of the four different versions. Each scenario together with the questions for the cause and the enabling condition was presented on a new page of an A5 booklet. The scenarios were presented in different random orders. Following each scenario participants were asked to identify the cause and the enabling condition, such as,

‘Which one of the two events allows the lamp to flash (i.e. makes it possible for the cause to work) ____ and which of them causes the lamp to flash (i.e. brings about the event) ____?’
We tested these materials by administering them to 9 Trinity College students in groups of 1-3 individuals, who received research credits or 4 euro for their participation. We excluded 3 participants as they failed to distinguish causes and enabling conditions on more than 50% of the trials. The remaining 6 participants were 5 women and 1 man with a mean age of 22 years, ranging from 19 to 34 years, and they all contributed 8 valid trials each for analysis.

Participants responses to the scenarios fell into four categories: consistent with the mental model theory, consistent with choosing the event paired with the word 'given', consistent with both of these explanations (e.g., when both explanations made the same prediction), or inconsistent with both explanations. For the purpose of our analysis however, trials were classified as consistent with the mental model theory (MM), inconsistent with the mental model theory (not-MM), consistent with 'given' (given) or inconsistent with 'given' (not-given). These categories are not mutually exclusive as in some cases a response could be counted as consistent with both 'MM' and 'given'. Our intention was to examine which of the two explanations accounted best for the data. Accordingly, any trial on which a participant chose the first event of the second sentence (regardless of whether the word 'given' appeared in this sentence), e.g., ‘However, if the yellow button is not pressed...’ as the enabling condition, was classified as consistent with the mental model theory. Any trial on which the event paired with 'given' was identified as the enabling condition was classified as 'given' and conversely any trial on which the event not paired with 'given' was identified as the enabling condition was classified as 'not-given'.

Table 5.6: Mean number of trials consistent with MM and 'given' with standard deviations in parenthesis

<table>
<thead>
<tr>
<th></th>
<th>MM</th>
<th>not-MM</th>
<th>given</th>
<th>not-given</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mean</td>
<td>2.33 (2.3)</td>
<td>5.66 (2.3)</td>
<td>3.63 (2.2)</td>
<td>2.38 (2.2)</td>
</tr>
</tbody>
</table>

As can be seen from Table 5.6 participants tended to go against the predictions made by the mental model theory, with a mean of 5.66 trials going against and a mean of 2.33 trials in favour of the mental model theory’s predictions, although this difference was
not reliable (Wilcoxon test, \( z = 1.5, p = .13 \)). However, Table 5.6 also shows that it was not simply the word ‘given’ that was guiding people’s choices. Although more participants identified the event paired with the word ‘given’ as the enabling condition (a mean of 3.63 trials) this number was not reliably different from those who chose the event not paired with the word ‘given’ (a mean of 2.38 trials). What seems to have happened most frequently is that participants chose the event that was mentioned second in sentence 2 (a mean of 5.66 trials). This finding was inconsistent with either of the two predictions we were testing.

On re-examining our materials and comparing them to the materials used by Goldvarg and Johnson-Laird (2001) we realised that perhaps including the word ‘given’ in both the first and the second sentence had led to some confusion. We had included the word ‘given’ in both sentences to maximise the impact of the potential linguistic cue and thereby provide a stronger test of our hypothesis. However, given these inconclusive results, we conducted a further pre-test in which we omitted the word ‘given’ from sentence 2.

**Materials pre-test 8.2**

The materials used in this pre-test were identical to the materials used in the previous pre-test, apart from the fact that we replaced the word ‘given’ in sentence 2 with the word ‘if’ (see Appendix D5 for the materials, p.223). The instructions were also identical to the previous pre-test. We tested seven Trinity College students in groups of 1-3 people, who received research credits or 4 euro for their participation. We excluded one participant for failing to distinguish causes and enabling conditions. The six participants included in the analysis were 2 men and 4 women with a mean age of 21 years, ranging from 19 to 25 years.

<table>
<thead>
<tr>
<th></th>
<th>MM</th>
<th>not-MM</th>
<th>given</th>
<th>not-given</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mean</td>
<td>3.8 (2)</td>
<td>4.2 (2)</td>
<td>6.5 (2)</td>
<td>1.5 (2)</td>
</tr>
</tbody>
</table>
The results of this pre-test are in Table 5.7. Participants predominantly chose the event paired with the word ‘given’ as the enabling condition (a mean 6.5 trials versus a mean of 1.5 trials). Participants’ choices supported the mental model theory (a mean of 3.8 trials) nearly as frequently as they went against it (a mean of 4.2 trials).

The results of this pre-test indicated that participants were basing their decision on the first sentence and in particular the word ‘given’ was guiding their choices. The results of Experiment 7 indicated that participants were able to distinguish enabling conditions correctly from scenarios such as the ones used in the experiment. However, participants were forced to consider each statement (as participants had to identify the cause and the enabling condition for each sentence separately), whereas in this experiment participants were able to complete the task by focusing on a cue given to them in the first sentence. For the main experiment we therefore decided to remove the linguistic cue ‘given’. Our primary aim was to demonstrate that people distinguish between causes and enabling conditions by considering the consistent possibilities for each event.

**Experimental Materials**

The materials for the experiment were informed by the two pre-tests. The experimental scenarios were identical to the ones used in the pre-test, with the difference that we removed any linguistic cues, such as ‘given’, from the scenarios that may lead participants to choose a particular event as the enabling condition without considering the different possibilities suggested by the scenarios. Participants received eight scenarios with different contents. An example of the materials follows:

‘If the yellow button is pressed, then if the blue button is pressed the lamp flashes. However, if the yellow button is not pressed, the lamp does not flash if the blue button is pressed.’

In this scenario the ‘yellow button’ is the enabling condition, whereas the ‘blue button’ is the cause. We constructed four versions of each scenario, testing one independent variable. The independent variable was whether the enabling condition was mentioned first or last in sentence one, e.g.,

‘If the blue button is pressed, then if the yellow button is pressed the lamp flashes. However, if the yellow button is not pressed, the lamp does not flash if the blue button is pressed.’
We also counterbalanced which of the two events was the cause and the enabling condition, e.g.,

‘If the yellow button is pressed, then if the blue button is pressed the lamp flashes. However, if the blue button is not pressed, the lamp does not flash if the yellow button is pressed.’

There were eight different contents and a full set of the materials can be seen in Appendix D5 (p.223).

**Design**

Participants were asked to identify the cause and the enabling condition for eight scenarios. In this experiment we only manipulated whether the enabling condition appeared as the first or the second event in sentence 1. We also counterbalanced which of the two events appeared as the enabling condition. Accordingly there were four versions of each content (Appendix D5 contains a full set of the materials, p.223). Each participant saw eight scenarios, one of each content and four each of the two different versions (In version 1 the enabling condition appeared first in sentence 1 and in version 2 the enabling condition appeared second in sentence 1). Each scenario together with the questions for the cause and the enabling condition was presented on a new page of an A5 booklet. The scenarios were presented in different random orders.

**Procedure**

Participants were Trinity College students who were tested in groups of 1-3 people. They were given the A5 booklet with an instructions sheet attached to the front. The following is an extract from the instructions participants received (see Appendix D4 for the full instructions, p.222):

This booklet contains eight descriptions, which each refer to two preceding events and an outcome. Each description is followed by a question asking you to identify what causes the outcome, and a question asking you to identify what enables the outcome to occur. A cause brings about an event, whereas an enabling condition makes it possible for the cause to work. Please be sure to select one preceding event as the cause and the other preceding event as the enabling condition. Which is which, of course, is for you to decide.
Each scenario was followed by a question about what causes the outcome and what enables the outcome:

Which one of the two events enables the lamp to flash (i.e. makes it possible for the cause to work) and which of them causes the lamp to flash (i.e. brings about the event)?

The questions were presented in counterbalanced order. There was no time limit and completion of the task took approximately 10 minutes.

Participants

Participants were Trinity College students and one visiting transition year school pupil who received course credit or 4 euro for their participation. Twenty-seven people participated in this study, 8 men and 19 women and their mean age was 24 years, with a range from 15 to 51 years.

Results and discussion

The 27 participants provided 216 trials for analysis, although 4 trials had to be excluded as participants had failed to distinguish between causes and enabling conditions on those trials. The results are in Table 5.8. Participants identified the event predicted by the mental model theory as the enabling condition somewhat more often than not, but this difference was not reliable (a mean of 4.2 trials versus 3.6, Wilcoxon’s $z = .72, p = .47$).

Table 5.8: Mean number of trials consistent with MM and location of enabler in first sentence, with standard deviations in parenthesis

<table>
<thead>
<tr>
<th></th>
<th>MM</th>
<th>not-MM</th>
<th>First</th>
<th>Last</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mean</td>
<td>4.2 (2.4)</td>
<td>3.6 (2.4)</td>
<td>5.6 (2.1)</td>
<td>2.3 (2.1)</td>
</tr>
</tbody>
</table>

Participants identified the event presented first in the scenarios more often as the enabler than the event presented second in the scenario, e.g., when the scenario was ‘if the yellow button is pushed then if the blue button is pushed the lamp flashes’ participants tended to identify the yellow button as the enabler rather than the blue button, regardless of what information they were presented with in the second part of the scenario, (a mean of 5.6 trials versus a mean of 2.3 trials) and this difference was reliable; Wilcoxon’s $z = 3.1, p$
The results indicate that participants were guided by the perceived temporal sequence of events rather than by the possibilities associated with them. Another possibility is that the instructions may have biased participants to pay attention to the temporal sequence of events. In the instructions we described an enabling condition as 'makes it possible for a cause to work'; participants may have interpreted the instructions as meaning an enabling condition occurs prior to a cause.

Summary
This experiment demonstrates that participants may be most sensitive to the temporal sequence of events when distinguishing between causes and enabling conditions. On a mean of 5.6 trials participants identified the first event as the enabling condition compared to a mean of 2.3 trials on which they chose the second event as the enabling condition. However, one possibility is that the instructions are responsible for this finding. There was no difference in the number of participants making causal assignments in line with the mental model theory and against the mental model theory's predictions.

General Discussion
The aim of this chapter was to examine further the distinction between causes and enabling conditions. In particular we aimed to investigate some of the factors people take into account when distinguishing between causes and enabling conditions. We predicted that participants would make their decisions by considering the possibilities that are consistent with the scenarios we gave them. A second aim was to examine whether inconsistent information is dealt with differently for causes and enabling conditions. In the remainder of this section we summarise the results of the two experiments reported in this chapter. We will then discuss the results with reference to other theories of causality.

Summary of findings
Experiment 7 (n = 18) demonstrated that consistent and inconsistent information is dealt with differently when making attributions of different causal roles. According to the mental model theory causes and enabling conditions are consistent with different possibilities. The descriptions we gave people were designed to demonstrate that each of the two causal factors was consistent with different possibilities. In this experiment we tested whether participants' sensitivity to these different possibilities would cause them to change the causal attributions they had made after the first sentence if the new information was inconsistent. For enabling conditions participants tended to respond in line with the different possibilities, as predicted by the mental model theory.
On consistent trials participants tended to identify the same event as the enabling condition after reading the second sentence as they did after reading the first sentence (88% maintained the same identification). On inconsistent trials just over half of the participants correctly switched their identification of enabling condition to the other event. Participants did not respond in line with the different possibilities set out for causes and enabling conditions when they were identifying the cause of the event.

Only half of the participants (58%) maintained their identification of a particular cause on consistent trials. On inconsistent trials the majority of participants (82%) incorrectly maintained their identification of the cause after reading the second sentence, thereby identifying the event disambiguated as the enabling condition as the cause.

The results for the enabling conditions showed that participants found it difficult to identify enabling conditions from the first sentence. We expected this difficulty as the first sentence in each trial was ambiguous as to the individual causal roles. Some participants used the word ‘given’ as a guide for identifying the enabling condition (Kuhnmünnich & Beller, 2005) and some participants did not distinguish between causes and enabling conditions, identifying both events as joint cause and enabling condition. For some of the materials participants were able to use their general knowledge to distinguish between causes and enabling conditions (e.g., they identified ‘being sensitive’ as the enabling condition and ‘being insulted’ as the cause for ‘a person becoming angry’). However, the results suggested that when participants were given both pieces of information they were able to distinguish between the different possibilities and therefore tended to correctly maintain their identifications of the enabling condition on consistent trials and switch their identification on inconsistent trials.

For the attribution of cause participants did not present the same pattern of responses as they did for the enabling conditions. A possibility for these differences is that the descriptions we gave participants highlight the possibility where the cause appears without the enabling condition and therefore there is no effect:

\[
\text{cause} \quad \text{no enabler} \quad \text{no effect}
\]

This possibility highlights the necessity of the enabling condition and emphasises the dependence of the cause on the enabling condition. Participants may therefore have focussed on the necessity of the enabling condition and attributed it both a causal and an enabling role, as evidenced by a tendency of some to identify the event disambiguated as the enabling condition as both the cause and the enabling condition. A second possibility is that participants considered the two sentences in isolation. When the second sentence is considered in isolation only one antecedent event (the event identified as the enabling
condition) has a causal role. When we consider the results for the enabling conditions together with the results for the causes, we cannot firmly conclude that participants were able to distinguish causes and enabling conditions based on different possibilities.

In Experiment 8 we examined some of the factors that influence people’s identification of cause and enabling condition. Participants were given scenarios like the ones used in Experiment 7, but this time both sentences were presented together. We first conducted two pre-tests (n = 6 and n = 6) of the materials in which we established that the word 'given' was guiding participants’ identification of the enabling condition. On a mean of 6.5 trials participants identified the event paired with the word ‘given’ as the enabling condition, compared to a mean of 1.5 trials on which they chose the event not paired with the word ‘given’. The finding that the word ‘given’ acted as a linguistic cue for identifying enabling conditions is support for Kuhnmünch and Beller’s (2005) criticism of Goldvarg and Johnson-Laird (2001).

The pre-test supported Kuhnmünch and Beller’s claim that the word ‘given’ can act as a linguistic cue, and we wanted to investigate people’s ability to distinguish causes and enabling conditions based on the possibilities each of the events is consistent with. Accordingly, in Experiment 8 (n = 27) we used materials which did not include the linguistic cues ‘given’ and ‘even if’ and did not refer to events for which participants could use their general knowledge. We manipulated whether the event identified as the enabling condition in the second sentence appeared first or second in the first sentence. Participants were asked to identify one event as the cause and the other as the enabling condition. The results of the experiment demonstrated that participants were more sensitive to the temporal sequence of the events, identifying the first event as the enabling condition on a mean of 5.6 trials (out of 8), than to the different possibilities each of the events was consistent with. Although causes and enabling conditions are consistent with different possibilities, participants in this experiment demonstrated a tendency to engage in a less effortful process for making their decision by basing their identifications on the temporal cue. Although, we cannot rule out an effect of instructions on participants’ responses.

**Implications of findings for other theories of causality**

The results of the experiments reported in this chapter demonstrate that people consider a variety of factors when they distinguish between causes and enabling conditions. The results of Experiment 7 suggest that there is a difference between causes and enabling conditions and that people may be able to consider different possibilities when they differentiate between causes and enabling conditions. In Experiment 7 there was also not a
reliable effect of the linguistic cue ‘given’ on the causal assignments participants made (pace Kühnmünch & Beller, 2005). It is not clear how the other theories of how causes and enabling conditions are distinguished, outlined in the introduction of this chapter, can account for the findings of Experiment 7. The fact that causes and enabling conditions are revised differently cannot be explained by differences in constancy (Cheng & Novick, 1991) or normality (Hart & Honoré, 1959/1985). The theory of conversational relevance may be able to account for some of the findings of Experiment 7. According to Hilton (1990) causes and enabling conditions are selected based on relevance to a why question. This dependence on a particular ‘why question’ means that in any given scenario any of the necessary events can take on the role of cause. As mentioned in the previous section, the second sentence of the scenarios used in Experiment 7 highlights the necessity of the enabling condition while at the same time playing down the sufficiency of the cause. Conversational relevance theory can perhaps account for why participants selected the event highlighted as necessary as the cause. However, this theory cannot explain why participants would then also say the same event is the enabling condition. According to relevance theory enabling conditions are part of the causal background and should therefore be treated separately from causes. As a result the same event could not be identified as both the cause and the enabling condition.

Experiment 8 lends some support to some of the other theories of causality. The results of the second pre-test for Experiment 8 are consistent with Kühnmünch and Beller’s (2005) assertion that the expression ‘given that’ acts as a linguistic cue for identifying enabling conditions. However, Experiment 7 demonstrated that this is not the only cue people use. Experiment 8 indicates that people are sensitive to the temporal sequence of events in the absence of other cues, such as actions versus states and linguistic cues such as ‘given’. This sensitivity to temporal sequence fits with Mill’s (1843/1973) analysis of how causes and enabling conditions can be distinguished. According to Mill enabling conditions occur prior to causes.

**Conclusions**

The experiments reported in this chapter suggest that the distinction between causes and enabling conditions is difficult to capture experimentally. The experiments suggest that people are sensitive to multiple cues when assessing causal roles. Previous research has suggested that temporal sequence, normality and relevance to conversation are not necessary for distinguishing between causes and enabling conditions (Cheng & Novick, 1991). In discovering that these characteristics are not always necessary, it is important to
acknowledge that these characteristics do play a role and that people are sensitive to them. It seems prudent to devise a set of experiments which systematically examine the contribution of each of these characteristics and identify whether different individuals are sensitive to different cues or whether certain cues take priority over other cues.

The results of Experiment 8 also call into question the findings of Goldvarg and Johnson-Laird’s Experiment 2, as their descriptions were confounded with the word ‘given’. However, the results from our priming experiments and Goldvarg and Johnson-Laird’s reasoning experiment (as described in the introduction to this chapter) support the idea that causes and enabling conditions are consistent with different possibilities. It appears that the descriptions used by Goldvarg and Johnson-Laird as well as in the experiments reported here may not be as effective in conveying the different possibilities as previously thought.

