

Northumbria Research Link

Citation: Haigh, Matthew and Stewart, Andrew (2011) The influence of clause order, congruency and probability on the processing of conditionals. *Thinking & Reasoning*, 17 (4). pp. 402-423. ISSN 1354-6783

Published by: Taylor & Francis

URL: <http://dx.doi.org/10.1080/10463283.2011.628000>
<<http://dx.doi.org/10.1080/10463283.2011.628000>>

This version was downloaded from Northumbria Research Link:
<https://nrl.northumbria.ac.uk/id/eprint/14047/>

Northumbria University has developed Northumbria Research Link (NRL) to enable users to access the University's research output. Copyright © and moral rights for items on NRL are retained by the individual author(s) and/or other copyright owners. Single copies of full items can be reproduced, displayed or performed, and given to third parties in any format or medium for personal research or study, educational, or not-for-profit purposes without prior permission or charge, provided the authors, title and full bibliographic details are given, as well as a hyperlink and/or URL to the original metadata page. The content must not be changed in any way. Full items must not be sold commercially in any format or medium without formal permission of the copyright holder. The full policy is available online: <http://nrl.northumbria.ac.uk/policies.html>

This document may differ from the final, published version of the research and has been made available online in accordance with publisher policies. To read and/or cite from the published version of the research, please visit the publisher's website (a subscription may be required.)



**Northumbria
University**
NEWCASTLE



UniversityLibrary

Haigh, M. & Stewart, A. J. (2011). The influence of clause order, congruency and probability on the processing of conditionals. *Thinking & Reasoning*, 17, 402-423.

The influence of clause order, congruency and probability on the processing of
conditionals

Matthew Haigh
Andrew J. Stewart

University of Manchester, UK

Address for correspondence:

Matthew Haigh

School of Psychological Sciences

University of Manchester

Manchester, M13 9PL

Tel: +44 (0)161 275 2570

matthew.haigh@manchester.ac.uk

Acknowledgement

This research was supported by a Leverhulme Trust grant (F/00 120/BT) awarded to the second author.

Abstract

Conditional information can be equally asserted in the forms *if p, then q* (e.g., “if I am ill, I will miss work tomorrow”) and *q, if p* (e.g., “I will miss work tomorrow, if I am ill”). While this type of clause order manipulation has previously been found to have no influence on the *ultimate* conclusions participants draw from conditional rules, we used self-paced reading to examine how it affects the real time incremental processing of everyday conditional statements. Experiment 1 revealed that clause order interacts with presuppositional congruency as readers hypothetically represent counterfactual statements. When *if p, then q* counterfactuals contained a presupposition that was incongruent with prior context, these statements took longer to read than when the presupposition was congruent, but for *q, if p* conditionals there was no such congruency effect. Experiment 2 revealed that reading times were influenced by the subjective probability of an indicative conditional *regardless* of clause order, with a penalty observed for low probability statements relative to high probability statements in both conditional clause orders. These data reveal a dissociation whereby clause order mediates the effect of suppositional congruency on reading times, but does not mediate the effect of subjective probability.

Conditionals of the form *if p, then q* allow us to hypothetically consider what could be (e.g., “*if student tuition fees rise, then the number of students from disadvantaged backgrounds will fall*”) or what could have been (e.g., “*if we had not gone to war, there would now be a greater threat from terrorism*”). Data from offline reasoning tasks have fuelled a great deal of theoretical debate concerning how we mentally represent and reason with the hypothetical possibilities stemming from *if...* (See Evans & Over, 2004 for a review). However, while these offline paper and pencil tasks reveal the conclusions that people *ultimately* draw from conditional information, relatively little is known about the incremental online processes that are used to mentally represent a conditional in real time (see Ferguson & Sanford, 2008; Stewart, Haigh & Kidd, 2009 for recent exceptions).

One potentially important variable that may influence real time processing is the order in which the antecedent and consequent clauses are asserted. For example, a conditional in the canonical clause order *if p, then q* (e.g., “*If I am ill, I will miss work tomorrow*”) can equally be asserted in the non-canonical forms *q, if p* (e.g., “*I will miss work tomorrow, if I am ill*”) or *q, only if p* (e.g., “*I will miss work tomorrow, only if I am ill*”). These three conditional rules are logically equivalent, given that they are only false when the antecedent is true and the consequent is false. However, *q, only if p* conditionals have a fundamentally lower $P(q \mid \text{not-}p)$ than both *if p, then q* and *q, if p* (Oaksford & Chater, 2007) and induce a different pattern of performance on reasoning tasks (Ormerod, Manktelow, & Jones, 1993). Therefore, since the experiments below aim to examine of the influence of clause order per se, we focus solely on canonical conditionals of the form *if p, then q* and non-canonical conditionals of the form *q, if p* as only these forms are logically, lexically and probabilistically equivalent.

While the psychological equivalence of canonical (*if p, then q*) and non-canonical (*q, if p*) conditionals has been indicated by offline reasoning tasks (Evans, Clibbens, & Rood, 1995; Ormerod et al., 1993) it is unclear how clause order interacts with other important variables such as subjective probability and congruency as we incrementally represent and evaluate conditionals in real time. There is good reason to suspect that clause order may have an effect on incremental processing, given that non-canonical

conditionals tend to present information in a way that violates the temporal order of events (unlike canonical conditionals). This violation requires the likelihood of the consequent event q (e.g., missing work) to first be evaluated in its own right, before being held in working memory and then re-evaluated within the bounds of the *if* clause. While there is no evidence that clause order has any direct effect on processing, there is some evidence that it can indirectly influence processing speed by interacting with temporal order. Evans and Newstead (1977) found that participants take longer to comprehend and verify conditional rules when clause order mismatches temporal order. This interaction suggests that clause order is potentially an important moderator that could also interact with other variables as a conditional is incrementally processed.