The two experiments reported in this chapter have demonstrated that people may consider different possibilities when considering different causal roles (as in Experiment 7), but that care must be taken not to confound materials with linguistic cues such as ‘given’ or instructions which may bias participants to respond in a particular way.
Chapter 6  Discussion

We explored two research questions in this thesis. The first research question examined the mental representation of factual and counterfactual causal conditionals. Previous research has demonstrated that factual conditionals tend to be understood by keeping in mind one possibility, whereas counterfactual conditionals tend to be understood by keeping in mind two possibilities (e.g., Byrne & Tasso, 1999). We intended to add to this research in two ways. Firstly, we examined causal counterfactual conditionals. We suggested that causal conditionals are understood by keeping in mind different possibilities for different causal relations. We investigated how an understanding of different causal relations might be affected by a counterfactual phrasing of the relation. Secondly, we made use of a novel, paraphrasing, methodology to investigate differences between factual and counterfactual causal conditionals. We also examined the effect of context on the inferences people make from causal counterfactual conditionals. We created a context by preceding the conditionals with stories that emphasise the facts and suggest a counterfactual alternative.

The second research question concerned the mental representation of different causes, namely strong causes, weak causes and enabling conditions. We examined the prediction made by the mental model theory that different types of causes are understood by keeping different possibilities in mind. We also examined the distinction between causes and enabling conditions. The mental model theory predicts that causes and enabling conditions are understood by keeping in mind different possibilities and can therefore be distinguished by considering these possibilities. We examined people’s ability to distinguish causes and enabling conditions and investigated the effect of inconsistent information on people’s distinction between causes and enabling conditions. Our research tested predictions made by the mental model theory. We also evaluated how alternative theories can account for our findings. In the 8 experiments reported in this thesis we used a variety of methods to investigate these predictions.

This chapter is divided into three main sections. We first summarise the main findings of the experiments examining people’s mental representation of factual and counterfactual causal conditionals, the effect of context on the inferences people make from causal counterfactual conditionals, and the mental representation of different causes and the differences between causes and enabling conditions. We consider the implications of these findings on theories of conditional reasoning. In the second section we consider the implications of the findings reported in this thesis for advancing our understanding of
different causes, counterfactual conditionals and the mental model theory. In the third and final section we consider some strengths and limitations of the research reported in this thesis and make suggestions for future work in this area.

Summary of findings

In Chapter 2 we investigated the effect of context on the inferences people make from causal counterfactual conditionals. In Chapter 3 we reported two experiments which examined the mental representation of factual ("if Joe cut his finger then it bled") and counterfactual ("if Joe had cut his finger then it would have bled") causes using a paraphrasing methodology. In Chapter 4 we reported two experiments which investigated the mental representation of different causes, strong causes, weak causes and enabling conditions, by using a priming methodology. In Chapter 5 we examined differences between causes and enabling conditions by examining how inconsistent information is dealt with and how people judge which of two events is the cause and which is the enabling condition.

The mental representation of factual and counterfactual causal conditionals

We examined the effect of context on the inferences people make from causal counterfactual conditionals (Chapter 2) as well as the differences between factual and counterfactual conditionals by comparing inferences in Experiment 1 and by using a paraphrasing paradigm in the two experiments reported in Chapter 3.

Inferences study

In Chapter 2 we reported two experiments (Experiments 1 and 2) in which we examined the inferences people make from counterfactual conditionals. We compared participants’ inferences when they first read a story which presented the facts of the situation mentioned in the conditional to when they were not aware of the facts.

In Experiment 1 we tested three conditions. Sixty-three participants received three conditionals and were asked to make four inferences, modus ponens (MP), modus tollens (MT), denial of the antecedent (DA) and affirmation of the consequent (AC). The ‘known counterfactual’ group first read stories from which each of the conditionals was derived (one story for each of the three conditionals). The stories emphasised the facts and also suggested a counterfactual alternative which would have led to a better outcome. One of the stories described a girl, Jane, who sprained her ankle the day before taking part in an Olympic 400 metre race. The side effects of the pain killer she took to treat the injury caused her to finish only in 4th place. The counterfactual alternative mentioned in the story
was that she had a choice between two drugs. The story also suggested that other athletes took the alternative drug and suffered no side effects. Therefore, the counterfactual alternative suggested a better outcome. The counterfactual conditional from which participants had to make inferences was about this counterfactual alternative, e.g., ‘if Jane had taken the newer drug she would have won the race’. The second group of participants, the ‘presuppositional counterfactual’ group, received only the counterfactual conditionals without first reading the stories, and the third group of participants, the ‘factual group’, received only a factual conditional in the indicative mood (e.g., ‘if Jane took the newer drug then she won the race’).

The experiment yielded two main results. Firstly, it corroborated previous findings of the difference between factual and counterfactual conditionals: participants made more of the negative inferences, MT and DA, from a counterfactual than from a factual conditional; for MT 81% versus 58% and for DA 46% versus 20%. A counterfactual conditional is understood by keeping in mind two possibilities, the conjecture and the presupposed facts, whereas a factual conditional is typically understood by just keeping in mind one possibility. This difference in representation means that it is easier to make the negative inferences from a counterfactual conditional than from a factual conditional as the relevant model is already mentally represented for the counterfactual, whereas the representation of the factual conditional must be fleshed out before making the negative inferences.

This experiment demonstrated that the pattern of inferences made from factual and counterfactual causal conditionals is the same as the pattern of inferences made from factual and counterfactual conditionals with non-causal content. Counterfactual causal conditionals result in more negative inferences (MT and DA) than factual conditionals.

Secondly, the experiment demonstrated that preceding a counterfactual conditional with a story which emphasises the facts has an effect on the inferences participants are willing to make. Contrary to our expectations, the story did not merely lead to a reduction in the affirmative inferences, MP and AC. Instead, the story appeared to modulate participants’ interpretation of the conditional, resulting in a reduction in the frequency of making the MP and MT inferences. When the inference task was preceded by a story, participants made the MP inference on 49% of trials, compared to 86% of trials when they considered the counterfactual conditional in isolation and they made the MT inference on 45% of trials compared to 81% of trials. This reduction in MP and MT inferences suggests that participants had doubt in the counterfactual alternative (‘if she had taken the newer drug she would have won the race’). However, the ‘if only’ thoughts generated in the
‘known counterfactual’ condition demonstrated that participants did tend to consider the alternative described in the counterfactual conditional. But they tended only to generate the antecedent of that conditional, which suggests that they were not willing to assert with confidence that the alternative would have resulted in the desired change. Perhaps, participants found it difficult to imagine that only one thing would have been altered and therefore, something else might have prevented the alternative outcome.

In Experiment 2 (n = 86) we examined the effect of the story by varying the amount of information provided. We wanted to pin point whether it was the mentioning of the facts (‘she lost the race’), the mentioning of a counterfactual alternative (‘she had to choose between two drugs’) or the mentioning of a counterfactual alternative together with information about how it would have been better (‘other athletes took the newer drug and suffered no side effects’) which was the cause for the pattern of results observed in Experiment 1. Perhaps mentioning a counterfactual alternative without information on how that alternative would have been better would have an even more marked effect on the MP and MT inferences made by participants, as this condition suggests an alternative without providing information on whether this alternative would have made any difference.

We tested four conditions. In the first condition, the ‘presuppositional counterfactual’ group, participants received only the counterfactual conditionals without the stories. The second, ‘known facts counterfactual’, group received the stories, but the information about the counterfactual alternative (e.g., Jane had to choose between two drugs) was omitted. The third, ‘suggested counterfactual’, group received the stories together with information about a counterfactual alternative, but the stories contained no information about how the alternative would have been better (e.g., other athletes took the newer drug and suffered no side effects). Finally, the fourth, ‘known counterfactual’, group received the stories in full, that is, the stories suggested a counterfactual alternative together with information on how this alternative would have been better.

We replicated the findings of the previous experiment in that a story emphasising the facts and suggesting a counterfactual alternative resulted in a reduction in the frequency of making the MP and MT inferences, but had no effect on the frequency of making the DA and AC inferences. In addition, this experiment allowed us to identify what aspect of the story was responsible for this effect.

We observed a graded effect of the story conditions on the frequency of making the MP and MT inferences. In the ‘presuppositional counterfactual’ condition participants made the MP inference on 86% and the MT inference on 81% of trials. In the ‘known facts counterfactual’ condition they made the MP inference on 68% and the MT inference on
59% of trials. In the two conditions which mentioned a counterfactual alternative they made the MP inference on 46% and on 42% of trials and the MT inference on 35% and on 48% of trials.

There was only a marginal effect of presenting a story which contained the facts (e.g., 'Jane only came in 4\textsuperscript{th} due to the side effects of the pain killer she took') but no counterfactual alternative (e.g., the fact that she chose between two drugs) on the frequency of making the MP and MT inferences compared to the 'presuppositional counterfactual' condition, in which participants received the conditional without a story. Reading a story which suggested a counterfactual alternative ('she had to choose between two drugs') resulted in a clear reduction in the frequency of making the MP and MT inferences, regardless of whether participants received more detailed information about this alternative (e.g., 'other athletes who took the alternate drug suffered no adverse side effects').

Presenting people with a counterfactual alternative ('she had a choice between two drugs') has a more profound effect on people's interpretation of a counterfactual conditional than presenting them with the facts only ('she suffered from side effects and only came 4\textsuperscript{th}'). The counterfactual alternative appears to initiate a process whereby people consider other alternatives and as a result lose their confidence in the effectiveness of the original alternative.

The patterns of inferences made by participants is consistent with an enabling interpretation of the conditional (Johnson-Laird & Byrne, 2002). An enabling condition makes an outcome possible, but the presence of the enabling condition is no guarantee for the presence of the outcome. Participants in the two experiments tended to interpret the counterfactual conditional as an enabling condition when it was preceded by a story which included a counterfactual alternative. Providing participants with one counterfactual alternative may encourage them to consider other possibilities too.

**Paraphrasing experiments**

In Chapter 3 we reported two experiments (n = 29 and n = 41) in which we examined the mental representation of causal conditionals phrased in the indicative and the subjunctive mood, that is, factual and counterfactual conditionals. Participants were presented with factual and counterfactual conditionals describing different causal relations (strong, weak and enabling) and asked to paraphrase the conditionals without using the word 'if'. Participants used a variety of connectives to paraphrase the conditionals.
We identified a subgroup of connectives as consistent with one possibility and another subgroup as consistent with multiple possibilities. Connectives consistent with one possibility are temporal connectives such as ‘when’ and conjunctions (‘and’). Connectives consistent with multiple possibilities are causal connectives, such as ‘because’ and conditional connectives, such as ‘provided’. In addition participants made use of subjunctive constructions, such as ‘had Joe cut his finger it would have bled’, which are also consistent with multiple possibilities.

Consistent with our predictions, participants in both experiments had a tendency to use different connectives to paraphrase factual and counterfactual conditionals. As expected, between 54% and 61% of the factual conditionals in both experiments were paraphrased by using connectives that reflect that people were keeping a single possibility in mind, such as temporal connectives like ‘when’. Only approximately 30% of counterfactual conditionals were paraphrased using single possibility connectives.

Counterfactual conditionals were predominantly paraphrased using connectives and phrasings which reflect that people were keeping multiple possibilities in mind, consistent with our predictions. In both experiments approximately 70% of counterfactual conditionals were paraphrased using connectives and phrasings that reflect multiple possibilities, such as causal connectives like ‘because’ and subjunctive phrasings like ‘had Joe cut his finger it would have bled’. In both experiments only about 40% of the factual conditionals were paraphrased using these multiple possibility rephrasings.

The findings that factual conditionals are paraphrased using connectives that reflect a single possibility and counterfactual conditionals are paraphrased using connectives and phrasings that reflect multiple possibilities are consistent with previous research which examined differences between factual and counterfactual conditionals (Byrne & Tasso, 1999; Santamaria et al., 2005; Thompson & Byrne, 2002) as well as predictions made by the mental model theory (Johnson-Laird & Byrne, 2002).

Other theoretical accounts of findings

In Chapters 2 and 3 we considered how other theories of conditional reasoning can account for the context effects reported in Chapter 2 and the differences between factual and counterfactual conditionals reported in Chapters 2 and 3. We considered mental logic theories (Braine & O’Brien, 1998), domain specific rule theories (Cheng & Holyoak, 1985; Fiddick et al., 2000) and the suppositional theory of if (Evans & Over, 2004) and we also considered whether the use of subjunctive constructions to paraphrase counterfactual conditionals in Chapter 3 could be accounted for by a more superficial strategy.
Mental logic theories do not provide a detailed account of how context affects the inferences people make. However, they assert that context may invite the logically invalid inferences DA and AC (Braine & O'Brien, 1998). Politzer and Braine (1991) suggest that context can affect the believability of premises and thereby have an effect on the inferences people make. They may therefore argue that the stories which included a counterfactual alternative had an effect on the believability of the conditional and as a result led to a reduction in the frequency of making the MP and MT inferences. However, it is not clear how the stories would have reduced the believability of the conditionals. If the stories affected the believability of the conditional, then they should have increased the believability of the conditionals, particularly in the ‘known counterfactual’ condition where we provided information on how the counterfactual alternative would have been better.

Mental logic theories do not have a corroborated account of counterfactual conditionals. Factual and counterfactual conditionals have the same logical form and thus no differences are predicted between the two as the same rules are applied to the two sorts of conditionals. Although, O'Brien, Dias, Roazzi, and Braine (1998) suggest that a counterfactual leads to a contradiction and its proposition should therefore be ignored. Mental logic theories are therefore unable to account for the finding that counterfactual conditionals led to more MT and DA inferences.

Mental logic theories also make no predictions about the number of possibilities a factual or counterfactual conditional is consistent with. They cannot therefore explain why a factual conditional is paraphrased using connectives reflecting a single possibility (e.g., Joe’s finger bled when he cut it’) and a counterfactual is paraphrased using connectives and phrasings that reflect multiple possibilities (e.g., ‘had Joseph cut his finger it would have bled’ or ‘Joseph’s finger bled because he cut it’).

Pragmatic reasoning schemas and domain general rules focus on very specific content effects and have been able to account for perspective effects found in domains such as permissions and obligations (Holyoak & Cheng, 1995). It is not clear how these theories can account for the context effects found in Experiments 1 and 2. The effects found seem to derive from the presence of a counterfactual alternative, not from the specific content of the conditional (i.e., a causal relation). Quelhas and Byrne (2003) suggest that reasoning well need not depend on situations that elicit specific rules and schemas, instead they propose that particular situations can act to clarify relevant counterexamples. In the two experiments reported in Chapter 2 it appears that the counterfactual alternative may have prompted participants to consider counterexamples.
Domain specific rule theories focus on the content of a conditional. They make no predictions about the use of different linguistic mood or tense (Egan, 2005). Accordingly, a factual conditional such as, ‘if the apples were ripe then they fell from the tree’ should be understood in the same way as a counterfactual conditional such as, ‘if the apples had been ripe then they would have fallen from the tree’. The results from the two paraphrasing experiments reported in Chapter 3 indicate that there are differences between factual and counterfactual conditionals. Participants in these two experiments were more sensitive to the mood of the conditional than to the content of the conditional as evidenced by differences in the connectives used to paraphrase factual and counterfactual conditionals and no differences in the connectives used to paraphrase different causes.

Domain specific rule theories are also unable to account for the difference in the frequency of making the negative inferences from a counterfactual conditional. This difference can only be explained by the difference in linguistic mood. However, domain specific rule theories focus on content only.

Evans and Over (2004) recognise the effects of pragmatics and believability on the inferences people make. Like mental logic theories, they may therefore argue that the counterfactual alternative had an effect on the believability of the conditional and as a result led to a reduction in the frequency of making the MP and MT inferences. Again it is not clear how the mentioning of a counterfactual alternative could have had an effect on the believability of the counterfactual.

The suppositional theory proposes that people understand all conditionals by keeping only one relevant possibility in mind (Evans et al., 2003). This theory therefore cannot explain why participants used different connectives to paraphrase factual and counterfactual conditionals, nor can this theory explain the difference in making the negative inference from the counterfactual conditional.

In Chapter 3 we considered the possibility that the use of subjunctive constructions to paraphrase counterfactual conditionals could be the result of a superficial strategy which complies with the task demands. Participants may have used subjunctive constructions as they appreciate that subjunctive constructions imply two possibilities, the counterfactual conjecture as well as the presupposed facts. Alternatively, they may have used this strategy because it complied with the task demands. Previous research on counterfactual conditionals suggests that people appreciate that the subjunctive phrasing implies multiple possibilities and would therefore favour the proposal that people use subjunctive constructions because they imply multiple possibilities.
We demonstrated that factual conditionals are predominantly paraphrased using connectives that reflect a single possibility. Participants could have used temporal connectives as part of their subjunctive construction, e.g., ‘Joe’s finger would have bled when he cut it’, but they chose not to include such a connective which would have hinted at only one possibility.

The research reported in Chapters 2 and 3 provides additional and converging evidence for the suggestion that factual and counterfactual conditionals are understood by keeping in mind different possibilities. Factual conditionals are understood by keeping in mind one possibility, whereas counterfactual conditionals are understood by keeping in mind multiple possibilities.

**The mental representation of different causes**

The aim of the six experiments reported in Chapters 3, 4 and 5 was to examine the mental representations of different causes. In Chapters 3 and 4 we examined strong causes, such as ‘if Joe cut his finger then it bled’, weak causes, such as ‘if the apples were ripe then they fell from the tree’ and enabling conditions such as ‘if the ignition key was turned then the car started’. In Chapter 5 we examined the distinction between causes and enabling conditions more closely.

Different types of causes are consistent with different possibilities (Johnson-Laird & Byrne, 1991). A strong cause is both necessary and sufficient and people cannot think of any counterexamples for why the effect might have happened or be prevented. According to the mental model theory, a strong cause is consistent with two possibilities ‘Joe cut his finger and it bled’ and ‘Joe did not cut his finger and it did not bleed’.

A weak cause is sufficient to bring about an effect but it is not necessary and people can readily think of alternative causes that would have led to the same outcome. According to the mental model theory, a weak cause is consistent with three possibilities, ‘the apples were ripe and they fell from the tree’, ‘the apples were not ripe and they fell from the tree’, and ‘the apples were not ripe and they did not fall from the tree’.