To date, theories of conditional reasoning are grounded predominately in data from offline reasoning tasks and therefore do not provide explicit accounts of how we incrementally process conditionals. Nevertheless, they do *imply* some predictions concerning clause order. For instance, the prominent mental models account of conditionals proposed by Johnson-Laird and Byrne (2002) states the initial representation of a conditional begins with a mental model that explicitly represents the True-True (TT) truth table conjunction, $p \ \& \ q$. While this conjunction accurately captures the described scenario, it necessarily throws away any information concerning clause order at the earliest possible opportunity. This is because the logical operator ‘&’ does not (and cannot) indicate the order of the clauses, only that they co-occur in a commutative manner. Therefore, from this perspective clause order should not influence how we subsequently process or reason with conditional information.

One theory that more readily accounts for processing level variables is the Suppositional Theory proposed by Evans and Over (2004). The Suppositional Theory is the psychological implementation of a proposal in philosophical logic that has become known as the Ramsey Test. Ramsey proposed that people judge their belief in conditionals by “...adding p hypothetically to their stock of knowledge and arguing on that basis about q ...[fixing] their degrees of belief in q given p ...” (Ramsey, 1931; 1990, p. 247).

The Ramsey Test is essentially a two stage processing account. First, the addressee must temporarily suppose the antecedent proposition as true. Second, the

conditional is evaluated by considering the subjective conditional probability of the consequent event (q) occurring within the bounds of this hypothetical world. Like the mental models account this theory also initially represents the TT possibility, but importantly it does not discard the original conditional form (i.e., the clause order). Although not explicitly formulated as a processing account, the step by step mechanism outlined in the Ramsey Test clearly identifies two separable and sequential stages of processing, with supposition preceding evaluation.

While there is much evidence to support the psychological reality of the Ramsey Test (e.g., Over, Hadjichristidis, Evans, Handley & Sloman, 2007), this mechanism as originally described by Ramsey is specific to conditionals of the form *if p , then q* . First the antecedent proposition (p) is supposed, and then only *after* this has occurred can the probability of the consequent (q) be evaluated. However, when the clauses are not presented in this sequential order (as with non-canonical conditionals) additional or even different cognitive processes may emerge. For this reason the two self-paced reading experiments below examined how clause order mediates both supposition (Experiment 1) and evaluation (Experiment 2) as a conditional is processed.

Experiment 1

Does clause order mediate the influence of congruency on reading times to counterfactual conditionals?

The first stage of processing according to the Suppositional Theory is to hypothetically suppose the antecedent event as though it were true. Experimental evidence using self-paced reading has shown that the supposition of counterfactual conditionals (which presuppose the negation of their antecedent) is bounded by our world knowledge (Stewart, Haigh & Kidd, 2009). Stewart et al. presented participants with canonical counterfactuals (e.g., if Darren had been athletic, he would have probably played on the rugby team) embedded in vignettes and manipulated prior context so that the presupposition was either congruent (i.e., that Darren was not actually athletic) or incongruent (i.e., that Darren was very athletic). They found a rapid reading time penalty

when the presupposition was incongruent with prior context (relative to when it was congruent) suggesting that the mental representation of counterfactual information is tightly constrained by prior context.

These findings suggest that hypothetical thinking is only successfully triggered for canonical counterfactuals when the presupposition communicated in the first clause (p) is globally congruent with prior context. But when the presupposition is presented in the second clause (as with non-canonical conditionals) there is a competing frame of reference. Readers can *either* integrate the presupposition into their discourse model of the global context (as with canonical conditionals) or alternatively they can integrate it with the congruent hypothetical context set up by the first clause. This is because a unique feature of counterfactuals is that they provide syntactic triggers for hypothetical thinking in the both the antecedent (i.e., *if*) and consequent (i.e., *would*) clauses, signalled by the conditional perfect tense.

The self-paced reading experiment below addressed this question by manipulating the congruency of the presupposition and also the direction of clause order of counterfactuals embedded in vignettes. This 2 x 2 (Congruency x Clause Order) design gives four conditions (see Example Vignette). The dependent variable was reading time to the conditional statement.

Example Vignette from Experiment 1

Participants read either a congruent (1) or incongruent (2) context sentence followed by a conditional that was either in the canonical (3) or non-canonical (4) clause order.

1. Joanne hated rock music. (Congruent context)
2. Joanne liked rock music. (Incongruent context)
...Her parents were both professional musicians.
3. If she had liked rock music, she would probably have gone to Glastonbury every year.
4. She would probably have gone to Glastonbury every year, if she had liked rock music.
...She lived in a neighbouring village.

For canonical conditionals (where the presupposition is presented in the first clause) it is known that a reading time penalty occurs when this presupposition is globally incongruent with prior context (Stewart et al., 2009). For non-canonical conditionals the presupposition is presented in the second clause. In this case if the presupposition is also evaluated in terms of its global congruence with prior context, regardless of clause order, we would expect identical congruency effects for both conditional forms (i.e., a main effect of Congruency).

However, an alternative possibility is that when the incongruent presupposition is presented in the second clause it is actually evaluated in terms of its local coherence with the first clause. In other words, when the first clause successfully initiates hypothetical thinking (using the conditional perfect tense) the presupposition is evaluated within this hypothetical world *rather* than in terms of its global coherence. In this case, we would expect an interaction between Clause Order and Congruency, with a congruency effect for canonical conditionals (where the presupposition is presented in the first clause) but *not* for non-canonical conditionals (where the presupposition is presented in the second clause).

Participants

Thirty-six native English speakers from the University of Manchester population took part. They were each paid £5.