An enabling condition is necessary, but not sufficient to bring about an effect and people can readily think of counterexamples that would have prevented the enabling condition from exerting its effect. According to the mental model theory, an enabling condition is consistent with the following three possibilities; ‘the ignition key was turned and the car started’, ‘the ignition key was turned and the car did not start’, and ‘the ignition key was not turned and the car did not start’. We expected these different possibilities to be reflected in the mental representations people form of different types of causes.
In Chapter 3 we reported two experiments in which we examined people’s paraphrases and in Chapter 4 we reported two experiments which made use of a priming methodology to investigate these mental representations. In Chapter 5 we reported two experiments in which we investigated how people distinguish between causes and enabling conditions.

Paraphrasing experiments

In Chapter 3 we described two experiments (Experiments 3 and 4) in which we examined participants’ mental representations of different causes by means of a paraphrasing task. In Experiment 3 participants were presented with conditionals describing strong causes, weak causes, and enabling conditions and asked to paraphrase the conditionals without using the word ‘if’. Half of the conditionals were presented in the indicative mood (factual) and half were presented in the subjunctive mood (counterfactual). In Experiment 4 these conditionals were presented in a context which emphasised the different causal relations.

In both experiments, against our predictions, the paraphrases participants made were only guided by the mood of the conditional rather than by the type of cause the conditional was describing. Approximately half of factual strong causes were paraphrased using connectives that reflect that participants were keeping a single possibility in mind. About 55% of factual weak causes were paraphrased using single possibility connectives and 60% of factual enablers were paraphrased using single possibility connectives. Whereas 62% (Experiment 3) and 76% (Experiment 4) of counterfactual strong causes were paraphrased using connectives that reflect that participants were keeping multiple possibilities in mind. Weak counterfactuals were paraphrased using multiple possibility rephrasings on approximately 70% of trials and counterfactual enablers were paraphrased using multiple possibility rephrasings on 65% of trials.

The paraphrasing task may not be a measure sensitive enough to detect the differences between different types of causes. Ormerod et al. (1993) suggest that people tend only to consider a single model for a paraphrasing task. The different sorts of causes can only be differentiated by considering multiple possibilities and participants may have only considered other possibilities when prompted by the mood of the conditional (i.e., for counterfactual conditionals).

In Experiment 4 participants may have focused on differentiating factual and counterfactual conditionals as the materials were presented together in different random orders. One possibility is that the mood of the conditional takes precedence over the content when understanding a causal conditional. Both the pre-test and the post-test for
Experiment 4 allow us to exclude the possibility that the different causal relations were not distinguishable from the materials.

**Priming experiments**

In Experiment 5 (n = 22) we compared the priming effects of conditionals describing enabling conditions to a baseline condition. Participants were given scenarios consisting of 7 sentences, or sentence fragments, such as:

- **Line 1**: Martin was telling Laura about his medicine bottle.
- **Line 2**: He told her that the lid had to be squeezed for it to open.
- **Line 3**: He also said
- **Line 4**: If the lid was twisted then the bottle opened.
- **Line 5**: When Martin showed Laura the bottle, she saw that
- **Line 6**: The lid was twisted and the bottle opened.
- **Line 7**: Laura went to get a drink.

The materials were tested in a pre-test (n = 18) and the 24 most suitable materials were selected for the experiment.

These scenarios were presented on a computer screen one line at a time. Participants determined the speed of presentation by pressing the space bar to move on to the next sentence. We measured the reading times for the conjunctions presented in line 6 (e.g., ‘the lid was twisted and the bottle opened’). The enabling interpretation was emphasised by mentioning an additional requirement in the second line of the scenarios (Byrne, 1989). In the baseline condition participants read a statement about the location or the colour of the antecedent of the conditional (e.g., ‘the lid on the bottle was white’) instead of reading the conditional in line 4. We used a within participants design and presented both conditions together in different random orders.

The results of Experiment 5 show that participants read the possibility in which both antecedent and consequent were present (e.g., ‘the lid was twisted and the bottle opened’) reliably faster (465 milliseconds) when they were primed by an enabling condition than in the baseline condition. They read the possibility in which the antecedent is present and the consequent is absent (e.g., ‘the lid was twisted and the bottle did not open’) reliably faster (404 milliseconds) when they were primed by an enabling condition than in the baseline condition. As predicted there was no reliable difference for the reading times of the possibility where the antecedent is absent and the consequent is present (‘the lid was not twisted and the bottle opened’). Against our predictions, there was no reliable difference for the reading times for the possibility where both the antecedent and the
consequent were absent ('the lid was not twisted and the bottle did not open'). The experiment supported three out of four of our predictions. Conditionals describing enabling conditions had a priming effect on two of the three consistent possibilities.

The results indicate that participants kept in mind only two of the three consistent possibilities. The mental model theory predicts that an enabling condition is consistent with three possibilities. However, the theory also acknowledges that due to working memory constraints people may not be able to keep all consistent possibilities in mind (Johnson-Laird & Byrne, 2002). The results indicate that the two most salient possibilities were the possibilities where both components are present and the possibility where the enabling condition is present but the effect does not occur (as the additional requirement is not fulfilled). The finding that participants were able to keep two possibilities in mind is inconsistent with Evans and Over's suggestion that people only keep one possibility in mind.

In Experiment 6 we used the same methodology to examine the priming effects of strong causes and weak causes. For weak causes the second sentence described an alternative cause to the one mentioned in the conditional (e.g., 'he told her that the bottle opened when it was thrown on the floor'). For the strong causes the second sentence was replaced with information about the antecedent of the conditional. This description was either about the colour or the location of the antecedent (e.g., 'he told her that the lid on the bottle was white'). In the baseline condition we replaced the conditional in line 4 ('if the lid was twisted then the bottle opened') with the same information used in the strong cause condition to replace the second sentence ('the lid on the bottle was white'). We pre-tested the materials on 48 participants.

Twenty-nine participants took part in the experiment. As predicted, the possibility in which both components occur (e.g., 'the lid was twisted and the bottle opened') was read reliably faster (508 milliseconds) when it was primed by a strong cause compared to the baseline condition. As predicted, the possibility in which neither of the two components appeared (e.g., 'the lid was not twisted and the bottle did not open') was read reliably faster (548 milliseconds) when it was primed by a strong cause, as predicted. We expected both of these possibilities to be primed by a strong cause. We did not expect the possibility in which the cause occurs and the effect does not occur to be primed (e.g., 'the lid was twisted and the bottle did not open'). However, this possibility was read 523 milliseconds faster when it was primed by a strong cause than in the baseline condition. As predicted, the possibility in which the antecedent does not occur, but the consequent does ('the lid was not twisted and it opened') was not primed by a strong cause. For strong
causes three out of four predictions were met. Strong causes primed the two consistent possibilities, as predicted. However, they also primed one of the inconsistent possibilities when compared to the baseline condition.

For weak causes, as expected, the possibility in which both cause and effect are present was read reliably faster (378 milliseconds) when it was primed by a weak cause compared to the baseline condition. As expected, the possibility in which the cause does not occur, but the effect still occurs (e.g., 'the lid was not twisted and the bottle opened') was read reliably faster (708 milliseconds) when it was primed by a weak cause compared to the baseline condition. The fact that these two possibilities were primed by a weak cause is consistent with our predictions. We predicted that the possibility in which neither cause nor effect occur might also be primed by a weak cause. However, consistent with the findings of Experiment 5, participants kept in mind only two of the three consistent possibilities.

Surprisingly, weak causes, like strong causes, primed the false possibility where the cause is present and the effect is absent (e.g., 'the lid was twisted and the bottle did not open'). This possibility was read 550 milliseconds faster following a weak cause than in the baseline condition. The results for weak causes were consistent with two of our predictions and went against two of our predictions. Weak causes primed two of the three consistent possibilities. They primed the single inconsistent possibility as well.

One possibility is that there are two mechanisms at work, a basic order of processing mechanism and an interpretational mechanism. The different conjunctions may be processed at different speeds by virtue of their components, for example, the processing of negated components of a conditional is more effortful than of non-negated components (Schroyens et al., 2001b). Accordingly, following a conditional, a conjunction of the two non-negated components ('the lid was twisted and the bottle opened') should be read more quickly than any of the other conjunctions. The possibility where the antecedent is present and the consequent is absent ('the lid was twisted and the bottle did not open') should be processed more quickly than a conjunction where the antecedent of the conditional is absent/negated. Hence, the priming of this possibility in the two experimental conditions in Experiment 6 may be explained by the order of processing. However, it does not explain our other findings in these experiments. The priming of consistent possibilities for the three sorts of causes is better accounted for by an interpretational mechanism. The interpretational mechanism is responsible for considering the content of the conditionals and the possibilities which are consistent with them.
Assigning causal roles (causes and enabling conditions)

In Chapter 5 we investigated the differences between causes and enabling conditions. Experiment 7 demonstrated that consistent and inconsistent information is dealt with differently when making attributions of different causal roles. In Experiment 8 we examined some of the factors that influence how a person attributes the roles of cause and enabling condition.

In Experiment 7 eighteen participants were given descriptions consisting of two antecedent events and an outcome (e.g., ‘Given that there is fertilizer, if the sun shines then the plants grow’). Participants were asked to identify the event that causes the outcome (e.g., ‘what causes the plants to grow, i.e., brings about the event’) and the event that enables the outcome to occur (e.g., ‘what allows the plants to grow, i.e., makes the event possible’). Following this identification participants were given additional information in which one of the antecedent events was disambiguated as the enabling condition (e.g., ‘if there is no sunshine then whether or not there is fertilizer the plants do not grow’). Taken together the two pieces of information suggest that the antecedent of the second sentence (‘if there is no sunshine’) was necessary for the outcome (‘the growth of the plants’) and therefore the enabling condition. This second piece of information was either consistent or inconsistent with the attributions of causal roles participants had made after reading the first sentence. Participants were again asked to identify the cause and the enabling condition.

We identified trials as either consistent or inconsistent. A trial was consistent when the event disambiguated in the second sentence as the enabling condition (e.g., ‘if there is no sunshine’) was the same event as the one a participant had identified as the enabling condition upon reading the first sentence (e.g., after reading the sentence ‘given that there is fertilizer, if the sun shines then the plants grow’ the person identified ‘sunshine’ as the enabling condition). A trial was inconsistent when the event disambiguated in the second sentence (e.g., ‘if there is no fertilizer’) was the other event to the one identified by the participant after the first sentence (e.g., ‘sunshine’).

According to the mental model theory causes and enabling conditions are consistent with different possibilities. The descriptions we gave people were designed to demonstrate that each of the two causal factors was consistent with different possibilities. In this experiment we tested whether participants’ sensitivity to these different possibilities would cause them to change the causal attributions they had made after the first sentence if the new information was inconsistent. For enabling conditions participants tended to respond in line with the different possibilities, as predicted by the mental model theory.
On consistent trials participants tended to identify the same event as the enabling condition after reading the second sentence as they did after reading the first sentence (88% maintained the same identification). On inconsistent trials just over half of the participants correctly switched their identification of enabling condition to the other event. Participants did not respond in line with the different possibilities set out for causes and enabling conditions when they were identifying the cause of the event.

Only half of the participants (57%) maintained their identification of a particular cause on consistent trials. On inconsistent trials the majority of participants (82%) incorrectly maintained their identification of cause after reading the second sentence, thereby identifying the event disambiguated as the enabling condition as the cause.

The results for the enabling conditions suggest that participants may have considered different possibilities in order to make their identifications. Although some participants demonstrated that they had some difficulty with this task, as evidenced by the tendency of some to identify both events as the cause and the enabling condition or identify one event as the cause as well as the enabling condition. Some participants used the word ‘given’ as a guide for identifying the enabling condition (Kuhnmünnich & Beller, 2005).

The results for the causes however, cast some doubt on people’s ability to differentiate between causes and enabling conditions based on their consideration of different possibilities from the descriptions used in this experiment. For the attribution of cause participants did not present the same pattern of responses as they did for the enabling conditions. A possibility for these differences is that the descriptions we gave participants highlight the possibility where the cause appears without the enabling condition and therefore there is no effect.

Essentially, this possibility highlights the necessity of the enabling condition and emphasises the dependence of the cause on the enabling condition. Participants may therefore have focussed on the necessity of the enabling condition and attributed it both a causal and an enabling role. A second possibility is that participants considered the two sentences in isolation. When the second sentence is considered in isolation only one antecedent event (the event identified as the enabling condition) has a causal role.

In Experiment 8 we examined some of the factors that influence people’s identification of causes and enabling conditions. Participants were given scenarios like the ones used in Experiment 7, but this time both sentences were presented together. We first conducted two pre-tests of the materials in which we established that the word ‘given’ was
guiding participants’ identification of the enabling condition. On a mean of 6.5 trials participants identified the event paired with the word ‘given’ as the enabling condition, compared to a mean of 1.5 trials on which they chose the event not paired with the word ‘given’. The finding that the word ‘given’ acted as a linguistic cue for identifying enabling conditions is support for Kuhnmünch and Beller’s (2005) criticism of Goldvarg and Johnson-Laird (2001).

Having established that the word ‘given’ acts as a linguistic cue for enabling conditions, we continued our investigation into people’s ability to consider different possibilities when distinguishing between causes and enabling conditions, omitting potential linguistic cues. We examined whether the temporal sequence of events or different possibilities were the determining factor in differentiating between causes and enabling conditions. The results of the experiment demonstrated that participants were more sensitive to the temporal sequence of the events, identifying the first event as the enabling condition on a mean of 5.6 trials (out of 8), than to the different possibilities each of the events was consistent with. Although causes and enabling conditions are consistent with different possibilities, participants in this experiment demonstrated a tendency to engage in a less effortful process for making their decision by basing their identifications on the temporal cue. One possibility is that the instructions biased participants to identify the first event as the enabling condition.

Other theoretical accounts of findings

In Chapters 3 and 4 we considered how other theories of conditional reasoning may account for the findings of Experiments 3-6. We considered mental logic theories (Braine & O'Brien, 1998; Rips, 1994), domain specific rule theories (Cheng & Nisbett, 1993; Fiddick et al., 2000), and the suppositional theory of if (Evans & Over, 2004). In Chapter 5 we considered how other accounts of how causes and enabling conditions may be distinguished can explain our findings from Experiments 7 and 8.

Mental logic theories do not predict any effects of content nor do they predict that people understand conditionals by keeping different possibilities in mind. The fact that we found no differences between the different types of causes in the paraphrasing experiments may be seen as support for mental logic theories. However, we suggested that the paraphrasing measure simply may not be sensitive enough to detect differences between the different causes. The paraphrasing methodology has not previously been used to investigate the possibilities people keep in mind when they understand conditionals. In
Experiments 5 and 6 we reported that different types of causes primed different possibilities. This finding cannot be accounted for by mental logic theories.

Cheng (Cheng & Nisbett, 1993; Cheng & Novick, 1992) proposes that causal reasoning schemas are responsible for people’s reasoning performance about causal relations and that understanding causes involves an evaluation of the contingency between a potential cause and effect. This evaluation of contingency suggests that people consider different possibilities to the ones that were primed in Experiment 6. The fact that Cheng and Novick (1991) view enabling conditions as constant may account for priming of the possibility where the enabling condition is present and the effect is absent (e.g., ‘The ignition key was turned and the car did not start’).

According to the suppositional theory, conditionals are assessed by considering the cases in which the antecedent is present (e.g., ‘Joe cut his finger and it bled’ and ‘Joe cut his finger and it did not bleed’). The suppositional theory cannot therefore account for priming of possibilities in which the antecedent is absent (e.g., ‘Joe did not cut his finger and it bled’ and ‘Joe did not cut his finger and it did not bleed’).

The finding that strong causes and weak causes primed the possibility in which the antecedent is present and the consequent is absent (e.g., ‘Joe cut his finger and it did not bleed’) is consistent with Evans and Over. However, in both priming experiments at least two possibilities were primed, including ones where the antecedent is absent. This finding is at odds with Evans and Over’s singularity principle, which claims that people keep only one relevant possibility in mind.

In Chapter 5 we considered how other theoretical accounts of how causes and enabling conditions can be distinguished can account for the results of Experiments 7 and 8. We considered Kuhnmünnich and Beller’s (2005) proposal that causes and enabling conditions can be distinguish by relying on linguistic cues, Cheng and Novick’s (1991) suggestion that causes and enabling conditions differ in terms of constancy, Hart and Honore’s (1959/1985) claim that causes and enabling conditions differ in terms of normality and Hilton’s (1990) conversational relevance theory.

Kuhnmünnich and Beller’s (2005) suggestion that the word ‘given’ acts as a linguistic cue was supported by the results of Experiment 8. The conclusions Kuhnmünnich and Beller draw from this finding may be too sweeping. They argue that causes and enabling conditions do not differ in meaning. However, the results of Experiment 7 suggest that people are able to move beyond this superficial cue and consider alternative information, such as possibilities. There may also be individual differences in the ability to consider different possibilities. According to the mental model theory causes and enabling
conditions are consistent with different possibilities. However, the initial possibility a person is likely to consider for both causes and enabling conditions is likely to be the same one (cause/enabler present and effect present). The ability to flesh out mental models is linked to working memory capacity. Accordingly, it is possible that only individuals with high working memory capacities are able to consider the different possibilities when they have received only such a small amount of information, as in the scenarios used in these experiments. In every day situations people are able to identify causes and enabling conditions, but it may be that the context facilitates this ability.

The view that causes and enabling conditions differ in terms of constancy (Cheng & Novick, 1991) cannot account for the results of Experiment 7 which demonstrated that participants were able to consider different possibilities to identify enabling conditions. However, the fact that the word ‘given’ acted as a linguistic cue may be related to the view that enabling conditions are constant. The word ‘given’ may be interpreted as signalling something that is already present, similar to something that is constant. Normality (Hart & Honoré, 1959/1985) cannot account for any of the findings reported in Chapter 5 as none of the materials used contained information on the normality of the events.

Conversational relevance theory (Hilton, 1990) can perhaps account for why participants in Experiment 7 selected the event highlighted as necessary as the cause. However, this theory cannot explain why participants would then also say the same event is the enabling condition. According to relevance theory enabling conditions are part of the causal background and presumably therefore separate from the cause, so the same event could not be both cause and enabling condition.

The results of Experiment 8 are consistent with Mill’s analysis of how causes and enabling conditions can be distinguished (Mill, 1843/1973). According to Mill enabling conditions occur prior to causes. Participants in Experiment 8 demonstrated a sensitivity to the temporal sequence of events and therefore attributed the first event the role of enabling condition and the second event the role of cause. Although, the instructions for this experiment may have contributed to this focus on temporal sequence.