Materials

Twenty-four vignettes were constructed (see Example above and Appendix 1). There were four versions of each vignette and each was four sentences long. Sentence one introduced the protagonist and described some attribute associated with them. This sentence was manipulated in order for the subsequent conditional sentence to be either congruent or incongruent. Sentence two provided additional contextual information. Sentence three was the counterfactual conditional and thus the target sentence. Sentence four provided additional contextual information. Four Latin-square lists were created with each list also containing sixteen fillers.

Procedure

Each participant was presented with the passages in a different random order. They were informed that they would be presented with 40 passages on a word-by-word basis. In order to advance through the passages, they pressed the ‘Next Word’ button on a button box. This brought up the next word in the passage and blanked-out the previous one so only one word at a time was visible. Dashes represented the rest of each passage. Comprehension questions appeared on 25% of the trials. Participants first completed two practice trials.

Results

Individual word reading times were summed to form one critical analysis region that included the conditional statement (i.e., sentence 3) plus the first word of the following sentence to capture any spill over effects (Ehrlich & Rayner, 1983).

Example analysis region

*...If she had liked rock music, she would probably have gone to Glastonbury every year.
She...*

Analysis for each region was performed using 2 x 2 (Congruency x Clause Order) ANOVAs with subjects ($F1$) and items ($F2$) as random factors. This revealed no reliable main effects of Congruency ($F1(1, 35) = 2.96, MSE = 278,146, p = 0.094, \eta_p^2 = 0.078$; $F2(1, 23) = 4.7, MSE = 116,054, p = 0.04, \eta_p^2 = 0.17$) or Clause Order (Both F s < 1). However, the interaction between Congruency and Clause Order *was* significant ($F1(1, 23) = 5.22, MSE = 250,992, p = 0.028, \eta_p^2 = 0.13$; $F2(1, 23) = 4.5, MSE = 210,262, p = 0.044, \eta_p^2 = 0.164$) (see Figure 1). Simple contrasts revealed a congruency effect for canonical conditionals ($t1(35) = 2.7, p = 0.01$; $t2(23) = 3.0, p = 0.006$) with those in the congruent condition (5508 msec.) read faster than those in the incongruent condition (5850 msec.). However, for non-canonical conditionals contrasts showed no reliable

difference in reading times between congruent (5737 msec.) and incongruent conditionals (5697 msec) ($t_1(35) = 0.34, p = 0.74; t_2(23) = 0.41, p = 0.69$).

FIGURE 1 ABOUT HERE

Discussion

Our data revealed that for canonical counterfactuals of the form *if p, then q* there was a congruency effect whereby congruent counterfactuals were read faster than incongruent counterfactuals (consistent with Stewart et al., 2009). The additional cognitive load associated with incongruent counterfactuals is consistent with the idea that readers evaluate the presupposition in terms of its global coherence with prior discourse. In contrast, there was no such congruency effect for non-canonical *q, if p* counterfactuals despite them being lexically, logically and probabilistically equivalent. This suggests that when the presupposition is presented in the second clause its local coherence with the first clause (which had previously set up a hypothetical world using ‘*would*’) overrides any influence of global coherence.

Experiment 2

Does clause order mediate the influence of subjective probability on reading times to conditional statements?

The aim of Experiment 2 is to determine whether the influence of a conditional’s truth (probability) on reading times is moderated by clause order. While the abstract truth functional conditional of philosophical logic can be deemed true or false based on the truth values of its antecedent and consequent clauses, conditionals describing uncertain everyday events cannot be accurately verified in this way (Evans & Over, 2004).

Therefore the truth of a conditional is commonly quantified as the extent to which it is subjectively perceived as probable (e.g., Over et al., 2007). This probability is formally expressed as $P(\text{if } p, \text{ then } q)$.

It has previously been shown that readers are sensitive to the probability of canonical indicative conditionals, with subjectively high $P(\text{if } p, \text{ then } q)$ conditionals read

faster than subjectively low P(if p then q) conditionals (Stewart, Haigh & Connell, 2010). A question that remains unanswered is whether subjective probability influences reading times in the same way for both canonical and non-canonical conditionals. In Experiment 2 we manipulated both P(if p, then q) and clause order then measured reading times to determine whether the previously demonstrated slow down for low (relative to high) P(if p, then q) canonical conditionals also occurs for non-canonical conditionals.

The first possibility is that the evaluation of a conditional is robust to variation in clause order, with canonical and non-canonical conditionals evaluated in the same way for both conditional forms. In this case we would predict only a main effect of Probability, with a slow down for low relative to high P(if p, then q) conditionals regardless of clause order.

However, there is reason to suspect that canonical and non-canonical indicative conditionals are not evaluated in the same way. For canonical clause order conditionals the Suppositional Theory proposes that people engage in a two stage process where they first hypothetically suppose the antecedent and then evaluate the probability of the consequent within this hypothetical world. In contrast, non-canonical indicative conditionals ostensibly cause additional cognitive load as the consequent clause must be evaluated as a bald statement of fact¹, held in working memory until the 'if' clause is processed, and then re-evaluated within this hypothetical world. These additional stages of processing suggest that non-canonical conditionals may impose a greater cognitive load. If this additional load is reflected in reading times (cf. Just, Carpenter & Woolley, 1982), then we would expect to find two main effects. One effect would relate to Probability (as above) and the second would relate to Clause Order (with canonical statements read faster than non-canonical statements).

An alternative possibility is that reversing the clause order disrupts the Ramsey Test, given that the clauses are incrementally encountered by readers in the opposite order to that originally described by Ramsey. If the Ramsey Test fails to operate online for non-canonical conditionals, then readers should not be sensitive to the difference

¹ While counterfactuals contain the conditional perfect 'would' in the consequent clause to indicate hypothetical possibility, indicative conditionals often have no such marker. This means that the consequent clause of a non-canonical indicative must initially be evaluated as an unqualified assertion (e.g., *I will miss work tomorrow*).

between high and low probability statements in this condition. Therefore, we would predict an asymmetrical interaction between Probability and Clause Order (similar to Experiment 1) with an effect of Probability on reading times for canonical conditionals but not for non-canonical conditionals.

Experiment 2 used self-paced reading to examine how reading times are influenced by both P(if p then q) and clause order. This was achieved by manipulating the subjective probability of indicative conditionals to be either high or low and clause order in a 2x2 repeated measures design. The dependent variable was reading time to the conditional statement.

Participants

Twenty-four native English speakers from the University of Manchester population took part. None of these took part in Experiment 1. They were each paid £5.

Materials

Thirty-two vignettes were constructed (see Example and Appendix 2). There were four versions of each vignette and each was four sentences long. Sentences one, two, and four provided contextual information. Sentence three contained the indicative conditional. We created four Latin-square lists, each list also contained sixteen fillers.

Example Vignette from Experiment 2

Participants read conditionals that were either high or low probability presented in either the canonical (1) or non-canonical (2) clause order.

The National Union of Students often highlights the link between student tuition fees and applications for university places. A number of reports into the link were recently completed. The Union argues that...

1. ...if student tuition fees fall, applications for university places will rise/fall.
2. ...applications for university places will rise/fall, if student tuition fees fall.

...At present university tuition fees can cost up to £3000 per year.

Procedure

The procedure was identical to Experiment 1.

Results

Individual word reading times were summed to form one critical analysis region identical to Experiment 1.

Example analysis region

...if student tuition fees fall, applications for university places will rise. At...

Analysis was performed using 2 x 2 (Probability x Clause Order) ANOVAs with subjects (*F1*) and items (*F2*) as random factors. This revealed a main effect of Probability (*F1* (1, 23) = 14.75, *MSE* = 433,572, *p* = 0.001, $\eta_p^2 = 0.39$; *F2* (1, 31) = 7.3, *MSE* = 1151,628, *p* = 0.011, $\eta_p^2 = 0.191$). For canonical conditionals high probability statements (5828 msec.) were read faster than low probability statements (6312 msec.) (*t1*(23) = 2.97, *p* = 0.007; *t2* (31) = 2.15, *p* = 0.039). This effect was also found for non-canonical conditionals, with high probability statements (5782 msec.) again read faster than low probability statements (6332 msec.) (*t1*(23) = 2.97, *p* = 0.007; *t2* (31) = 2.50, *p* = 0.018). There was no main effect of Clause Order (both *F*s <1) and no interaction between Probability and Clause Order (both *F*s <1) (See Figure 2).

FIGURE 2 ABOUT HERE

Discussion

Our data reveal that reading times to indicative conditionals are influenced by Probability (with high probability conditionals read faster than low probability conditionals), but not

by Clause Order. The reading time penalty corresponding to low $P(\text{if } p, \text{ then } q)$ was apparent for both canonical and non-canonical forms. This suggests that the influence of probability on reading time to a conditional statement is independent of clause order.

General Discussion

Two experiments show that clause order mediates the effect of suppositional congruency (Experiment 1) but not subjective probability (Experiment 2) on reading times to conditional statements. In Experiment 1 clause order interacted with presuppositional congruency to influence reading times. Specifically, a congruency effect was found on reading times to canonical but not to non-canonical counterfactuals. This shows that the antecedent presupposition is constrained by global coherence for canonical counterfactuals but by local coherence for non-canonical counterfactuals. In other words, hypothetical thinking is bounded by prior context for canonical counterfactuals, but at least temporarily unbounded for non-canonical counterfactuals. Experiment 2 then showed that reading times to indicative conditionals are affected by subjective probability but not by clause order, with readers equally sensitive to low $P(\text{if } p \text{ then } q)$ in both conditional forms. This suggests that the online probabilistic evaluation of a conditional is robust to variation in clause order. These two experiments indicate conditional processing can be divided into at least two distinct stages (supposition and evaluation) that interact differentially with clause order.

In terms of suppositional processing Experiment 1 shows that so long as the first clause successfully initiates hypothetical thinking using the conditional perfect tense (i.e., *if* or *would*) the second clause will be evaluated within this frame of reference (and not in terms of prior context). It has been argued that '*if*' has a special capacity to trigger hypothetical thought. Our data suggest that this capacity applies to the conditional perfect tense in general, with '*would*' also successfully triggering hypothetical thinking. What is important is that a hypothetical world is successfully set up in the first clause and this can be achieved using both '*if*' and '*would*'. When the first clause is incongruent with prior context, hypothetical thinking is not easily initiated (evidenced by a slow down in reading

times). However, once this hypothetical world is set up the evaluation of the second clause appears to be isolated from prior context.

Stalnaker (1968) proposed a version of the Ramsey Test in which people temporarily update their beliefs, making the minimal possible change to their world knowledge so that the antecedent proposition is true within this hypothetical world. This is consistent with our findings for canonical counterfactuals. When the presupposition was incongruent (thus requiring a large minimal change) the conditional took longer to read than when it was congruent (which required a much smaller minimal change, if any). For non-canonical counterfactuals however, we found no congruency effects. This is more consistent with the unbounded approach to suppositional thinking described by Cosmides and Tooby (2000). They propose that suppositional thinking is temporarily decoupled from prior context, occurring in isolation from other propositions. They state:

“Supposition involves the introduction of propositions of unevaluated or suspended truth value, which are treated as true within a bound scope...The operator “if”, for example, opens up a suppositional world...whose contents are kept isolated from other proposition-sets, so that true propositions are not intermixed and hence confused with false ones...or potentially false ones...” (Cosmides & Tooby, 2000 p. 65)

Our data support a mechanism whereby a minimal change mechanism is employed to evaluate the first clause of a conditional, consistent with Stalnaker; but once the first clause successfully triggers hypothetical thinking, the second clause is temporarily decoupled and evaluated within the bounds of this supposition consistent with definition of supposition put forward by Cosmides and Tooby (2000). In other words, information presented in the first clause appears to be bounded by prior discourse context and requires a minimal change, but once the first clause successfully triggers hypothetical thinking, information in the second clause is isolated from other propositions and evaluated only within this hypothetical world.