**Implications**

In this section we consider the implications of the research reported in this thesis for causal and counterfactual conditionals as well as the mental model theory, from which we had derived predictions for the research reported in this thesis. We consider implications for our understanding of causal conditionals, counterfactual conditionals, and for the mental model theory in turn.
Implications for causal conditionals

The research reported in this thesis has extended our knowledge about causal conditionals. Previous research on causal conditionals has examined the inferences people make and suggests that people keep different possibilities in mind for different types of causes. As a result, they make different inferences from different types of causes. The research reported in this thesis suggests that the initial representation of different causes may differ from how they are represented when people reason from them.

In the paraphrasing experiments reported in Chapter 3 we observed no differences in the connectives used to rephrase different types of causes. There are three possible explanations for this. Firstly, the paraphrasing measure may not be sensitive enough to identify differences between different causes. Secondly, the mood of the conditional, factual or counterfactual, may have overridden the effect of the content, at least in this task. Thirdly, the paraphrasing task may not encourage people to flesh out their mental representation of the different causes.

In the priming experiments participants were presented with conjunctions describing the different possibilities associated with the conditionals. The results of these experiments suggest that participants fleshed out their mental representations of the different causes in a way that allowed them to differentiate between the different types of causes; strong causes, weak causes and enabling conditions all primed different possibilities. However, weak causes and enabling conditions both primed only two of the three consistent possibilities. This finding is at odds with research on the inferences people make from causal conditionals (e.g., Cummins et al., 1991).

If people were keeping in mind only two of three consistent possibilities, they would not show the pattern of inferences reported in the literature. As reported in Chapter 1, conditionals about weak causes, that is, conditionals which have alternative antecedents, block DA and AC inferences. Whereas conditionals about enabling conditions, that is, conditionals which have additional requirements, block MP and MT inferences. If people represent weak causes by keeping in mind only the two possibilities primed in Experiment 6, that is,

\[ 'p \text{ and } q' \]
\[ '\neg p \text{ and } q' \]

then, as reported in the literature, they should make the MP inference (\( p \) therefore \( q \)) and the AC inference should be blocked (\( q \) therefore \( p \) may or may not be present). However, the MT inference could not be made as none of the possibilities include ‘not-\( q \)’ and paradoxically the DA inference (\( \neg p \)) should result in an affirmation of the consequent
('q'). Similarly, inferences based on the possibilities primed by the enabling conditions would result in an MT inference from ‘not-q’ to ‘p’. Research on people’s reasoning from causal conditionals therefore suggests that when people are required to make inferences from these conditionals they flesh out their mental representations further in order to accomplish this task.

Experiment 7 provided some evidence of people’s ability to consider different possibilities when identifying an enabling condition, though the results are not conclusive. Experiment 8 demonstrated that when there were other, cognitively less demanding, cues, such as linguistic cues or temporal sequence, then participants made use of these cues instead of considering different possibilities. The experiments reported in Chapter 5 highlight the importance of considering multiple cues for distinguishing between causes and enabling conditions. When causal relations were presented in impoverished scenarios like the ones used in the experiments in Chapter 5 participants demonstrated some difficulty in distinguishing between causes and enabling conditions. People’s ability to distinguish between causes and enabling conditions should be considered within a larger context. We consider possibilities for research in this area in the ‘future directions’ section.

**Implications for counterfactual conditionals**

The results reported in this thesis provide additional evidence for the idea that people keep different possibilities in mind for understanding factual and counterfactual conditionals as well as extending our knowledge about counterfactual conditionals by suggesting that counterfactual alternatives modulate people’s interpretation of counterfactual conditionals.

According to the mental model theory a factual conditional such as ‘if Jane took the newer drug then she won the race’ is understood by keeping just one possibility in mind ‘Jane took the newer drug and she won the race’. The counterfactual version of the conditional ‘if Jane had taken the newer drug then she would have won the race’ is understood by keeping two possibilities in mind, the counterfactual conjecture ‘Jane took the newer drug and won the race’ and the presupposed facts ‘Jane did not take the newer drug and she did not win the race’.

The results of the two paraphrasing studies are consistent with previous research on differences in the mental representation of factual and counterfactual conditionals. Factual conditionals were paraphrased using connectives that reflect that people were keeping a single possibility in mind, such as temporal connectives, whereas counterfactual conditionals were paraphrased using connectives and phrasings that suggest that people
were keeping multiple possibilities in mind, such as causal connectives and subjunctive phrasings.

Experiment 1 provided further support for the idea that factual and counterfactual conditionals are understood by keeping different possibilities in mind. Participants made more of the negative inferences, MT and DA from a counterfactual conditional than from a factual conditional. The negative inferences require access to the negative possibility, the presupposed facts ‘Jane did not take the newer drug and she did not win the race’.

Most importantly, the research in this thesis uncovered an effect of counterfactual alternatives on the inferences people are willing to make from a counterfactual conditional. The effect of context on the inferences people make from deontic counterfactual conditionals has already been demonstrated (Egan, 2005; Quelhas & Byrne, 2003) and we extend the investigation of the role of context to the examination of counterfactual alternatives in reasoning from causal counterfactual conditionals. The results of Experiments 1 and 2, reported in Chapter 2, suggest that a counterfactual alternative modulates the interpretation of a causal counterfactual conditional. Although participants were willing to accept the counterfactual alternative as an alternative antecedent they were not willing to give a determinate response about the consequence of this alternative. The effect of context on the modulation of counterfactual conditionals is worthy of further examination.

These findings also raise a question over the everyday ‘if only’ thoughts people generate and the inferences they may be willing to make from them. Do the counterfactual thoughts people generate about their own lives also focus on antecedents, or do people find it easier to imagine alternative outcomes as a result of their own, personal, ‘if only’ thoughts? If everyday ‘if only’ thoughts also focus on antecedents, then how seriously do people take them? Can ‘if only’ thoughts help future planning if people are not confident in the effectiveness of a counterfactual alternative?

Implications for the mental model theory

The experiments reported in this thesis derived their predictions from the mental model theory. We now consider the implications of the results of these experiments for the mental model theory. The findings reported in this thesis are largely consistent with the predictions made by the mental model theory.

The comparison of inferences made from factual and counterfactual conditionals in Experiment 1 yielded results consistent with the mental model theory. Participants made more of the negative inferences from counterfactual conditionals than they did from factual
conditionals. This result is predicted by the mental model theory due to the difference in how the two sorts of conditionals are mentally represented.

The other findings reported in Chapter 2, namely the reduction in modus ponens and modus tollens inferences after reading a story which mentioned a counterfactual alternative, are readily explained by the mental model theory. Mentioning a counterfactual alternative led to modulation of the interpretation of the conditional. Although participants accepted the counterfactual alternative mentioned in the story as a potential alternative, they were not willing to assert that this alternative would definitely result in a different outcome. Further examination of this modulating effect of context may be a worthwhile avenue for future research.

The results of the paraphrasing experiments reported in Chapter 3 are consistent with the mental model theory. Factual and counterfactual conditionals were paraphrased using connectives that suggest participants were keeping one possibility in mind for factual conditionals and multiple possibilities for counterfactual conditionals.

Experiments 5 and 6, reported in Chapter 4, demonstrated that different causes are understood by keeping different possibilities in mind. We found these differences both in the materials pre-tests and in the two priming experiments. The priming experiments revealed that the different causes each primed two consistent possibilities, suggesting that participants may have represented the other consistent possibilities implicitly. The mental model theory proposes that due to working memory constraints people tend to consider few possibilities and only consider additional possibilities if the circumstances require it.

All three sorts of causes primed the possibility where both antecedent and consequent are present. According to the mental model theory our initial mental representation of a conditional consists of this possibility. In addition each sort of cause primed a possibility which made it possible to distinguish the different types of causes. Strong causes primed the possibility where neither the antecedent nor the consequent is present, ‘Joe did not cut his finger and it did not bleed’. Weak causes primed the possibility where the antecedent is absent but the consequent is present, ‘the soil was not watered and the plants grew’. Finally, enabling conditions primed the possibility which marks it out from other causes, that is, the antecedent is present but the consequent does not occur, ‘the ignition key was turned and the car did not start’. These findings are all consistent with our predictions and the mental model theory.

Strong causes and weak causes however, also primed one false possibility, ‘the soil was watered and the plants did not grow’. This finding is inconsistent with the mental model theory as it predicts that people only keep in mind true possibilities. Espino et al.
(2006) also found no priming effect of false possibilities. One possibility is that the priming of the false possibility resulted from the order of processing. Further research is required to examine whether there are circumstances when people consider false possibilities.

The results reported in Chapter 5 provide some food for thought for the mental model theory. Experiment 7 did not conclusively demonstrate that people are able to identify enabling conditions by considering possibilities and Experiment 8 demonstrated that people will not always consider different possibilities in order to identify enabling conditions. Instead, they make use of other cues, such as temporal sequence and linguistic cues. Future research could examine under which circumstances people make use of the different cues that have been suggested in the literature for distinguishing causes and enabling conditions.

**Future directions**

In this section we consider some of the strengths and weaknesses of the research reported in this thesis and make some suggestions for future research.

The main body of research on causality focuses on causal induction, that is, how people identify events as causes. The research reported in this thesis has focused on how different causes are understood and mentally represented. In order to achieve the aims of our research we employed a variety of methods, some of them quite novel. Using a variety of methods is a definite strength of the research reported in this thesis. However, making use of novel methods always carries some risks. For example, the paraphrasing methodology has been successfully used in previous investigations (Byrne & Johnson-Laird, 1992; Fillenbaum, 1974b) and in our experiments it proved successful for distinguishing factual and counterfactual conditionals, but it was not sensitive enough to detect differences between different causes. However, a strength of the two paraphrasing experiments is that the samples were drawn from two very different populations who produced very similar patterns of paraphrasing factual and counterfactual conditionals.

Perhaps the biggest challenge for the research carried out in this thesis was to identify suitable materials for our investigations. Particularly for the priming experiments, reported in Chapter 4, we needed to ensure the materials conveyed the different sorts of causal relations. We conducted extensive pre-testing on our materials and identified the most suitable materials. A particular difficulty for the priming experiments was that we had to use the same content to convey the different sorts of causal relations in order to ensure that we could compare the reading times for the conjunctions. In Experiment 6, where we
compared strong causes and weak causes, we used the same materials in both conditions (including an alternative cause to describe a weak cause). However, using the same materials to compare strong and weak causes may have weakened differences between the two conditions.

An advantage of conducting materials pre- and post-tests is that it allowed us to rule out some possible explanations for some of our findings, for example, we know from the pre- and post-tests of the materials used in the paraphrasing experiment (Experiment 4) that participants were aware of the differences between the different types of causes.

The materials we used to examine causes and enabling conditions in Chapter 5 were impoverished of any context. Some participants had difficulty identifying the enabling condition from these materials. The findings suggest there may be individual differences in people's ability to identify enabling conditions by considering possibilities. The most likely candidate for this difference is working memory capacity. Future studies could examine the relationship between working memory capacity and the ability to identify causes and enabling conditions from short descriptions like the ones used here. Alternatively, the descriptions did not capture the different possibilities as well as we thought. Future studies could examine alternative phrasings for example, the inclusion of modal words, such as 'may' and 'can' may make it easier for participants to identify the different possibilities.

A weakness of some of the research reported in this thesis is that we excluded a large number of participants from some of our analyses. In the priming studies, reported in Chapter 4, we excluded participants primarily for failing to answer the questions correctly and some for having too many outliers. The task of reading the scenarios and answering the questions was not a difficult one. It is not clear why so many participants failed to answer the questions correctly; perhaps they lacked the motivation to engage in the task. Some participants may have found it difficult to sustain attention. Including a measure to screen out participants who may not have completed the task conscientiously means that our analysis is based on participants who did. It seems worthwhile including measures in future experiments which allow the experimenter to screen out participants who failed to engage in the task.

In the experiments reported in Chapter 5, we were also forced to exclude participants. Particularly in Experiment 7 participants' failure to distinguish between causes and enabling conditions meant that we had to exclude them from our analysis. Our materials were deliberately designed to be ambiguous, but we expected participants to adhere to the instructions and identify one event as the cause and the other as the enabling
condition, even if their identifications were somewhat arbitrary. Instead, one group of participants identified both events as the cause and the enabling condition and therefore had to be excluded from the analysis. The majority of participants identified one event as the cause and the other as the enabling condition, but one group of participants identified just one event as the cause and the enabling condition. As a result, we had to analyse causes and enabling conditions separately. The materials used in Experiment 7 may not have been plausible to some of our participants. An investigation of what makes a description of a cause and an enabling condition plausible will enhance our understanding of what factors mark out the distinction between the two sorts of events.

In everyday life people do not appear to have difficulties in differentiating between causes and enabling conditions. There is a possibility that context facilitates the ability to consider the different possibilities. Alternatively, context may contain additional cues, such as temporal sequence, constancy, or conversational relevance. Future studies could attempt to examine how context exerts its effect in facilitating this ability.

The distinction between causes and enabling conditions in terms of meaning may have important implications for law (Johnson-Laird, 1999). As part of their discussion of causation and the law, Hart and Honoré (1959/1985) suggest that causes and enabling conditions can be distinguished in terms of normality, enabling conditions are normal whereas causes are abnormal. Future studies could examine how responsibility for an outcome is judged for enabling conditions that vary in terms of the characteristics suggested in the literature, that is, normality, constancy, conversational relevance and consistent possibilities.

Combining ‘if only’ thoughts with inferences allowed us to gain insight into the thought processes involved in evaluating inferences from a counterfactual alternative. The experiments reported in this thesis suggest that participants believed the counterfactual alternative suggested by the story was an acceptable alternative, but they were not willing to assert its consequent with confidence. Future studies could examine this effect further. In particular, future research could compare reasoning from counterfactuals pertaining to a person’s own life, compared to counterfactuals that arise from stories, such as the ones used in the research reported here. People may find it easier to imagine alternative outcomes when the counterfactual is considered within the context of their own life.

Conclusion

In this thesis we have examined the mental representations and cognitive processes in causal and counterfactual thinking in a series of eight experiments. Our findings
demonstrate that people understand counterfactual conditionals and different types of causes by keeping in mind different possibilities. People’s mental representations of different types of causes allow them to distinguish between them, but their representations may not include all of the consistent possibilities. A comparison of the findings from our paraphrasing and priming studies and the reasoning studies reported in the literature suggests that people may keep different possibilities in mind for different tasks and situations. Furthermore, causes and enabling conditions, though consistent with different possibilities, are sometime differentiated using cognitively less demanding cues. The research reported in this thesis also demonstrated that a counterfactual alternative can modulate a person’s interpretation of a counterfactual conditional. Our findings have implications for theories of conditional reasoning as well as for our understanding of causal and counterfactual thinking. The research reported in this thesis highlights the importance of examining people’s mental representations and reasoning for a variety of contents, contexts and tasks as people’s mental representations are not static and adapt to the varying circumstances.
References


A1. Instructions for Experiments 1 and 2

Thank you for agreeing to participate in this study. This booklet contains three scenarios. The scenarios and associated tasks are about how people think in their daily lives and are not tests of intelligence. Each scenario is followed by a set of questions. Please read each scenario carefully and answer the questions that follow. Please answer the questions in the order in which they are presented and do not try to change your answers once you have written them.

On the final page of this booklet I have outlined the aim of the experiment. Please do not read it until you have completed all of the questions. Thank you for agreeing to participate in this study.

A2. Materials for Experiments 1 and 2

Factual Conditionals

If Jane took the newer drug then she won the race.
If Mrs Wallace pleaded with her husband then he lived.
If the taxi driver picked up Eugene and Tina then they arrived safely.

Counterfactual Conditionals for 'presuppositional' condition

If Jane had taken the newer drug she would have won the race.
If Mrs Wallace had pleaded with her husband he would have lived.
If the taxi driver had picked up Eugene and Tina they would have arrived safely.

Stories

'Known counterfactual' condition:

Runner story
Jane is a runner and since the age of eight she has competed in the sprint races in local track and field events. Up through school she had won every race in which she had competed. It was at the age of 13 that she began to dream about the Olympics. At the age of 18, before starting college, she decides to give the Olympics one all out shot. She makes the Irish Olympic team for the 400 metre race.

On the day before the 400 metre race, in a freak accident during training, she sprains her left ankle. Although there is no break or fracture, when she tries to run, the pain is excruciating. Her trainer tells her about many advances in pain killing medications and assures her that she will still be able to participate. He recommends that she chooses between two drugs, both legal according to Olympic guidelines. One is a well-known painkiller that has been proved effective but also has some serious side effects including temporary nausea and drowsiness. The other painkiller is a newer and less well-known drug. Although the research suggests that the newer drug might be a more effective painkiller, its side effects are not yet known because it has not been widely used.

After considerable thought, she elects to go with the more well-known drug. On the day of the race, although there is no pain in her ankle, she already begins to feel the nausea and finds herself fighting off fatigue. She finishes in fourth place, only 1 tenth of a second from a bronze medal, 4 tenths from a silver, and 5 tenths from a gold medal.

After the event, she learns that some athletes in other events who were suffering from similar injuries used the other, newer drug. They felt no pain and experienced no side effects.
Imagine that in the days and weeks following the race Jane thinks “if only ...”. How do you think she completed this thought?

Plane story
Mrs. Wallace was somewhat distressed about her husband flying from Dublin to London for a convention. She herself was afraid of flying, and neither her nor her husband had ever flown anywhere before. In the past, they had either taken the fast ferry and driven or taken the train to their destination. On this occasion, however, Mrs. Wallace was not accompanying her husband on this two day business trip. Mr. Wallace told his wife that he was going to book a flight because he didn’t want to spend so many hours on the ferry and driving or taking the train. Mr. Wallace booked a flight even though he had originally considered taking the ferry.

Mr. Wallace, although a little uneasy about flying for the first time, tried to assure his wife that everything would be alright. These assurances did little to put her at ease. She thought about pleading with him to take the train instead. But she didn’t because she felt silly doing so, even though she knew that her husband would definitely have changed his plans at her request if she pleaded.