In terms of the evaluation of a conditional, clause order has no effect on reading times (Experiment 2). Participants read high probability statements faster than low probability statements regardless of clause order. This shows that clause order does not

mediate the probabilistic evaluation of a conditional. Furthermore, our experiments did not detect any indication that clause order increases processing load in its own right, although this is not to say that experiments with greater experimental power will also fail to find such an effect. What our data do suggest is that proposed evaluative mechanisms such as the Ramsey Test appear to operate successfully regardless of clause order. Whether the *same* strategy is used for both canonical and non-canonical conditionals is a question for future research. The Ramsey Test is a good candidate, but must ultimately be modified to explain how it deals with both conditional forms.

The experiments above show the importance of processing level variables to the mental representation of conditionals. Until recently, reasoning research has tended to overlook real time processes. This is due to largely to the traditional reliance on the Deduction Paradigm, which has proven successful in revealing the ultimate conclusions participants draw from conditional premises. However, to gain a full understanding of how we reach these conclusions it is necessary to identify and tease apart the real time processes that enable us to represent and evaluate conditionals.

References

- Cosmides, L., & Tooby, J. (2000). Consider the source: The evolution of adaptations for decoupling and metarepresentation. In D. Sperber (Ed.), *Metarepresentations* (pp. 53-115). Oxford: Oxford University Press.
- Ehrlich, K., & Rayner, K. (1983). Pronoun assignment and semantic integration during reading: eye-movements and immediacy of processing. *Journal of Verbal Learning and Verbal Behavior*, *22*, 75–87.
- Evans, J.St.B.T., Clibbens, J., & Rood, B. (1995). Bias in conditional inference - implications for mental models and mental logic. *Quarterly Journal of Experimental Psychology*, *48A*, 644-670.
- Evans, J.St.B.T., & Newstead, S. E. (1977). Language and reasoning: a study of temporal factors. *Cognition*, *5*, 265-283.
- Evans, J.St.B.T., & Over, D.E. (2004). *If*. Oxford: Oxford University Press.
- Ferguson, H.,J., & Sanford, A.J. (2008). Anomalies in real and counterfactual worlds: An eye-movement investigation. *Journal of Memory and Language*, *58*, 609-626.
- Just, M. A., Carpenter, P. A., & Woolley, J. D. (1982). Paradigms and processes in reading comprehension. *Journal of Experimental Psychology: General*, *111*, 228-238.
- Oaksford, M., & Chater, N. (2001). The probabilistic approach to human reasoning. *Trends in Cognitive Sciences*, *5*, 349-357.
- Oaksford, M., & Chater, N. (2007). *Bayesian rationality the probabilistic approach to human reasoning*. Oxford: Oxford University Press.
- Ormerod, T.C., Manktelow, K.I., & Jones, G.V. (1993). Reasoning with 3 types of conditional - biases and mental models. *Quarterly Journal of Experimental Psychology*, *46A*, 653-677.
- Over, D.E., Hadjichristidis, C., Evans, J.St.B.T., Handley, S.J., & Sloman, S.A. (2007). The probability of causal conditionals. *Cognitive Psychology*, *54*, 62-97.
- Ramsey, F. P. (1990). General propositions and causality. (original publication, 1931). In D. H. M. Mellor (Ed.) *Philosophical papers* (pp. 145-163). Cambridge: Cambridge University Press.

- Stalnaker, R. (1968). A theory of conditionals. *American Philosophical Quarterly Monograph Series*, 2, 98-112.
- Stewart, A.J., Haigh, M., & Connell, L. (2010). Evaluating the probability of indicative conditionals as they are read. Poster presented to the 51st annual meeting of the Psychonomics Society, St. Louis, USA, November 2010.
- Stewart, A.J., Haigh, M., & Kidd, E. (2009). An investigation into the online processing of counterfactual and indicative conditionals. *Quarterly Journal of Experimental Psychology*, 62, 2113-2125.
- Johnson-Laird, P.N., & Byrne, R. M. J. (2002). Conditionals: A theory of meaning, pragmatics, and inference. *Psychological Review*, 109, 646-678.

Appendix 1: Experimental materials used for Experiment 1

The first sentence in each item was manipulated to generate each of the incongruent and congruent conditions. The target sentence is the third sentence. The order of the clauses in this sentence was manipulated to generate each of the *if p, then q* and *q, if p* conditions.

1 Joanne liked rock music/ Joanne hated rock music. Her parents were both professional musicians. If she had liked rock music, she would probably have gone to Glastonbury every year/ She would probably have gone to Glastonbury every year, if she had liked rock music. She lived in a neighbouring village.

2 Ahmed was a devout Muslim who prayed regularly at the local mosque/ Ahmed was not a devout Muslim and never visited the local mosque. He lived just round the corner from the mosque. If he had been a devout Muslim, he would probably have prayed at the mosque every day/ He would probably have prayed at the mosque every day, if he had been a devout Muslim. All his family were very religious.

3 Naomi was a lively 6 year old and had learned to walk at a young age/ Naomi had not yet learned to walk as she was just 6 months old. She was always full of energy. If she had been old enough to walk, she could have taken herself to the local playground/ She could have taken herself to the local playground, if she had been old enough to walk. Every afternoon it was full of the children from the local neighbourhood.

4 Jane loved being a vegetarian and enjoyed eating tasty tofu burgers/ Jane loved eating sausage and bacon sandwiches. She spent a lot of time eating out at restaurants. If she had been a vegetarian, she would probably have enjoyed eating the lentil bake at the local vegan café/ She would probably have enjoyed eating the lentil bake at the local vegan café, if she had been a vegetarian. The café regularly won awards in the national vegan food and drink competition.

5 Rick loved rough and energetic sports such as judo/ Rick hated rough and energetic sports but enjoyed games like golf. He was very sociable and a member of lots of clubs at

University. If he had liked energetic sports, he would probably have enrolled in kickboxing classes at the University sports centre/ He would probably have enrolled in kickboxing classes at the University sports centre, if he had liked energetic sports. All his friends had signed up.

6 Like most young children, Kim liked dogs/ Like some young children, Kim didn't like dogs. Her teacher often brought his puppy to school. If she had liked dogs, she would probably have wanted to own a pet dog/ She would probably have wanted to own a pet dog, if she had liked dogs. Many children enjoy looking after cute puppies.

7 Adam was very outgoing and not at all shy/ Adam was not very outgoing and rather shy. His friends had joined the drama club at school. If he had been outgoing, he could have auditioned for the school play/ He could have auditioned for the school play, if he had been outgoing. The play was always a highlight of the school year.

8 John lived in the countryside, voted Tory and enjoyed pheasant shooting/ John lived in the countryside, voted Green and objected to pheasant shooting. He really enjoyed rural life. If he had enjoyed pheasant shooting, he would probably have joined the local hunting club/ He would probably have joined the local hunting club, if he had enjoyed pheasant shooting. The club was a good place to meet new people.

9 Alex owned a really powerful Ferrari/ Alex owned a really slow, rusty Fiesta. He was a big fan of motorsports. If he had owned a powerful car, he would probably have had points on his licence/ He would probably have had points on his licence, if he had owned a powerful car. There were lots of speed cameras where he lived.

10 Andy loved to drink beer and spirits/ Andy had given up beer and spirits for health reasons. He loved going out and socialising. If he drank spirits, he would probably have enjoyed drinking single malt whisky/ He would probably have enjoyed drinking single malt whisky, if he drank spirits. All his friends were whisky connoisseurs.

11 Luke was a fantastic guitar player/ Luke had never learned how to play guitar. He enjoyed listening to rock music. If he had known how to play guitar, he could have joined his friend's band/ He could have joined his friend's band, if he had known how to play guitar. They had attracted a lot of media attention.

12 Tim was fit and strong/Tim was in bad physical shape. He was looking forward to the weekend. If he had been fit and strong, he would probably have gone cycling/He would probably have gone cycling, if he had been fit and strong. The local cycling track was in the middle of a beautiful forest.

13 Lewis was terrified of heights/Lewis had never been afraid of heights. His sister had once taken him abseiling. If he had been afraid of heights, he would probably not have been able to go rock climbing with his friends/He would probably not have been able to go rock climbing with his friends, if he had been afraid of heights. They went climbing almost every weekend during the summer.

14 Tom had developed sensitive hearing after damaging his eyesight in a childhood accident/ Tom had lost his hearing in a childhood accident. When a child, he had accidentally swallowed some powerful chemicals. If he had had good hearing, he would probably have been more confident as a teenager/ He would probably have been more confident as a teenager, if he had had good hearing. He often felt socially isolated.

15 Poppy was an enthusiastic animal rights supporter/ Poppy loved going fox hunting. She really enjoyed the rural life. If she had been an animal rights supporter, she would probably have protested against the hunts in her local village/ She would probably have protested against the hunts in her local village, if she had been an animal rights supporter. Many of her friends were involved in anti-hunt protests.

16 Ed was keenly interested in environmental issues/ Ed had no interest in environmental issues. He had recently watched the Al Gore film. If he had been interested in environmental issues, he would probably have started taking the train to work/ He would

probably have started taking the train to work, if he had been interested in environmental issues. The station was right next door to his office.

17 Dave was interested in learning to fly planes/ Dave had no interest in learning to fly planes. He lived near a flying school. If he had been interested in learning to fly, he would probably have signed up at the local flying school/ He would probably have signed up at the local flying school, if he had been interested in learning to fly. All his school friends had signed up for lessons.

18 Jessica was one of the most fluent French speakers in her class/ Jessica was one of the worst French speakers in her class. She enjoyed going on school trips abroad. If she had been a fluent French speaker, she would probably have enjoyed her school trip to France more/ She would probably have enjoyed her school trip to France more, if she had been a fluent French speaker. Her classmates spoke only French while on their trip.

19 Emma was a good swimmer/ Emma had never learned to swim. One year, she flew to the Bahamas with her friends for a holiday. If she had been a good swimmer, she would probably have enjoyed swimming in the sea/ She would probably have enjoyed swimming in the sea, if she had been a good swimmer. The water was crystal clear.

20 Jennifer had a good singing voice/ Jennifer had a dreadful singing voice. She had been brought up listening to a lot of classical music. If she had been a good singer, she could have joined the choir at her school/ She could have joined the choir at her school, if she had been a good singer. It was always winning national competitions.

21 Darren was very athletic/ Darren was not at all athletic. He had just started University and was looking for some clubs and societies to join. If he had been athletic, he could have tried out for the rugby team/ He could have tried out for the rugby team, if he had been athletic. The team was small but everyone on it was really friendly.

22 Louise was rich/ Louise was poor. She lived in a flat in London. If she had been rich, she could have spent a lot of money shopping/ She could have spent a lot of money shopping, if she had been rich. Her flat was near Harrods.