One week later, Mr. Wallace took his flight to London. About midway through the flight, the plane crashed, tragically killing Mr. Wallace and all others on board. In the weeks following the crash, a formal investigation found evidence from the debris and flight recorder that indicated that the plane’s engine had spontaneously malfunctioned, leaving the pilot no time for an emergency landing. The investigation also determined that the plane’s engine was inspected thoroughly by a qualified maintenance team prior to takeoff. Other plane engines of the same model were also inspected for structural flaws in manufacturing, but this inspection revealed that the engines were well constructed.

Imagine that in the days and weeks following the accident Mrs Wallace thinks “if only ...”.
How do you think she completed this thought?

Taxi story
Eugene and Tina were a young married couple who lived in the country. Both were partially paralysed and confined to wheelchairs. They had met four years before when Tina was a counsellor with the Irish Paraplegic Association, had fallen in love, and were married one year later.

On this particular evening, Eugene had phoned to request a taxi to take them into town. When the taxi driver arrived, Eugene and Tina were waiting by the street. On seeing that they were both in wheelchairs, the taxi driver refused their fare because he thought it would be too crowded in the taxi with both of them and the wheelchairs. So the taxi driver headed back into town without them. Because there was no time to call another taxi, Eugene and Tina took Tina’s car, which was equipped with special hand controls. In order to get into town from their house, they had to travel across a bridge over Rupert River.

A severe storm the night before had weakened the structure of the bridge. About 5 minutes before Eugene and Tina reached it, a section of the bridge collapsed. In the dark, Eugene and Tina drove off the collapsed bridge and plummeted into the river below. Both of them were badly injured.

It is later reported that the taxi driver had reached the bridge about 15 minutes before them, and made it safely across.
Imagine that in the days and weeks following their accident, Eugene and Tina often thought “if only ...”
How do you think they completed this thought?

Known facts: condition

Runner story

Jane is a runner and since the age of eight she has competed in the sprint races in local track and field events. Up through school she had won every race in which she had competed. It was at the age of 13 that she began to dream about the Olympics. At the age of 18, before starting college, she decides to give the Olympics one all out shot. She makes the Irish Olympic team for the 400 metre race.

On the day before the 400 metre race, in a freak accident during training, she sprains her left ankle. Although there is no break or fracture, when she tries to run, the pain is excruciating. Her trainer tells her about many advances in pain killing medications and assures her that she will still be able to participate. He recommends that she takes a drug, legal according to Olympic guidelines. It is a well-known painkiller that has been proved effective but also has some serious side effects including temporary nausea and drowsiness.

After considerable thought, she elects to go with the drug. On the day of the race, although there is no pain in her ankle, she already begins to feel the nausea and finds herself fighting off fatigue. She finishes in fourth place, only 1 tenth of a second from a bronze medal, 4 tenths from a silver, and 5 tenths from a gold medal.

Plane story

Mrs. Wallace was somewhat distressed about her husband flying from Dublin to London for a convention. She herself was afraid of flying, and neither her nor her husband had ever flown anywhere before. Mr. Wallace told his wife that he was going to book a flight. Mr. Wallace, although a little uneasy about flying for the first time, tried to assure his wife that everything would be alright. These assurances did little to put her at ease.

One week later, Mr. Wallace took his flight to London. About midway through the flight, the plane crashed, tragically killing Mr. Wallace and all others on board. In the weeks following the crash, a formal investigation found evidence from the debris and flight recorder that indicated that the plane's engine had spontaneously malfunctioned, leaving the pilot no time for an emergency landing. The investigation also determined that the plane's engine was inspected thoroughly by a qualified maintenance team prior to takeoff. Other plane engines of the same model were also inspected for structural flaws in manufacturing, but this inspection revealed that the engines were well constructed.

Taxi story

Eugene and Tina were a young married couple who lived in the country. Both were partially paralysed and confined to wheelchairs. They had met four years before when Tina was a counsellor with the Irish Paraplegic Association, had fallen in love, and were married one year later.

On this particular evening, they were going into town. Eugene and Tina took Tina's car, which was equipped with special hand controls. In order to get into town from their house, they had to travel across a bridge over Rupert River.

A severe storm the night before had weakened the structure of the bridge. About 5 minutes before Eugene and Tina reached it, a section of the bridge collapsed. In the dark,
Eugene and Tina drove off the collapsed bridge and plummeted into the river below. Both of them were badly injured.

'Suggested counterfactual' condition

Runner story

Jane is a runner and since the age of eight she has competed in the sprint races in local track and field events. Up through school she had won every race in which she had competed. It was at the age of 13 that she began to dream about the Olympics. At the age of 18, before starting college, she decides to give the Olympics one all out shot. She makes the Irish Olympic team for the 400 metre race.

On the day before the 400 metre race, in a freak accident during training, she sprains her left ankle. Although there is no break or fracture, when she tries to run, the pain is excruciating. Her trainer tells her about many advances in pain killing medications and assures her that she will still be able to participate. He recommends that she chooses between two drugs, both legal according to Olympic guidelines. One is a well-known painkiller that has been proved effective but also has some serious side effects including temporary nausea and drowsiness. The other painkiller is a newer and less well-known drug. Although the research suggests that the newer drug might be a more effective painkiller, its side effects are not yet known because it has not been widely used.

After considerable thought, she elects to go with the more well-known drug. On the day of the race, although there is no pain in her ankle, she already begins to feel the nausea and finds herself fighting off fatigue. She finishes in fourth place, only 1 tenth of a second from a bronze medal, 4 tenths from a silver, and 5 tenths from a gold medal.

Plane story

Mrs. Wallace was somewhat distressed about her husband flying from Dublin to London for a convention. She herself was afraid of flying, and neither her nor her husband had ever flown anywhere before. In the past, they had either taken the fast ferry and driven or taken the train to their destination. On this occasion, however, Mrs. Wallace was not accompanying her husband on this two day business trip. Mr. Wallace told his wife that he was going to book a flight because he didn't want to spend so many hours on the ferry and driving or taking the train. Mr. Wallace booked a flight even though he had originally considered taking the ferry.

Mr. Wallace, although a little uneasy about flying for the first time, tried to assure his wife that everything would be alright. These assurances did little to put her at ease.

One week later, Mr. Wallace took his flight to London. About midway through the flight, the plane crashed, tragically killing Mr. Wallace and all others on board. In the weeks following the crash, a formal investigation found evidence from the debris and flight recorder that indicated that the plane's engine had spontaneously malfunctioned, leaving the pilot no time for an emergency landing. The investigation also determined that the plane's engine was inspected thoroughly by a qualified maintenance team prior to takeoff. Other plane engines of the same model were also inspected for structural flaws in manufacturing, but this inspection revealed that the engines were well constructed.

Taxi story

Eugene and Tina were a young married couple who lived in the country. Both were partially paralysed and confined to wheelchairs. They had met four years before when Tina
was a counsellor with the Irish Paraplegic Association, had fallen in love, and were married one year later.

On this particular evening, Eugene had phoned to request a taxi to take them into town. When the taxi driver arrived, Eugene and Tina were waiting by the street. On seeing that they were both in wheelchairs, the taxi driver refused their fare because he thought it would be too crowded in the taxi with both of them and the wheelchairs. So the taxi driver headed back into town without them. Because there was no time to call another taxi, Eugene and Tina took Tina's car, which was equipped with special hand controls. In order to get into town from their house, they had to travel across a bridge over Rupert River.

A severe storm the night before had weakened the structure of the bridge. About 5 minutes before Eugene and Tina reached it, a section of the bridge collapsed. In the dark, Eugene and Tina drove off the collapsed bridge and plummeted into the river below. Both of them were badly injured.

**Example of the inference task** *(in the story conditions this appeared on the sheet following the story)*

If Jane had taken the newer drug she would have won the race.

**Suppose Jane took the newer drug**

What follows?

- Jane won the race
- Jane did not win the race
- Jane may or may not have won the race

**Suppose Jane did not win the race**

What follows?

- Jane did not take the newer drug
- Jane took the newer drug
- Jane may or may not have taken the newer drug

**Suppose Jane did not take the newer drug**

What follows?

- Jane did not win the race
- Jane won the race
- Jane may or may not have won the race
Suppose Jane won the race

What follows?

☐ Jane took the newer drug
☐ Jane did not take the newer drug
☐ Jane may or may not have taken the newer drug

A3. Debriefing for Experiments 1 and 2

This study aims to examine the way thinking about past possibilities affects the way people make inferences from ‘if…then’ sentences about causal relations. Some people were given additional information which should enable them to think of how things could have turned out differently and some people were asked to generate an ‘If only…’ thought before answering the questions on the second page. The study compares how being told about an alternative possibility and being asked to think about an alternative possibility affects people’s reasoning.
Appendix B

B1. Instructions for Experiment 3
Thank you for agreeing to participate in this study. The study examines the psychological processes implicated in text comprehension. This is not a test of intelligence. Your answers will be treated as confidential and anonymous, and you may withdraw your participation at any time.
The study consists of 28 sentences, such as
"If there is a square on the blackboard then there is a triangle.”
Your task will consist of rephrasing each sentence as accurately as you can. You should try to keep its meaning as much as possible, but without using the word ‘IF’. Imagine that you are rewording each sentence for someone else so that they can make sense of it as fully and exactly as possible. Your task is not to improve the sentences or make them more sensible, but to paraphrase them, rewording each in a way that captures its meaning as accurately as possible.
The example above could be rephrased in many ways using the fragments ‘a square on the blackboard’ and ‘a triangle on the blackboard’ that do not include the word ‘IF’ but use other words to convey the same meaning.
Please work through the sentences in the booklet in the order that they are given and do not look back at your answers.
Overall, this part of the study will last approximately 20 minutes. If you have any questions, please ask the experimenter who will be pleased to answer them. After you completed the tasks today you will be given an explanation of the main aims of the study. Thank you for your participation.

B2. Materials for Experiment 3

Factual conditionals

Strong causes
If Joseph cut his finger then it bled.
If Larry grasped the glass with his bare hands then his fingerprints were on it.
If the gong was struck then it sounded.
If the doorbell was pushed then it rang.

Weak causes
If Alvin read without his glasses then he got a headache.
If Mary jumped into the swimming pool then she got wet.
If the apples were ripe then they fell from the tree.
If water was poured on the campfire then the fire went out.

Enabling conditions
If the trigger was pulled then the bullet was released.
If the switch was flipped up then the light went on.
If the ignition key was turned then the car started.
If the match was struck then the flame appeared.

Counterfactual conditionals

Strong causes
If Joseph had cut his finger then it would have bled.
If Larry had grasped the glass with his bare hands then his fingerprints would have been on it.  
If the gong had been struck then it would have sounded.  
If the doorbell had been pushed then it would have rang.

**Weak causes**

If Alvin had read without his glasses then he would have got a headache.  
If Mary had jumped into the swimming pool then she would have got wet.  
If the apples had been ripe then they would have fallen from the tree.  
If water had been poured on the campfire then the fire would have gone out.

**Enabling conditions**

If the trigger had been pulled then the bullet would have been released.  
If the switch had been flipped up then the light would have gone on.  
If the ignition key had been turned then the car would have started.  
If the match had been struck then the flame would have appeared.

**Filler conjunctions and disjunctions**

There is a star and there is a cross on the blackboard.  
There is a diamond or there is a heart on the blackboard.  
Sharon is in Dublin and Tony is in Kerry.  
Richard is in Belfast or Sophie is in Kilkenny.

**B3. Instructions and materials for memory task (post-test) in Experiment 4**

This booklet contains some questions about the scenarios you have just read. Please tick all the answers that apply.

**Strong causes**

**What led to Joseph's finger bleeding?**

- [ ] Joseph pricked his finger with a needle.  
- [ ] Joseph was cutting vegetables.  
- [ ] Joseph was stood by the sink.  
- [ ] Joseph cut his finger.

**What led to Larry's finger prints being on the glass?**

- [ ] Larry was in the living room.  
- [ ] Larry touched the glass with his bare hands.  
- [ ] Larry didn't wear any gloves.  
- [ ] Larry murdered somebody.

**What led to the doorbell ringing?**

- [ ] The doorbell was pushed.  
- [ ] The boss was in the garden.  
- [ ] The doorbell was pulled.  
- [ ] The doorbell was struck.

**What led to the gong sounding?**

- [ ] There was a strong wind.  
- [ ] The gong was pushed.  
- [ ] The gong was struck.
The monks were by the pond.

**Weak causes**

What led to the apples falling from the tree?
- The apples were ripe.
- It was stormy.
- Children climbed the tree.
- Thomas picked some flowers.

What led to Mary getting wet?
- Mary had a shower.
- Mary walked in the rain.
- Mary jumped into the swimming pool.
- Mary had a massage.

What led to the campfire going out?
- There was not enough wood.
- There was a strong wind.
- Sand was poured on the campfire.
- Water was poured on the campfire.

What led to Alvin having a headache?
- He was listening to loud music.
- He read without his glasses.
- He did not have enough to drink.
- He ate some chocolate.

**Enabling conditions**

What led to the car starting?
- The battery was charged.
- New spark plugs were fitted.
- The car was pushed.
- The ignition key was turned.

What led to the gun firing?
- The trigger was pulled.
- There was a shooting competition.
- There was a bullet in the chamber.
- The gun was well oiled.

What led to the light going on?
- The light fitting was wired up correctly.
- There was a bulb in the fitting.
- The switch was flipped up.
- Jimmy went to the supermarket.

What led to the match lighting?
- Sarah got some cookies.
- The match was struck.
- Sarah’s dad did it.
- The match was dry.
B4. Debriefing sheet for Experiments 3 and 4
This study aims to examine the way people understand if...then sentences about different types of causal relations, i.e. strong causes, weak causes and causes where other contributing factors must be taken into account. We are testing the idea that different sorts of causes may be understood by keeping different possibilities in mind. The study also compares the way people reason about 'if' phrased about matters of possibility in the past, e.g., If Joe cut his finger, then it bled, and about matters that were once possible but are so no longer, e.g., If Joe had cut his finger, then it would have bled.
Thank you again for your participation. If you have any further questions please ask the experimenter.

B5. Instructions for Experiment 4
Thank you for agreeing to participate in this study. The study examines the psychological processes implicated in text comprehension. This is not a test of intelligence. Your answers will be treated as confidential and anonymous, and you may withdraw your participation at any time.
The study consists of 12 scenarios, such as:

- Sam was talking to Michelle about a blackboard in the other room.
- Sam told Michelle that
- If there was a square on the blackboard then there was a triangle.
- Sam also told Michelle that the students were asked to follow this rule when writing on the blackboard.

When Michelle went into the classroom she saw that

- There was a triangle on the blackboard.
- Michelle went to the coffee lounge.

The scenario will be followed by a sentence from the scenario, such as:

- "If there is a square on the blackboard then there is a triangle."

Your task will consist of rephrasing this sentence as accurately as you can. You should try to keep its meaning as much as possible, but without using the word ‘IF’. Imagine that you are rewording each sentence for someone else so that they can make sense of it as fully and exactly as possible. Your task is not to improve the sentences or make them more sensible, but to paraphrase them, rewording each in a way that captures its meaning as accurately as possible.
The example above could be rephrased in many ways using the fragments ‘a square on the blackboard’ and ‘a triangle on the blackboard’ that do not include the word ‘IF’ but use other words to convey the same meaning.
Please work through the scenarios in the booklet in the order that they are given and do not look back at your answers.
Overall, this part of the study will last approximately 20 minutes. On completion of this task you will be asked to answer additional questions about the scenarios you have read. If you have any questions, please ask the experimenter who will be pleased to answer them.
After you completed the tasks today you will be given an explanation of the main aims of the study. Thank you for your participation.

B6. Materials for Experiment 4
The example is for a factual conditional, strong cause.

Andrew was talking to Jenny about a murder suspect Larry.
Andrew told Jenny that
If Larry grasped the glass with his bare hands, then his fingerprints were on it.
Andrew also told Jenny that Larry was in the living room when he left his fingerprints.
When the forensic report arrived Jenny saw that
Larry’s fingerprints were on the glass.
Jenny went to the canteen.

Please rephrase the sentence below as accurately as you can without using the word ‘if’:
If Larry grasped the glass with his bare hands, then his fingerprints were on it.

**The conditionals (counterfactual conditionals are in italics)**

*Strong causes*

Peter was talking to Mary about his friend Joseph.
Peter told Mary that
If Joseph cut his finger, then it bled.
If Joseph had cut his finger, then it would have bled.
Peter also told Mary that Joseph stood by the kitchen sink when he bled.
When Mary went into the kitchen she saw that
Joseph was bleeding.
Mary went to welcome the new guests.

Andrew was talking to Jenny about a murder suspect Larry.
Andrew told Jenny that
If Larry grasped the glass with his bare hands, then his fingerprints were on it.
If Larry had grasped the glass with his bare hands, then his fingerprints would have been on it.
Andrew also told Jenny that Larry was in the living room when he left his fingerprints.
When the forensic report arrived Jenny saw that
Larry’s fingerprints were on the glass.
Jenny went to the canteen.

Julie was talking to Suzanne about her boss’ house in the suburbs.
Julie told Suzanne that
If the doorbell was pushed, then it rang.
If the doorbell had been pushed, then it would have rang.
Julie also told Suzanne that her boss was in the garden when the doorbell rang.
When Suzanne arrived at the house she saw that
The doorbell rang.
Suzanne went into the living room.

Lisa was talking to David about a Buddhist temple.
Lisa told David that
If the gong was struck, then it sounded.
If the gong had been struck, then it would have sounded.
Lisa also told David that the monks were by the pond when the gong sounded.
When David went into the temple he saw that
The gong sounded.
David went to a meditation class.

*Weak causes*
Martin was talking to Thomas about the apples in the garden.  
Martin told Thomas that
If the apples were ripe, then they fell from the tree.  
*If the apples had been ripe, then they would have fallen from the tree.*
Martin also told Thomas that the apples fell from the tree when it was stormy.
When Thomas went into the garden he saw that
The apples had fallen from the tree.
Thomas went to pick some flowers.

Andy was talking to Tara about his friend Mary.  
Andy told Tara that
If Mary jumped into the swimming pool, then she got wet.  
*If Mary had jumped into the swimming pool, then she would have got wet.*
Andy also told Tara that Mary got wet when she had a shower.
When Tara saw Mary she saw that
Mary was wet.
Tara went for a massage.