23 Henry loved sushi and all aspects of Japanese culture/ Henry hated sushi but loved Japanese culture. He had first visited Japan when he was a teenager. If he had liked sushi, he would probably have enjoyed his holidays in Japan much more/ He would probably have enjoyed his holidays in Japan much more, if he had liked sushi. He spent about a month there every summer.

24 Mary was a student who had taken out a student loan/ Mary was a student who had never needed a student loan. She graduated with a first class degree. If she had taken out a student loan, she would probably have been able to go on holiday after graduation/ She would probably have been able to go on holiday after graduation, if she had taken out a student loan. Instead, she had to start earning money almost immediately.

Appendix 2: Experimental materials used in Experiment 2

Each item shows the high and low P(if p then q) conditions in the canonical order. For the non-canonical condition the order of the clauses was simply reversed.

01 Living with the threat of terrorism and negotiating numerous security checks have become familiar burdens for those travelling by air. Security officials from Britain's largest airports today met to discuss future directions for airport security. They reason that if the threat of terrorism rises, airport security checks will increase/decrease. Officials will continue to monitor the situation on a daily basis.

02 Town planning officials from Greater Manchester are undertaking a survey to determine how many new houses will be needed to account for predicted changes in population over the next ten years. This will form the basis of their new housing strategy. Inevitably, if the population of Manchester increases, the number of new houses built annually in Manchester will rise/fall. The city currently has a population of 452,000.

03 With space at a premium in New York new housing is always in high demand. Houses and flats are often sold within days of them being advertised. It is therefore inevitable that if the population of New York increases, the number of new houses built annually in New York will rise / fall. The city currently has a population of over eight million.

04 With China striving to compete with the West, heavy industry has become a familiar sight. Campaigners have expressed concern over the pollution this may cause. They argue that if the amount of Carbon Dioxide produced by China each year rises, levels of air pollution in China will increase/decrease. The health risks associated with air pollution have been known for many years.

05 Flooding in Britain regularly makes the national news. However, the subsequent financial impact this has on house insurance premiums often goes unreported. A new report by a top insurance company suggests that if the number of serious floods in Britain

increases, house insurance prices will rise/fall. House insurance is a major monthly expenditure for most households.

06 Computer technology has advanced rapidly over the past 20 years. For many people it is difficult to imagine their lives without modern computer technology. Experts in computing predict that if advances in computer technology increase, dependency on computer technology will rise/fall. At present millions of people make use of computer technology each day.

07 A recent campaign by celebrity chef Jamie Oliver has criticised the nutritional value of school dinners. His campaign has attracted a great deal of media attention. He believes strongly that if government spending on school dinners rises, the nutritional value of school dinners will increase/decrease. Currently the majority of school children take school dinners at least three times a week.

08 Budget airlines now account for a large proportion of the world's air traffic. Each day flights are available across Europe for as little as 99p. Campaigners argue that if the number of people flying with budget airlines rises, pollution caused by aeroplanes will increase / be reduced. Environmental campaigns are now a familiar sight in the media.

09 A recent psychological study has suggested a link between television violence and violent crime. This finding has been published in a top peer reviewed journal. The authors predict that if the amount of violence shown on television increases, the amount of violent crime committed will rise/fall. In light of these findings campaigners have called for a review of programming policies.

10 Mobile phones are an integral part of modern life with mobile phone shops now as common on city high streets as newsagents or convenience stores. In the phone industry it is important to anticipate future trends. Business analysts predict that if mobile phone use increases, the number of mobile phone shops on the High Street will rise/fall. Phone companies are very flexible and are able to adapt to a changing market.

11 With top football players earning more and more money the Football Association are looking into ways to make ticket prices more accessible to lower income groups. Many people cannot afford to watch their local team. Some fans believe that if the wages of top footballers increase, ticket prices for games will rise/fall. Tickets at top clubs can cost as much as £50.

12 Conflicts in the Middle East have destabilised the price of oil subsequently affecting petrol prices in the UK. This has caused a great deal of uncertainty for consumers. Analysts predict that if the cost of oil increases, the cost of petrol will rise/fall. Consumers need to be aware of these potential changes.

13 The boom in online retail has commonly been linked to identity theft. Thieves often use these identities to launder money. Many experts agree that if the popularity of online shopping increases, the risk of identity theft will rise/fall. Each day thousands of pounds are spent online.

14 Cancer Research UK have recently released a report summarising the extent of their research into life threatening cancers. Despite many breakthroughs much more research is needed. In appealing for donations they remind us that if the amount of money spent annually on cancer research rises, the amount of research into cancer treatment will increase/decrease. Donations can be made through the Cancer Research UK website.

15 AIDS charities constantly appeal for donations to fund research into treatments. While our knowledge is constantly improving much more research is needed. These charities are keen to emphasise the message that if the amount of money spent annually on AIDS research rises, the amount of research into AIDS treatment will increase/decrease. This could affect many millions of lives.

16 The current popularity of organic food is reflected by its presence on our supermarket shelves. The Soil Association aim to promote organic food and encourage a healthier

lifestyle. They believe that if the amount of organic food sold in shops rises, the popularity of organic food will increase/decrease. Only by expanding the range will sales increase.

17 A leaked report commissioned by the Department for Transport has suggested a link between motorway congestion and petrol prices. So far the Department of Transport have refused to comment. The leaked report predicts that if the cost of petrol falls, motorway congestion at peak times will worsen / improve. At present journey times can be doubled at peak times.

18 The National Union of Students often highlight the link between student tuition fees and applications for university places. A number of reports into the link were recently completed. The Union argues that if student tuition fees fall, applications for university places will rise/fall. At present university tuition fees can cost up to £3000 per year.

19 Despite the number of new housing estates in Britain, getting on the property ladder has traditionally been a difficult task for first time buyers. Many seek professional advice on this issue from mortgage advisors. The majority of mortgage advisors now agree that if the number of new houses built annually across the UK falls, getting on the property ladder will become harder/easier. Each year thousands of first time buyers take out new mortgages.

20 The Department of Health report that sexually transmitted diseases (STDs) are on the increase. Catching the infections early stops them spreading. The Department thinks that if the amount of money spent annually on treating STDs decreases, the number of people who catch STDs each year will rise/fall. It is estimated that thousands people may have an untreated STD.

21 Greenpeace are working on a new campaign to make people more energy efficient. They want people to realise the benefits of saving energy. Greenpeace argue that if the

use of energy efficient technology in the home increases, utility bills will fall/rise. The campaign is set to be launched later this year.

22 The government minister for the environment has recently proposed plans to tackle pollution caused by aeroplanes. Hundreds of flights arrive and depart from Britain every hour. He argued that if taxes on air travel fall, pollution caused by aeroplanes will increase/decrease. Many people now consider their carbon footprint when travelling by air.

23 The Environment minister has unveiled plans to produce a strategy which will reduce inner city pollution. The strategy will be based on a five year study of pollution levels. The study suggests that if the government decreases its spending on the environment, inner city pollution will increase / decrease. Inner city pollution is caused primarily by carbon dioxide emitted from car engines.

24 The Treasury receives millions of pounds each year from cigarette taxes. However, attitudes to smoking may change in the future. The Treasury must therefore account for the possibility that if the number of people who take up smoking each year increases, government revenue from cigarette taxes will rise/fall. Money from cigarette taxes is often spent on public services such as the NHS.

25 The British Heart Foundation continually campaigns to generate funds for research into heart disease. This research could potentially save many thousands of lives. They believe strongly that if the amount of money spent annually on preventing heart disease decreases, levels of heart disease will rise/fall. Donations can be made to the British Heart Foundation through their website.

26 Because of a recent shortage of oil, electricity companies are trying to reduce the amount of electricity that consumers use. They think that changing their pricing tariffs is the best way to achieve this. They reason that if the cost of electricity falls, electricity

consumption will increase/decrease. Electricity bills are a substantial outlay for most households across the country.

27 Proposals to change the current British driving test have been welcomed by insurers. Young drivers are often hardest hit by insurance prices. Insurers predict that if driving tests are made easier, car insurance prices for young drivers will rise/fall. Driving standards in Britain are currently among the best in Europe.

28 Greater Manchester Water Authorities are worried about the limits of the water supply system to people's homes. They are thinking of changing the way in which water bills are calculated. They think that if water bills are cut, tap water usage will rise/fall. Each day millions of gallons of tap water is consumed in the UK.

29 Local authorities with only limited landfill sites are under a lot of pressure to encourage their residents to recycle waste. In the recent elections a number of mainstream parties proposed shared recycling goals. They argue that if the rate of recycling falls, the amount of waste buried in landfill sites will increase/decrease. Each year millions of tonnes of waste are buried in landfill sites.

30 Charity workers from Oxfam work tirelessly to raise money to tackle food shortages in the third world. Each day many people die due to starvation. They strongly believe that if the amount of money spent annually on reducing third-world poverty rises, food shortages in third-world counties will decrease/increase. Oxfam encourage people to donate their unused clothes so that the money raised can support their cause.

31 Government health advisors have recently presented to parliament the findings of a new report into tackling obesity. The report is likely to influence future spending by the NHS. It suggests that if the amount of money spent annually on tackling obesity decreases, levels of obesity will rise/fall. Each year obesity related illnesses cost the NHS millions of pounds.

32 A number of car manufacturers are working together to develop new forms of fuel efficient engines. This new breed of engines will have both environmental and financial benefits. Manufacturers propose that if the fuel efficiency of cars decreases, the amount of money people spend on petrol each year will increase/decrease. Top car manufacturers spend millions of pounds each year developing new engines.

Figure 1: Mean reading times and standard errors to the critical region in Experiment 1

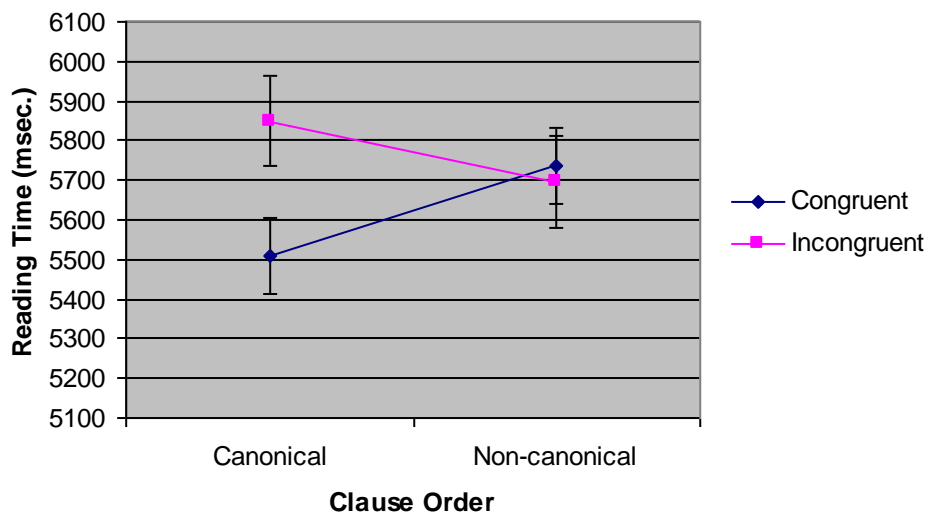


Figure 2: Mean reading times and standard errors to the critical region in Experiment 2