Lisa was talking to Brian about the campfire.  
Lisa told Brian that
If water was poured on the campfire, then the fire went out.  
*If water had been poured on the campfire, then the fire would have gone out.*
Lisa also told Brian that the fire went out when sand was poured on it.
When Brian went to look at the campfire he saw that
The fire had gone out.
Brian went to brush his teeth.

Rita was talking to Sinead about her son Alvin.  
Rita told Sinead that
If Alvin read without his glasses, then he got a headache.  
*If Alvin had read without his glasses, then he would have got a headache.*
Rita also told Sinead that Alvin got a headache when he ate chocolate.
When Sinead saw Alvin she saw that
Alvin had got a headache.
Sinead went to an art exhibition.

Enabling conditions

Marcus was talking to Steven about his new gun.  
Marcus told Steven that
If the trigger was pulled, then the gun fired.  
*If the trigger had been pulled, then the gun would have fired.*
Marcus also told Steven that the gun fired when a bullet was in the chamber.
When Steven saw the gun he saw that
The gun had fired.
Steven went to watch a shooting competition.

Katy was talking to Jimmy about the kitchen light.  
Katy told Jimmy that
If the switch was flipped up, then the light went on.  
*If the switch had been flipped up, then the light would have gone on.*
Katy also told Jimmy that the light went on when a bulb was in the fitting.
When Jimmy walked into the kitchen he saw that
The light had gone on.
Jimmy went to the supermarket.

Jason was talking to Nancy about her car.
Jason told Nancy that
If the ignition key was turned, then the car started.

\textit{If the ignition key had been turned, then the car would have started.}

Jason also told Nancy that the car started when the battery was charged.
When Nancy went to her car she saw that
The car had started
Nancy went to buy some sponges.

Curtis was talking to Sarah about matches.
Curtis said that
If the match was struck, then it lit.

\textit{If the match had been struck, then it would have lit.}

Curtis also said that the match lit when the match was dry.
When Sarah went into the living room she saw that
The match was lit.
Sarah went to get some cookies.
Appendix C

C1. Instructions for pre-tests 5.1 and 6.1
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 be presented with 28 items. Each consists of a short paragraph and each paragraph is followed by four sentences. Your task is to decide if each of these sentences is consistent or inconsistent with regard to the preceding paragraph. You will be given items based on different people talking about different topics. For example:

Rachel was telling her friend Liam about a chemical reaction.
She told him that the chemicals had to be handled carefully for the mixture to solidify.
She also said
Adding chemical X or chemical Y meant the mixture solidified.

Your task is to decide whether each assertion is consistent or inconsistent with regard to the information you have been given.

<table>
<thead>
<tr>
<th>Consistent</th>
<th>Inconsistent</th>
</tr>
</thead>
<tbody>
<tr>
<td>Chemical X was added and the mixture solidified</td>
<td>0</td>
</tr>
<tr>
<td>Chemical X was not added and the mixture solidified</td>
<td>O</td>
</tr>
<tr>
<td>Chemical X was added and the mixture did not solidify</td>
<td>O</td>
</tr>
<tr>
<td>Chemical X was not added and the mixture did not solidify</td>
<td>0</td>
</tr>
</tbody>
</table>

Please work through the items in the order they are presented to you and do not look back at your previous answers. Overall, the study will last approximately 20 minutes. If you have any questions, the experimenter will be pleased to answer them. After you have completed the 28 problems, you will be given an explanation of the main aims of this study. Thank you again for your participation.

C2. Materials for pre-test 5.1

*Enabling Conditions*

Oisin was telling Tammy about his lilies.
He told her that the lilies had to be fully open for the pollen to stain.
He also said
If he touched the lilies then the pollen stained his hand.

Janet and her friend Marcus were conducting a chemistry experiment.
He told her that the mixture needed to be heated for the mixture to turn blue.
He also said
If chemical A was combined with chemical B, then the mixture turned blue.

Andrew was telling his friend Cathy about his new gadget.
He told her that the gadget had to be held vertically to turn it on.
He also said
If the green button was pushed then the gadget turned on.

Martin was telling his friend Laura about his medicine bottle.
He told her that the lid had to be squeezed to open it.
He also said
If the lid was twisted then the bottle opened.

Jason was telling his friend Nancy about his car.
He told her that the battery had to be charged for the car to start.
He also said
If the ignition key was turned, then the car started.

Charlie was telling Steven about his new gun.
He told him that a bullet had to be in the chamber for the gun to fire.
He also said
If the trigger was pulled, then the gun fired.

Sharon was telling Julie about her new sewing machine.
She told her that the pedal had to be pressed for the machine to work.
She also said
If the needle was threaded then the sewing machine worked.

Diane was telling Patrick about her new office chair.
She told him that a person had to be sat on the chair for the chair to go down.
She also said
If the lever was pulled, then the chair went down.

Fiona was telling her son Robert about snow.
She told him that the air had to be moist for it to snow.
She also said
If it was cold then it snowed.

Curtis was telling Paula about his skin condition.
He told her that it had to be hot for his skin to swell up.
He also said
If his skin was scratched then it swell up.

Amy was telling her sister Nadine about her weight loss plans.
She told her that she had to cut out snacks for her to lose weight.
She also said
If she exercised regularly then she lost weight.

Marie was telling her brother Cathal about staying cool in her new car.
She told him that the air conditioning had to be switched on for the car to be cool.
She also said
If the windows were closed then the car cooled down.

Rita was talking to Sinead about her son Alvin.
Rita told Sinead that Alvin had to be tired for him to get a headache.
She also said
If Alvin read without his glasses, then he got a headache.
Justin was telling his son Liam about evidence that he had touched something. He told him that a person's hands had to be warm for their fingerprints to be left behind. He also said
If a person's hands were bare then their fingerprints were left behind.

Tracy was telling Kevin about her biceps muscles. She told him that she had to do weight training for her muscles to grow. She also said
If she drank protein shakes, then her muscles grew.

Katy was telling Jimmy about the kitchen light. She told Jimmy that a bulb had to be in the fitting for the light to go on. She also said
If the switch was flipped up, then the light went on.

Stuart was telling his daughter Alice about the washing up. He told her that the water had to be hot for the grease to be removed. He also said
If washing up liquid was used then the grease was removed.

Gary was telling Thomas about the apples in the garden. He told Thomas that the apples had to be heavy for them to fall from the tree. He also said
If the apples were ripe, then they fell from the tree.

Tristan was telling Sarah about matches. He told her that the match had to be dry for it to light. He also said
If the match was struck, then it lit.

Danny was telling Tina about the new doorbell. He told her that the wires had to be connected for the bell to ring. He also said
If the button was pushed then the bell rang.

Aoife was telling her friend Brian about the plants in the garden. She told him that the sun had to shine on the plants for them to grow. She also said
If the plants were watered, then the plants grew.

Kerry was telling her son Adam about making bread. She told him that the mixture needed to contain yeast for the dough to double. She also said
If the dough was placed in a warm place then it doubled.

Audrey was telling her friend Timmy about baking cakes. She told him that baking powder had to be added to the mixture for the cake to rise. She also said
If the mixture was heated in the oven then the cake rose.

Suzanne was telling Dermot about her upcoming statistics exam.
She told him that she had to use her calculator for her to do well in the exam. She also said If she was given the statistics tables, then she did well in the exam.

Kira was telling Jamie about the remote control. She told him that the button had to be pressed for the channel to change. She also said If the batteries were charged then the channel changed.

Gerry was telling his friend Karen about the fireplace. He told her that there had to be fire-lighter for there to be a fire. He also said If there was coal then there was a fire.

Nicole was telling her friend Tara about her car. She told her that she had to shift to a lower gear for the car to slow down. She also said If the break was depressed then the car slowed down.

Maureen was telling her guest Phillip about her shower. She told him that the cord had to be pulled for there to be hot water. She also said If the tap was turned to the left, then there was hot water.

Alex was telling his wife Carol about his job. He told her that he had to be caught stealing for him to lose his job. He also said If he brought home office paper then he lost his job.

Derek was telling Winston about the stock market. He told him that the currency market had to be stable for the stock market index to rise. He also said If the shares for Cirtec rose then the stock market index rose.

Ivy was telling Michael about her sun tan. She told him that she had to use browning oil for her to get a sun tan. She also said If she laid in the sun then she got a sun tan.

Johnny was telling Lorraine about his headphones. He told her that the cable had to be intact for the music to come through. He also said If the headphones were plugged in then the music came through.

Ella was telling Gerard about her grandmother’s sight. She told him that the print had to be large for her to be able to read a book. She also said If the book was in English then she read the book.

Tony was telling Laurie about memory. He told her that a person had to have a hippocampus for them to form memories. He also said
If a person rehearsed a list of words then they formed a memory of it.

Suzie was telling Owen about her epilepsy.  
She told him that she had to be off her medication for her to have a seizure.  
She also said  
If there was strobe lighting, then she had a seizure.

Richard was telling Sharon about his broken leg.  
He told her that he had to have a metal plate inserted for his bone to heal straight.  
He also said  
If he rested his leg then the bone healed straight.

Ollie was telling Brenda about his Chinese friend Lee.  
He told her that he had to use plain English for Lee to understand him.  
He also said  
If he spoke clearly then Lee understood him.

Moira was telling Luther about heart disease.  
She told him that a patient had to be overweight for them to have a heart attack.  
She also said  
If a patient suffered from stress, then they had a heart attack.

Weak causes

Nikki was telling Matthew about a school for hearing impaired children.  
She told him that the children had to read her lips to understand her.  
She also said  
If she used sign language, then the children understood her.

David was telling Christian about his insomnia.  
He told him that drinking coffee meant he had sleepless nights.  
He also said  
If he suffered from stress, then he had sleepless nights.

Francis was telling Emer about lung cancer.  
He told her that he had to smoke for him to contract lung cancer.  
He also said  
If he worked with dangerous chemicals then he contracted lung cancer.

Albert was telling Lara about his allergies.  
He told her that he had to have peanuts for him to have an allergic reaction.  
He also said  
If he had dairy products then he had an allergic reaction.

Molly was telling Alan about her dog Sparky.  
She told him that Sparky had to have fleas for him to scratch himself.  
She also said  
If Sparky had a skin disease then he scratched himself.

Andy was telling Rachel about his friend Mary.  
Andy told Rachel that Mary had to have a shower for her to get wet.  
He also said
If Mary jumped into the swimming pool, then she got wet.

Lisa was telling Simon about the campfire. She told him that sand had to be poured on the campfire for the fire to go out. He also said If water was poured on the campfire, then the fire went out.

Christine was telling Trevor about traffic congestion in Grimsby. She told him there had to be an accident for there to be congestion. She also said If the traffic lights on the High street fell out then there was congestion.

Brandon was telling Kelly about his new mobile phone. He told her that he had to receive a text message for the phone to vibrate. He also said If he received a phone call then the phone vibrated.

Strong causes
Connor was telling Emma about unemployment in his home town. He told her that there had to be a news report were the unemployment figures to go up. He also said If the Plastics factory closed down, then the unemployment figures went up.

Elaine was telling Joanne about her boss' house in the suburbs. She told her that her boss had to have his hearing aid switched on for him to hear the bell. She also said If the doorbell was pushed, then it rang.

Lisa was talking to David about a Buddhist temple. Lisa told David that the monks had to be by the pond for them to hear the gong. She also said If the gong was struck, then it sounded.

Barry was talking to Jenny about a murder suspect Larry. He told her that Larry had to be in the living room for him to have left his fingerprints. He also said If Larry grasped the glass with his bare hands, then his fingerprints were on it.

Peter was talking to Mary about his friend Joseph. Peter told Mary that Joseph had to be using a knife for him to cut his finger. He also said If Joseph cut his finger, then it bled.

Alfie was telling Cora about his new medication. He told her that for him to suffer memory loss was very upsetting. He also said If he took this medication, then he would suffer from memory loss.

Gavin was telling Justine about the election. He told her that people had to have a good reason for them to re-elect the labour party. He also said
If the labour party agreed to increase the minimum wage then they were re-elected.

Bridget was telling Oscar about the greenhouse effect.
She was telling him that there had to be concern about the ice caps melting.
She also said
If there was global warming then the ice caps melted.

Linda was telling Malcolm about handicrafts.
She told him he had to be careful for the glue was very sticky.
She also said
If the glue was on the paper then the sheets stuck together.

C3. Instructions for Experiments 5 and 6

Instructions
Thank you for agreeing to participate in this study. The study examines the psychological processes implicated in text comprehension. This is not a test of intelligence. Your answers will be treated as confidential and anonymous, and you may withdraw your participation at any time.

The study consists of 24 short stories like the one below. Your task will consist of reading the stories quickly and accurately. The stories are about two people talking in various situations. The stories will be presented to you sentence by sentence. When you finish reading a sentence and are ready to read the next sentence, please press the space bar. After reading each story, you must answer a question concerning a different part of the story. For example:

Tom and Lucy’s mother was asking them which program they want to watch.
Tom wanted to watch Inspector gadget and Lucy wanted to watch Teletubbies.
Their mother said that they can watch Inspector Gadget or Teletubbies
The mother turned on the TV
They all watched Inspector Gadget
Lucy was upset at first, but then quite enjoyed it
Did Tom and Lucy’s mother ask them about which program they want to watch?
The answer to this question is ‘yes’. To answer ‘yes’ to a question please press the ‘yes’ key on the right side and to answer ‘no’ please press the ‘no’ key on the left side of the keyboard.

You will first be shown four practice problems so you can familiarise yourself with the procedure.

Overall, this part of the study will last approximately 15 minutes. If you have any questions, please ask the experimenter who will be pleased to answer them. After you completed all the tasks today you will be given an explanation of the main aims of the study. Thank you for your participation.

Please press the space bar to begin the practice problems.

C4. Materials for Experiment 5

Practice Problems:
Sharon went to a jewellers with her husband Alan
Sharon told him that at this jewellers
There were chains or there were bracelets
When they arrived at the jewellers they saw that
The chains were silver and the bracelets were gold.
Sharon and Alan went to a book shop.  
Were the chains gold and the bracelets silver?

Martin went to a flower shop with his sister.  
She told him that in this shop  
There were roses or there were daffodils.  
When they arrived at the shop they saw that  
There were roses and there were daffodils.  
Martin and his sister went to the cinema.  
Did Martin and his sister go to a flower shop?

Sinead went to an opticians with her mother.  
The met Sinead's father.  
Sinead told her father about her homework  
When they got to the opticians they saw that  
There were glasses and there were contact lenses.  
Sinead went to meet her friend.  
Did Sinead tell her father about her music lesson?

Suzanne went to a department store with her friend Lisa.  
Lisa told her that in this store  
There were perfumes and there were colognes.  
When they arrived at the shop they saw that  
There were perfumes and colognes.  
Suzanne and Lisa went to a café for some lunch.  
Did Lisa say in this store there were perfumes and there were colognes?

Experimental Materials  
(Baseline sentences appear in italics beneath the conditional statements they replaced)

Jason was telling Nancy about his dad's car.  
He told her that the battery had to be charged for the car to start.  
He also said  
If the key was turned, then the car started.  
The key was on the kitchen table.  
When Jason showed Nancy the car she saw that  
The key was turned and the car started.  
Nancy went to buy some sponges.  
Was Jason telling Nancy about his mother's car?

Charlie was telling Sharon about his new gun.  
He told him that the bullets had to be inserted for the gun to fire.  
He also said  
If the trigger was pulled, then the gun fired.  
The trigger on the gun was silver.  
When Marcus showed Sharon the gun she saw that  
The trigger was pulled and the gun fired.  
Sharon went to a shooting competition.  
Did Charlie say if the trigger was pulled, then the gun exploded?

Sharon was telling Julie about her sewing machine.  
She told her that the pedal had to be pressed for the machine to work.  
She also said
If the needle was threaded, then the machine worked.
The needle was attached to a bar.
When Sharon showed Julie the machine, she saw that
The needle was threaded and the machine worked
Julie went to watch some TV.

Did Julie go to the cinema?

Katy was telling Jimmy about the kitchen light.
She told him that the bulb had to be inserted for the light to shine.
She also said
If the switch was flipped, then the light shone.
The switch was next to the door.
When Jimmy walked into the kitchen he saw that
The switch was flipped and the light shone.
Jimmy went to the garden centre.
Did Jimmy go to the furniture store?

Danny was telling Tina about the new doorbell.
He told her that the wires had to be connected for the bell to ring.
He also said
If the button was pushed, then the bell rang.
The button for the bell was black.
When Danny showed Tina the bell she saw that
The button was pushed and the bell rang.
Tina went to make a sandwich.
Did Danny say if the button was pulled, then the ball rang?

Audrey was telling Timmy about baking chocolate cake.
She told him that the baking-powder had to be added for the cake to rise.
She also said
If the mixture was heated, then the cake rose.
The mixture was poured in a tin.
When Amy showed Timmy the cake, he saw that
The mixture was heated and the cake rose.
The mixture was heated and the cake did not rise.
Timmy went to make some coffee.
Was Audrey telling Timmy about baking chocolate cake?

Diane was telling Patrick about her office chair.
She told him that a person had to be seated for the chair to descend.
She also said
If the lever was pulled, then the chair descended.
The lever was underneath the seat.
When Diane showed Patrick the chair, he saw that
The lever was pulled and the chair descended.
The lever was pulled and the chair did not descend.
Patrick went to get some stationary.
Did Diane say if the button was pushed, then the chair descended?

Fiona was telling Robert facts about snow.
She told him that the air had to be moist for the snow to fall.
She also said
If the temperature was below freezing, then the snow fell.
_The temperature was measured next to the door._
When Fiona and Robert went outside, he saw that
The temperature was below freezing and the snow fell.
Robert went to ride his bike.
Did Fiona and Robert go into the cellar?

Aoife was telling Brian about her garden plants.
She told him that the sun had to shine for the plants to grow.
She also said
If the soil was watered, then the plants grew.
_The soil in the garden was brown._
When Aoife showed Brian the plants, he saw that
The soil was watered and the plants grew.
Brian went to the garden shed.
Was Aoife telling Brian about her new bicycle?

Ivy was telling Michael about her daughter’s tan.
She told him that the lotion had to be used for the tan to appear.
She also said
If the sun was shining, then the tan appeared.
_The sun was highest at mid day._
When Ivy pointed out her daughter, he saw that
The sun was shining and the tan appeared.
Michael went to buy an ice-cream.
Was Ivy telling Michael about her daughter’s hair?

Justin was telling Tara about evidence of fingerprints.
He told her that the object had to be touched for his fingerprints to mark.
He also said
If his hands were bare, then his fingerprints marked.
_His hands were by his sides._
When Justin showed Tara cctv footage, she saw that
His hands were bare and his fingerprints marked.
Tara went to see her supervisor.
Did Tara go to see her supervisor?

Maureen was telling Phillip about her shower.
She told him that the cord had to be pulled for the shower to operate.
She also said
If the tap was turned, then the shower operated.
_The tap was beneath the soap dish._
When Maureen showed Phillip the shower, he saw that
The tap was turned and the shower operated.
Phillip went to buy some postcards.
Did Maureen say the cord had to be pulled for the shower to operate?

Kira was telling Jamie about the remote control.
She told him that the button had to be pressed for the remote to work.
She also said
If the batteries were charged, then the remote worked.
_The batteries had green writing on them._
When Kira showed Jamie the remote, he saw that
The batteries were charged and the remote worked.
Jamie went to get some crisps.
Were the batteries charged and the remote worked?

Johnny was telling Cora about his old headphones.
He told her that the cable had to be intact for the headphones to work.
He also said
If the plug was connected, then the headphones worked.
The plug on these headphones was gold.
When Johnny showed Cora his headphones, she saw that
The plug was connected and the headphones worked.
Cora went to pick some CDs.
Was the plug not connected and the headphones did not work?

Kerry was telling Adam about making fresh dough.
She told him that the mixture had to contain yeast for the dough to double.
She also said
If the bowl was covered, then the dough doubled.
The bowl was made of orange plastic.
When Kerry showed Adam the dough, he saw that
The bowl was covered and the dough doubled
Adam went to do some gardening.
Did Kerry say if the bowl was covered then the dough doubled?

Janet was telling Marcus about a mixture.
She told him that the beakers had to be heated for the mixture to darken.
She also said
If the chemicals were combined, then the mixture darkened.
The chemicals used in the experiment were blue.
When Janet showed him the experiment he saw that
The chemicals were combined and the mixture darkened.
Marcus went to a maths lesson.
Did Janet tell Marcus the beakers had to be chilled for the mixture to darken?
Were the chemicals combined and the mixture did not darken?
Were the chemicals not combined and the mixture did not darken?

Ella was telling Gerard about her grandmother.
She told him that the print had to be large for her grandmother to read.
She also said
If the book was fiction, then her grandmother read.
The books were on the top shelves.
When Ella pointed out her grandmother, he saw that
The book was fiction and her grandmother read.
Gerard went to make some tea.
Did Ella say if the book was non-fiction then her grandmother read?

Suzanne was telling Dermot about the statistics students.
She told him that the tables had to be used for the students to succeed.
She also said
If the calculator was permitted, then the student succeeded.
The calculator was on the desk.
When Suzanne showed Dermot the results he saw that
the calculator was permitted and the students succeeded.
Dermot went to buy some wine.
Did Dermot go to buy some cheese?
Did Suzanne say if the calculator was permitted then the student succeeded?

Martin was telling Laura about his medicine bottle.
He told her that the sides had to be squeezed for the bottle to open.
He also said
If the lid was twisted, then the bottle opened.
_The lid on the bottle was white._
When Martin showed Laura the bottle, she saw that
The lid was twisted and the bottle opened.
Laura went to get a drink.
Was the lid twisted and the bottle opened?

Andrew was telling Cathy about his new gadget.
He told her that the object had to be vertical for the gadget to launch.
He also said
If the button was pushed, then the gadget launched.
_The button on the gadget was green._
When Andrew showed Cathy the gadget, she saw that
The button was pushed and the gadget launched.
The button was not pushed and the gadget launched.
Cathy went to the laboratory.
Was Andrew telling Cathy about his new gadget?

Gerry was telling Karen about having a BBQ.
He told her that the fire-lighter had to be set for the BBQ to light.
He also said
If the coal was used, then the BBQ lit.
_The coal was kept in the shed._
When Gerry showed Karen the grill, she saw that
The coal was used and the BBQ lit.
Karen went to read a book.
Did Karen go to write a letter?

Oisin was telling Tammy about his oriental lilies.
He told her that the buds had to be open for the lilies to stain.
He also said
If the inside was touched then the pollen stained.
_The inside of the flower was pink._
When Oisin showed Tammy the lilies, she saw that
The inside was touched and the pollen stained.
Tammy went to buy some groceries.
Did Tammy go to buy some groceries?
Did Oisin show Tammy the tulips?

Marie was telling Cathal about his bedroom.
She told him that the conditioning had to be on for the room to cool.
She also said
If the windows were closed, then the room cooled.
The windows were on the left wall. When Marie showed Cathal the room, he saw that the windows were closed and the room cooled. Cathal went to visit his grandma. Did Marie tell Cathal the conditioning had to be on for the room to cool?

Nicole was telling Liam about her car. She told him a lower gear had to be used for the car to slow. She also said if the brake was depressed, then the car slowed. The brake pedal was in the middle. When Nicole showed Liam the car, he saw that the brake was depressed and the car did not slow. Liam went to check the map. Did Liam go to check tyre pressure?

C5. Results of Power tests for the planned comparisons in Experiment 5

Power was calculated using the following formula (Hinkle, 1998):

$$(\mu_1 - \mu_2) - (1.645)(s_{x_1} - s_{x_2}) = 0 - (1.645)(1.78)$$

Where

$$s_{x_1} - s_{x_2} = \sqrt{s^2(1/n_1 + 1/n_2)}$$

Table C1: Power tests comparing reaction times for conjunctions following primes with conditional and baseline sentences

<table>
<thead>
<tr>
<th>Conjunction</th>
<th>80% Power to detect a difference of</th>
</tr>
</thead>
<tbody>
<tr>
<td>p &amp; q</td>
<td>.02</td>
</tr>
<tr>
<td>p &amp; not q</td>
<td>.02</td>
</tr>
<tr>
<td>not p &amp; q</td>
<td>.02</td>
</tr>
<tr>
<td>not p &amp; not q</td>
<td>.02</td>
</tr>
</tbody>
</table>

C6. Materials for pre-test 6.1

Weak causes and enabling conditions

(weak causes were presented with the italicised sentence instead of the one preceding it)

Jason was telling Nancy about his dad's car. He told her that the car started when the battery was charged. He told her that the car started when the button was pushed. He also said if the key was turned, then the car started.

Charlie was telling Sharon about his new gun. He told her that the gun fired when the bullets were inserted. He also said if the trigger was pulled, then the gun fired.
Sharon was telling Julie about her sewing machine.
She told her that the machine worked when the pedal was pressed.  
*She told her that the machine worked when the needle had wool in it.*
She also said
If the needle was threaded, then the machine worked.

Katy was telling Jimmy about the kitchen light.
She told him that the light shone when the bulb was inserted.  
*She told him that the light shone when the string was pulled.*
She also said
If the switch was flipped, then the light shone.

Danny was telling Tina about the new doorbell.
He told her that the bell rang when the wires were connected.  
*He told her that the bell rang when the lever was pulled.*
He also said
If the button was pushed, then the bell rang.

Audrey was telling Timmy about baking chocolate cake.
She told him that the cake rose when baking-powder was added.  
*She told him the cake rose when additives were stirred in.*
She also said
If the mixture was heated, then the cake rose.

Diane was telling Patrick about her office chair.
She told him that the chair descended when a person was seated.  
*She told him that the chair descended when someone stood on it.*
She also said
If the lever was pulled, then the chair descended.

Fiona was telling Robert facts about snow.
She told him that snow fell when the air was moist.  
*She told him that snow fell when a snow machine was used.*
She also said
If the temperature was below freezing, then the snow fell.

Aoife was telling Brian about her garden plants.
She told him that the plants grew when the sun shined.  
*She told him that the plants grew when it rained.*
She also said
If the soil was watered, then the plants grew.

Ivy was telling Michael about her daughter’s tan.
She told him that the tan appeared when she used lotion.  
*She told him that the tan appeared when she used the sun bed.*
She also said
If the sun was shining, then the tan appeared.

Justin was telling Tara about evidence of fingerprints.
He told her that his fingerprints marked when the object was touched.  
*He told her that his fingerprints marked when there was a whole in the gloves.*
He also said
If his hands were bare, then his fingerprints marked.

Maureen was telling Phillip about her shower. She told him that the shower operated when the cord was pulled. 
*She told him that the shower operated when the dial was turned.*
She also said
If the tap was turned, then the shower operated.

Kira was telling Jamie about the remote control. She told him that the remote worked when the button was pressed. 
*She told him that the remote worked when it was plugged in.*
She also said
If the batteries were charged, then the remote worked.

Johnny was telling Cora about his old headphones. He told her that the headphones worked when the cable was intact. 
*He told her that the headphones worked when the aerial was pulled out.*
He also said
If the plug was connected, then the headphones worked.

Kerry was telling Adam about making fresh dough. She told him that the dough doubled when the mixture contained yeast. 
*She told him that the dough doubled when the bowl was placed in a warm place.*
She also said
If the bowl was covered, then the dough doubled.

Janet was telling Marcus about a mixture. She told him that the mixture darkened when the beakers were heated. 
*She told him that the mixture darkened when water was added.*
She also said
If the chemicals were combined, then the mixture darkened.

Ella was telling Gerard about her bilingual grandmother. 
*Ella was telling Gerard about her bilingual grandmother.*
She told him that her grandmother read when the print was large.
*She told him that her grandmother read when the book was in English.*
She also said
If the book was fiction, then her grandmother read.
If the book was in French then her grandmother read.

Suzanne was telling Dermot about the statistics students. She told him that the students succeeded when they used the tables. 
*She told him that the students succeeded when they used mental arithmetic*
She also said
If the calculator was permitted, then the students succeeded.

Martin was telling Laura about his medicine bottle. He told her that the bottle opened when the sides were squeezed. 
*He told her that the bottle opened when it was thrown on the floor.*
He also said
If the lid was twisted, then the bottle opened.
Andrew was telling Cathy about his new gadget. 
He told her that the gadget launched when it was held vertical.  
*He told her that the gadget launched when it was stepped on.* 
He told her that  
He also said  
If the button was pushed, then the gadget launched.

Gerry was telling Karen about having a BBQ.  
He told her that the BBQ lit when fire lighter was set.  
*He told her that the BBQ lit when wood was placed on it* 
He also said  
If the coal was used, then the BBQ lit.

Oisin was telling Tammy about his oriental lilies.  
He told her that the pollen stained when the buds were open.  
*He told her that the pollen stained when the buds fell.* 
He also said  
If the buds were touched then the pollen stained.

Marie was telling Cathal about his bedroom.  
She told him that the room cooled when the fan was on.  
*She told him that the room cooled when the door was open.*  
She also said  
If the windows were open, then the room cooled.

Nicole was telling Liam about her car.  
She told him that the car slowed when a lower gear was used.  
*She told him that the car slowed when the tire burst*  
She also said  
If the brake was depressed, then the car slowed.

Martin was talking to Thomas about apples.  
Martin told Thomas that apples fell from the tree when they were heavy.  
*Martin told Thomas that apples fell from the tree when it was stormy.*  
Martin also said  
If the apples were ripe, then the apples fell.

Andy was talking to Tara about Mary.  
Andy told Tara that Mary got wet when she attended swimming class.  
*Andy told Tara that Mary got wet when it rained.*  
Andy also said  
If she jumped into the swimming pool, then Mary got wet.

Laurie was telling Richard about driving fines.  
She told him that she incurred a fine when a traffic warden caught her.  
*She told him that she incurred a fine when she was speeding.*  
She also said  
If she parked on double yellow lines then a fine was incurred.

Lisa was talking to Brian about the campfire.  
Lisa told Brian that the fire went out when a big bucket was used  
*Lisa told Brian that the fire went out when it was very windy.*
She also said
If water was used, then the fire went out.

Brandon was telling Kelly about his new mobile phone.
He told her that the phone vibrated when the vibrate function was selected.
*He told her that the phone vibrated when a text message was received.*
He also said
If a person phoned then the phone vibrated.

Christine was telling Trevor about traffic in Kilkenny.
She told him that there was traffic congestion when it was summer.
*She told him that there was traffic congestion when an accident happened.*
She also said
If there were road works then there was traffic congestion.

Connor was telling Elaine about hallucinations.
He told her that hallucinations occurred when he was sick.
*He told her that hallucinations occurred when he was on drugs.*
He also said
If he had a strong fever then hallucinations occurred.

Albert was telling Lara about his allergies.
He told her that he had an allergic reaction when he was run down.
*He told her that he had an allergic reaction when he ate peanuts.*
He also said
If he had dairy products then he had an allergic reaction.

Francis was telling Emer about lung cancer.
He told her that he developed lung cancer when he had a genetic predisposition.
*He told her that he developed lung cancer when he smoked cigarettes*
If he worked with dangerous chemicals then lung cancer developed.

Holly was telling Andrew about pain.
She told him that her pain eased when she relaxed.
*She told him that her pain eased when she took analgesia.*
She also said
If she was hypnotised then her pain was eased.

Nikki was telling Matthew about hearing impaired children.
She told him that the children understood her when she spoke English.
*She told him that the children understood her when she used sign language.*
She also said
If the children read her lips, then the children understood her.

Amy was telling Owen about drinks.
She told him that she drank water when she exercised.
*She told him that she drank water when she ate salty food.*
She also said
If she went to the gym then she drank water.

Lisa was telling Brian about computers.
She told him that the computer crashed when the fan was broken.  
*She told him that the computer crashed when there was a hard drive failure.*  
She also told him  
If the machine ran hot then the computer crashed.

Martin was telling Orla about the grass.  
He told her that the grass got wet when the hose pipe was connected.  
*He told her that the grass got wet when it was raining.*  
He also said  
If sprinkler was on then the grass was wet.

Liam was telling Janet about sweating.  
He told her that he sweat heavily when it was hot outside.  
*He told her that he sweat heavily when he was in a sauna.*  
He also said  
If he exercised inside then he sweat heavily.

Richard was telling Ella about spots  
He told her that spots appeared when he had oily skin.  
*He told her that spots appeared when he had chicken pocks.*  
He also said  
If he developed acne then spots appeared.

Brenda was telling Phillip about becoming a parent  
She told him that she became a parent when she was financially secure.  
*She told him that she became a parent when she gave birth.*  
She also said  
If she adopted a child then she became a parent.

Dermot was telling Kira about water.  
He told her that the water boiled when salt was used.  
*He told her that the water boiled when it was heated in the kettle.*  
He also said  
If the water was heated in the saucepan then the water boiled.

Paula was telling Curtis about keeping dry.  
She told him that he kept dry from the rain when he kept away from puddles.  
*She told him that he kept dry from the rain when he wore a raincoat.*  
She also said  
If he used an umbrella then he kept dry from rain.

Sandra was telling Mervin about going out.  
She told him that she went to the cinema when she had enough money.  
*She told him that she went to the cinema when her friends went.*  
She also said  
If my brother met me then I went to the cinema.

Phillip was telling Alice about studying.  
He told her that he studied in the library all evening when the library was open late.  
*He told her that he studied in the library all evening when he had textbooks to read.*  
He also said  
If he had an essay to write then she studied in the library all evening.
Sheila was telling Travis about getting wet.  
He told her that he got wet when he went for a walk.  
*He told her he got wet when it snowed.*  
He also said  
If it rained then I got wet.  

Carlos was telling Linda about the grass.  
He told her that he cut the grass when he fixed the faulty lawnmower.  
*He told her that he cut the grass when it was the weekend.*  
He also said  
If he took the afternoon off work then he cut the grass.  

Trisha was telling Louis about fish.  
She told him that she had fish dinner when she knew how to gut fish.  
*She told him that she had fish dinner when she bought some fish.*  
She also said  
If she caught some fish then she had fish dinner  

Ian was telling Karen about dinner.  
He told her that he had a pleasant dinner when he had decent ingredients in the cupboard.  
*He told her that he had a pleasant dinner when he went to a restaurant.*  
He also said  
If he cooked himself then he had a pleasant dinner.  

Sheila was telling Nathan about rowing.  
She told him that she went rowing when the boats were in working condition.  
*She told him that she went rowing when her friend lent her his.*  
She also said  
If the boat house had boats available then she went rowing.  

Joseph was telling Janice about grades.  
He told her that he got high grades when he concentrated in classes.  
*He told her that he got high grades when the exam was easy.*  
He also said  
If he studies hard then he got high grades.  

Molly was telling Alan about her dog.  
She told him that the dog scratched himself when his claws were long.  
*She told him that the dog scratched himself when he had fleas.*  
She also said  
If the dog had a skin disease then Sparky scratched himself.  

Daryl was telling Lily about matches  
He told her that the match lit when it was dry.  
*He told her that the match lit when it was held into a flame.*  
He also said  
If the match was struck then it lit.  

Fergus was telling Ethna about the plants  
He told her that the plants grew quickly when there was sunshine.  
*He told her that the plants grew when they were planted in fertile soil.*
He also said
If fertilizer was used then the plants grew quickly.

**Strong causes**
Connor was telling Emma about unemployment in his home town.
He told her that the unemployment figures went up when there was a news report.
He also said
If the Plastics factory closed down, then the unemployment figures went up.

Elaine was telling Joanne about her boss' house in the suburbs.
She told her that her boss heard the bell when his hearing aid was switched on.
She also said
If the doorbell was pushed, then it rang.

Lisa was talking to David about a Buddhist temple.
Lisa told David that the monks heard the gong when they were by the pond.
She also said
If the gong was struck, then it sounded.

Barry was talking to Jenny about a murder suspect Larry.
He told her that Larry was in the living room when he left his fingerprints.
He also said
If Larry grasped the glass with his bare hands, then his fingerprints were on it.

Peter was talking to Mary about his friend Joseph.
Peter told Mary that Joseph cut his finger when he used a knife.
He also said
If Joseph cut his finger, then it bled.

Alfie was telling Cora about his new medication.
He told her that he was very upset when he suffered memory loss.
He also said
If he took this medication, then he would suffer from memory loss.

Gavin was telling Justine about the election.
He told her that people re-elected the labour party when they had good reason.
He also said
If the labour party agreed to increase the minimum wage, then they were re-elected.

Bridget was telling Oscar about the greenhouse effect.
She told him that there was concern when the ice caps were melting.
She also said
If there was global warming, then the ice caps melted.

Linda was telling Malcolm about handicrafts.
She told him that he had to be careful for the glue was very sticky.
She also said
If the glue was on the paper, then the sheets stuck together.

Stuart was telling Anna about his arm.
He told her that he was frustrated when his arm hurt.
He also said
If he broke his arm, then his arm hurt.

Michelle was telling Geoffrey about music. She told him that she listened to music when she was happy. She also said If Doreen plays the flute, then there is music.

Aisling was telling Peter being tired. She told him that she was tired when she was at home. She also said If she went to sleep late, then she was tired.

C7. Materials for Experiment 6
(Underlined sentences replaced sentence two in the strong condition, italicised sentences replaced the conditional sentence in the baseline condition.)

Jason was telling Nancy about his dad’s car. He told her that the car started when the button was pushed. He told her that the key had a silver key ring. He also said If the key was turned, then the car started. The key had a silver key ring. When Jason showed Nancy the car she saw that The key was turned and the car started. Nancy went to buy some sponges. Did Jason tell Nancy about his dad’s car?

Danny was telling Tina about the new doorbell. He told her that the bell rang when the lever was pulled. He told her that the button for the bell was black. He also said If the button was pushed, then the bell rang. The button for the bell was black. When Danny showed Tina the bell she saw that The button was pushed and the bell rang. Tina went to make a sandwich. Did Danny say if the button was pushed then the bell rang?

Diane was telling Patrick about her office chair. She told him that the chair descended when someone stood on it. She told him that the lever was underneath the seat. She also said If the lever was pulled, then the chair descended. The lever was underneath the seat. When Diane showed Patrick the chair, he saw that The lever was pulled and the chair descended. Patrick went to get some stationary. Was the lever pulled and the chair descended?

Aoife was telling Kevin about her garden plants. She told him that the plants grew when there was rainfall.
She told him that the soil in the garden was brown.  
She also said  
If the soil was watered, then the plants grew.  
*The soil in the garden was brown.*  
When Aoife showed Brian the plants, he saw that  
The soil was watered and the plants grew.  
Brian went to the garden shed.  
Did Brian go to the market?

Ivy was telling Michael about her daughter’s tan.  
She told him that her daughter’s tan appeared when she used the sunbed.  
She told him that the sun was highest at mid day.  
She also said  
If the sun shone, then her daughter’s tan appeared.  
*The sun was highest at mid day.*  
When Ivy pointed out her daughter, he saw that  
The sun was shining and the tan appeared.  
Michael went to buy an ice-cream.  
Was Ivy telling Michael about her daughter’s hair?

Justin was telling Millie about evidence of fingerprints.  
He told her that fingerprints marked when gloves had a hole.  
*He told her that his hands were beside his legs.*  
He also said  
If his hands were bare, then his fingerprints marked.  
*His hands were beside his legs.*  
When Justin showed Millie cctv footage, she saw that  
His hands were bare and his fingerprints marked.  
Millie went to see her supervisor.  
Did Justin say if his hands were bare then his fingerprints marked?  
Did Justin say his hands were beside his legs?

Kerry was telling Adam about making fresh dough.  
She told him that the dough doubled when it was in a warm place.  
*She told him that the bowl was made of orange plastic.*  
She also said  
If the bowl was covered, then the dough doubled.  
*The bowl was made of orange plastic.*  
When Kerry showed Adam the dough, he saw that  
The bowl was covered and the dough doubled.  
Adam went to do some gardening.  
Was the bowl covered and the dough doubled?

Jordan was telling Laura about his medicine bottle.  
He told her that the bottle opened when it was thrown on the floor.  
*He told her that the lid on the bottle was white.*  
He also said  
If the lid was twisted, then the bottle opened.  
*The lid on the bottle was white.*  
When Jordan showed Laura the bottle, she saw that  
The lid was twisted and the bottle opened.  
Laura went to get a drink.
Did Laura go to get a sandwich?

Fintan was telling Cathy about his new gadget.
He told her that the gadget launched when it was stepped on.
He told her that the button on the gadget was green.
He also said
If the button was pushed, then the gadget launched.
The button on the gadget was green.
When Andrew showed Cathy the gadget, she saw that
The button was pushed and the gadget launched.
Cathy went to the laboratory.
Was the button pushed and the gadget launched?

Gerry was telling Sinead about having a BBQ.
He told her that the BBQ lit when wood was placed on it.
He told her that the coal was kept in the shed.
He also said
If the coal was used, then the BBQ lit.
The coal was kept in the shed.
When Gerry showed Sinead the BBQ, she saw that
The coal was used and the BBQ lit.
Sinead went to read a book.
Did Gerry say if the coal was used then the BBQ lit?
Did Gerry say the coal was kept in the kitchen?

Oisin was telling Tammy about his oriental lilies.
He told her that the lilies stained when the buds fell off.
He told her that the pollen of the flowers was orange.
He also said
If the pollen was touched then the lilies stained.
The pollen of the flowers was orange.
When Oisin showed Tammy the lilies, she saw that
The pollen was touched and the lilies stained.
Tammy went to buy some groceries.
Did Tammy go to buy some groceries?

Marie was telling Cathal about his room.
She told him that the room cooled when the door was ajar.
She told him that the windows were on the left wall.
She also said
If the windows were open, then the room cooled.
The windows were on the left wall.
When Marie showed Cathal the room, he saw that
The windows were open and the room cooled.
Cathal went to visit his grandma.
Did Marie say the room cooled when the door was ajar?
Did Marie say the windows were on the right wall?

Laurie was telling Bernard about driving fines.
She told him that a fine was incurred when she parked illegally.
She told him that speed was measured by the speedometer.
She also said
If she was speeding then a fine was incurred.  
*Speed was measured by the speedometer.*  
When Bernard saw Laurie he saw that  
She was speeding and a fine was incurred.  
Bernard went to buy a newspaper.  
Was Laurie speeding and a fine was incurred?

Brandon was telling Kelly about his new mobile phone.  
He told her that the phone vibrated when text messages were received.  
He told her that a person rang up from Italy daily.  
He also said  
If a person rang up then the phone vibrated.  
*A person rang up from Italy daily.*  
When Kelly saw the phone she saw that  
A person phoned and the phone vibrated.  
Kelly went to check her emails.  
Was Brandon say if a person rang up then the phone vibrated?  
Did Brandon say a person rang up from France daily?

Connor was telling Elaine about hallucinations.  
He told her that hallucinations occurred when he was on drugs.  
He told her that a strong fever was treated with rest.  
He also said  
If he had a strong fever then hallucinations occurred.  
*A strong fever was treated with rest.*  
When Elaine saw Connor she saw that  
He had a strong fever and hallucinations occurred.  
Elaine went to make a cup of tea.  
Did Elaine go to make a cup of tea?

Albert was telling Lara about his allergic reactions.  
He told her that he had a reaction when he ate peanuts.  
He told her that dust accumulated under the bed.  
He also said  
If he encountered dust then he had a reaction.  
*Dust accumulated under the bed.*  
When Lara saw Albert she saw that  
He encountered dust and he had a reaction.  
Lara went to play with the cat.  
Was Albert telling Lara about his wisdom tooth?

Nikki was telling Matthew about hearing impaired children.  
She told him that the children understood her when she used sign language.  
She told him that reading lips was learnt at home.  
She also said  
If they read lips, then the children understood her.  
*Reading lips was learnt at home.*  
When Matthew saw the children he saw that  
They read lips and the children understood her.  
Matthew went to speak to a teacher.  
Did Matthew go to speak to a teacher?
Amy was telling Owen about drinking. She told him that she drank water when she ate salty food. She told him that the yoga class was in the gym. She also said If she went to yoga then she drank water.

The yoga class was in the gym.
When Owen saw Amy he saw that She went to yoga and she drank water. Owen went to buy a book. Did she go to yoga and drink water?

Lisa was telling Brian about computers. She told him that the computer crashed when the hard drive failed. She told him that the fan was behind the mother board. She also said If the fan was broken then the computer crashed.

The fan was behind the mother board.
When Brian saw the computer he saw that The fan was broken and the computer crashed. Brian went to the photocopier. Did Brian say if the fan was broken then the computer crashed? Did Brian say the fan was in front of the mother board?

Martin was telling Orla about the grass. He told her that the grass got wet when there was rainfall. He told her that the sprinkler was next to the tree. He also said If the sprinkler spun then the grass got wet.

The sprinkler was next to the tree.
When Orla saw the grass she saw that The sprinkler spun and the grass got wet. Orla went to meet her mother. Did Martin say the grass got wet when there was rainfall? Did Martin say the sprinkler was next to the shed?

Richard was telling Ella about red spots. He told her that red spots appeared when he had chicken pocks. He told her that greasy skin developed on the forehead. He also said If he had greasy skin then red spots appeared.

Greasy skin developed on the forehead.
When Ella saw Richard she saw that He had greasy skin and red spots appeared. Ella went to water the plants. Did Ella go to the gym?

Trisha was telling Louis about cooking. She told him that she cooked fishcakes when she bought some salmon. She told him that trout could be found in the lake. She also said If she caught some trout then she cooked fishcakes.

Trout could be found in the lake.
When Louis saw Trisha he saw that
She caught some trout and she cooked fishcakes.
Louis went to buy some wine.
Did she catch some trout and cook fishcakes?

Molly was telling Alan about her dog.
She told him that the dog scratched when he had fleas.
She told him that skin disease was detected behind the ears.
She also said
If he had skin disease then the dog scratched.
Skin disease was detected behind the ears.
When Alan saw the dog he saw that
He had skin disease and the dog scratched.
Alan went to buy some dog food.
Did Molly say if he had skin disease then the dog scratched?
Did Molly say skin disease was detected under the eyes?

Daryl was telling Lily about matches.
He told her that the match lit when a flame ignited it.
He told her that the head of the match was red.
He also said
If the head was struck then the match lit.
The head of the match was red.
When Lily saw the matches she saw that
The head was struck and the match lit.
Lily went to buy some chocolate.
Was Daryl telling Lily about matches?

C8. Results of Power tests for the planned comparisons in Experiment 6

Table C2: Power tests comparing reaction times for conjunctions following primes with strong causes, weak causes and baseline sentences

<table>
<thead>
<tr>
<th>Conditions</th>
<th>Conjunction</th>
<th>80% Power to detect a difference of:</th>
</tr>
</thead>
<tbody>
<tr>
<td>Strong &amp; baseline</td>
<td>p &amp; q</td>
<td>.03</td>
</tr>
<tr>
<td></td>
<td>p &amp; not q</td>
<td>.03</td>
</tr>
<tr>
<td></td>
<td>not p &amp; q</td>
<td>.03</td>
</tr>
<tr>
<td></td>
<td>not p &amp; not q</td>
<td>.03</td>
</tr>
<tr>
<td>Weak &amp; baseline</td>
<td>p &amp; q</td>
<td>.03</td>
</tr>
<tr>
<td></td>
<td>p &amp; not q</td>
<td>.03</td>
</tr>
<tr>
<td></td>
<td>not p &amp; q</td>
<td>.03</td>
</tr>
<tr>
<td></td>
<td>not p &amp; not q</td>
<td>.03</td>
</tr>
<tr>
<td>Strong &amp; weak</td>
<td>p &amp; q</td>
<td>.03</td>
</tr>
<tr>
<td></td>
<td>p &amp; not q</td>
<td>.03</td>
</tr>
<tr>
<td></td>
<td>not p &amp; q</td>
<td>.03</td>
</tr>
<tr>
<td></td>
<td>not p &amp; not q</td>
<td>.03</td>
</tr>
</tbody>
</table>
Appendix D

D1. Instructions for Experiment 7
Thank you for agreeing to participate in this study. This booklet contains ten statements. Each statement is followed by a set of questions. The statements and associated tasks are about how people think in their daily lives and are not tests of intelligence. Please read each statement carefully and answer the questions that follow with reference to the information you have been given in the statement that preceded it. For this task we would like you to ignore any other knowledge you have about the topics referred to in the statements. Please answer the questions in the order in which they are presented and do not change your answers once you have written them.

D2. Materials for Experiment 7

The four versions of sentence 1 for the physiological content
Given that a person exercises, if they follow this diet then they lose weight.
Given that a person follows this diet, if they exercise then they lose weight.
If a person exercises, then given that they follow this diet they will lose weight.
If a person follows this diet, then given that they exercise they will lose weight.

The two versions of sentence 2 for the physiological content
If a person does not exercise then whether or not they follow the diet they do not lose weight.
If a person does not follow the diet then whether or not they exercise they do not lose weight.

Examples of sentence 1 for the remaining contents
Psychological: Given that a person is sensitive, if they are insulted then they get angry.
Mechanical: Given that there is a bullet in the chamber, if the trigger is pulled then a gun fires.
Biological: Given that there is fertilizer, if the sun shines then the plants grow.
Socioeconomic: Given that there is low unemployment, if the banks lower the interest rates then the economy will flourish.

D3. Debriefing for Experiment 7
This experiment aims to investigate how people distinguish causes and enabling conditions, i.e. factors that bring about an event and factors that allow an event to happen. We are also interested in how people adjust their beliefs in light of new information.

D4. Instructions for Experiment 8
Thank you for agreeing to participate in this study. This booklet contains eight descriptions, which each refer to two preceding events and an outcome. Each description is followed by a question asking you to identify what causes the outcome, and a question asking you to identify what enables the outcome to occur. A cause brings about an event, whereas an enabling condition makes it possible for the cause to work. Please be sure to
select one preceding event as the cause and the other preceding event as the enabling condition. Which is which, of course, is for you to decide.

D5. Materials for Experiment 8

Pre-test 1

Given that the gadget is twisted, if the button is pushed, then the gadget launches. However, given that the gadget is not twisted, the gadget does not launch even if the button is pushed.

If the yellow button is pressed then, given that the blue button is pressed, the lamp flashes. However, if the yellow button is not pressed, the lamp does not flash even given that the blue button is pressed.

Given that the small lever is pulled, if the large lever is pulled, then the machine operates. However, given that the small lever is not pulled, the machine does not operate even if the large lever is pulled.

If the golden key is turned then, given that the silver key is turned, the door opens. However, if the golden key is not turned, the door does not open even given that the silver key is turned.

Given that the green tap is turned, if the yellow tap is turned, then the water flows. However, if the yellow tap is not turned, the water does not flow even given that the green tap is turned.

If the ‘s’ key is pressed then, given that the ‘k’ key is pressed, the picture appears. However, given that the ‘k’ key is not pressed, the picture does not appear even if the ‘s’ key is pressed.

Given that the L-card is shown, if the P-card is shown, then the discount is received. However, if the P-card is not shown, the discount is not received even given that the L-card is shown.

If the black chemical is used then, given that the red chemical is used the reaction occurs. However, given that the red chemical is not used, the reaction does not occur even if the black chemical is used.

Pre-test 2

Given that the gadget is twisted, if the button is pushed, then the gadget launches. However, if the gadget is not twisted, the gadget does not launch even if the button is pushed.

If the yellow button is pressed then, given that the blue button is pressed, the lamp flashes. However, if the yellow button is not pressed, the lamp does not flash even if the blue button is pressed.

Given that the small lever is pulled, if the large lever is pulled, then the machine operates. However, if the small lever is not pulled, the machine does not operate even if the large lever is pulled.
If the golden key is turned then, given that the silver key is turned, the door opens. However, if the golden key is not turned, the door does not open even if the silver key is turned.

Given that the green tap is turned, if the yellow tap is turned, then the water flows. However, if the yellow tap is not turned, the water does not flow even if the green tap is turned.

If the ‘s’ key is pressed then, given that the ‘k’ key is pressed, the picture appears. However, if the ‘k’ key is not pressed, the picture does not appear even if the ‘s’ key is pressed.

Given that the L-card is shown, if the P-card is shown, then the discount is received. However, if the P-card is not shown, the discount is not received even if the L-card is shown.

If the black chemical is used then, given that the red chemical is used the reaction occurs. However, if the red chemical is not used, the reaction does not occur even if the black chemical is used.

**Experimental materials**

If the gadget is twisted, then if the button is pushed the gadget launches. However, if the gadget is not twisted, the gadget does not launch if the button is pushed.

If the yellow button is pressed, then if the blue button is pressed the lamp flashes. However, if the yellow button is not pressed, the lamp does not flash if the blue button is pressed.

If the small lever is pulled, then if the large lever is pulled the machine operates. However, if the small lever is not pulled, the machine does not operate if the large lever is pulled.

If the gold key is turned, then if the silver key is turned the door opens. However, if the gold key is not turned, the door does not open if the silver key is turned.

If the green tap is turned, then if the yellow tap is turned the water flows. However, if the yellow tap is not turned, the water does not flow if the green tap is turned.

If the ‘s’ key is pressed, then if the ‘k’ key is pressed the picture appears. However, if the ‘k’ key is not pressed, the picture does not appear even if the ‘s’ key is pressed.

If the L-card is shown, then if the P-card is shown the discount is received. However, if the P-card is not shown, the discount is not received if the L-card is shown.

If the black chemical is used then, if the red chemical is used the reaction occurs. However, if the red chemical is not used, the reaction does not occur even if the black chemical is used.

**D6. Debriefing sheet for Experiment 8**

This experiment aims to investigate how people distinguish causes and enabling conditions, i.e. factors that bring about an event and factors that allow an event to happen.
Dear [Name],

The Department of Psychology Ethics Committee met recently to consider your application entitled "Learning and Writing: SLI'ing". I am pleased to tell you that the Committee has approved your application.

Yours sincerely,

Kevin Tierney
Chairperson,
Department of Psychology Ethics Committee
Dear Professor Byron and Mr. Fassch

The Department of Psychology Ethics Committee met recently to consider your application entitled "What mental and emotional consequences underlie normal and-of functioning?"

I am pleased to inform you that the Committee has approved your application.

Yours sincerely,

Kevin Tierney
Chairperson,
Department of Psychology Ethics Committee