Northumbria Research Link

www.northumbria.ac.uk/nrl

northumbria
UNIVERSITY NEWCASTLE

Haigh, M., Stewart, A. J., & Connell, L. (2013). Reasoning as we read: establishing the probability of causal conditionals. Memory & Cognition, 41, 152-158.

Reasoning as we read: establishing the probability of causal conditionals.

Matthew Haigh

Andrew J. Stewart

Louise Connell

University of Manchester, UK

Address for correspondence:

Matthew Haigh

School of Psychological Sciences

University of Manchester

Manchester, M13 9PL

Tel: +44 (0)161 2757331

matthew.haigh@manchester.ac.uk

Abstract

Indicative conditionals of the form if p then q (e.g., if student tuition fees rise, then applications for university places will fall) invite the consideration of a hypothetical event (e.g., tuition fees rising) and one of its possible consequences (e.g., applications falling). Since a rise in tuition fees is an uncertain event with equally uncertain consequences, a reader may believe the statement to a greater or lesser extent. As a conditional is read, the earliest point at which this probabilistic evaluation can take place is as the consequent clause is wrapped-up (e.g., as the critical word 'fall' is read in the example above). Wrap-up processing occurs at the end of clause as it is evaluated and integrated into the evolving discourse representation. There are five sources of probability that may plausibly influence the evaluation of a conditional as it wrapped up; these are $P(p)$, $P(q)$, $P(pq)$, $P(q|p)$ and $P(\text{not-}p \text{ or } q)$. One hundred and twenty eight conditionals were constructed with these probabilities calculated for each item in a pre-test. The conditionals were then embedded in vignettes and read by thirty-six participants on a word-by-word basis. Using linear mixed-effects modeling we found that wrap-up reading times were predicted by pre-test ratings of $P(p)$ and $P(q|p)$. There was no influence of $P(q)$, $P(pq)$ or $P(\text{not-}p \text{ or } q)$ on wrap-up reading times. Our findings are consistent with the Suppositional Theory of conditionals proposed by Evans and Over (2004), but do not support the Mental Models theory advanced by Johnson-Laird & Byrne (2002).

Introduction

Indicative conditionals of the form if p then q invite the consideration of a hypothetical event (p) and one of its possible consequences (q). For instance, a newspaper opinion piece that asserts *'if* student tuition fees rise, then applications for university places will fall' encourages the reader to mentally entertain a possible state of the world in which the number of university applications falls following a rise in student tuition fees. Since a rise in tuition fees is an uncertain future event with equally uncertain consequences, a reader may believe the statement to a greater or lesser extent. This subjective degree of belief can be quantified as the probability of the conditional, or P(if p then q).

The ability to rapidly evaluate the probability of a conditional describing a hypothetical event is central to everyday reasoning and decision making (see Evans & Over, 2004). However, there remains no consensus about how people subjectively establish P(if p then q). Some argue that this judgement is equivalent to the subjective conditional probability (P(q|p)) of the consequent event given the antecedent event (e.g., the probability that student applications will fall given a rise in tuition fees; Evans & Over, 2004). Others suggest that people base their belief initially on the subjective conjunctive probability (P(pq)) of the antecedent and consequent events occurring together (e.g., the probability that both tuition fees will rise and applications will fall) but can, in some cases, also arrive at a conclusion by thinking about all the possibilities in which the conditional is true (i.e., P(not-p or q)) (Johnson-Laird & Byrne, 1991; 2002). In this paper we examine processing load associated with P(p), P(q), P(pq), P(q|p) and P(not-p or q) to determine which probabilities readers use to rapidly guide their evaluation of a conditional during comprehension.

Within the conditional reasoning literature, the Ramsey Test is an influential perspective that describes a mechanism for engaging in hypothetical thought. Ramsey proposed that people judge their belief in conditionals of the form if p then q 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 has been formalised by psychologists in the field of human reasoning as the Suppositional Theory of If (Evans & Over, 2004). The Suppositional Theory proposes that people use epistemic mental models to evaluate their degree of belief in a conditional. Degree of belief is established by making a probability judgement about the extent to which they believe that the consequent event will occur within a hypothetical world in which the antecedent is true (e.g., following the example above, this would be the subjective probability of student applications falling given a rise in tuition fees). This probability judgement is known as the subjective conditional probability, or P(q|p), and has been shown to play a central role in how conditionals are ultimately interpreted (e.g., Oberauer & Wilhelm, 2003).

An alternative perspective is based on the idea that people represent conditional information using semantic (rather than epistemic) mental models (Johnson-Laird & Byrne, 1991; 2002). The mental model theory proposes that people mentally represent the truth verifiable possibilities asserted by a conditional (rather than the possibilities in which p holds, as the suppositional theory claims). For an indicative conditional of the form if p then q these possibilities are the truth table rows that make the conditional true (see Figure 1).

(Figure 1 about here)

An important feature of the model theory is that the initial representation of a conditional statement only makes explicit the p & q case with the other possibilities being implicit until they are required (as denoted by ellipsis).

p & q

…

If required, this initial model can then be fleshed out to represent all the states of the world in which the statement is true. This makes the fully fleshed out model equivalent to the truth functional material conditional of propositional logic, which is always true in cases where there is not-p or q.

p & q

not-p & q

not-p & not-q

In terms of establishing degrees of belief in a conditional statement, it has been argued that these mental models can be used to determine P(if p then q) (Girotto & Johnson-Laird, 2004; Johnson-Laird, Legrenzi, Girotto, Legrenzi, & Caverni, 1999). This can be achieved in two ways. Firstly, because people will often fail to flesh out their initial mental model (e.g., due to working memory limitations) they will simply base their belief in a conditional on the probability of the initial model, i.e., P(pq) (e.g., the probability that both tuition fees will rise and applications will fall). Alternatively, if this initial model is successfully fleshed out, belief in the conditional can be calculated by summing the probabilities of the models in which the statement is true (Johnson-Laird et al., 1999). The probability of this fully fleshed

out mental model is equivalent to the probability of the material conditional (i.e., P(not-p or q)).

To examine how participants judge the probability of conditionals Evans, Handley and Over (2003) presented abstract conditional statements and associated probability distributions (e.g., if the card is yellow, then it has a circle printed on it). They attempted to reveal which of three probabilities participants used to establish their degree of belief in a conditional statement (i.e., P(if p then q)). These probabilities were P(q|p), P(pq) and P(not-p or q (i.e., the probability of the material conditional). They found no evidence that people base their belief on the probability of the material conditional, but rather found that participants fell into two groups. One group based their belief on P(q|p) while the other, slightly smaller group, based their belief on P(pq) (see also Oberauer & Wilhelm, 2003; Politzer, Over & Baratgin, 2010 for similar findings). It has since been shown that adults who initially judge a conditional as P(pq) tend to switch to a P(q|p) interpretation as more and more trials are presented (Fugard , Pfeifer, Mayerhofer, & Kleiter, 2011). The influence of P(pq) has been attributed to a form of shallow processing (Evans et al., 2003) and also to individual differences in cognitive ability (Evans, Neilens & Over, 2008); however, this effect is not consistently replicated in the literature (Evans, Handley, Neilens & Over, 2007).

It is only recently that attention has turned to how the comprehension of everyday causal conditionals might be influenced by our real world knowledge. Over, Hadjichristidis, Evans, Handley and Sloman (2007) examined the probability of everyday conditional statements (e.g. if the cost of petrol increases, then traffic congestion will improve) by asking participants to assign probabilities to the truth table conjunctions p & q, p & not-q, not-p & q and not-p & not-q. From these ratings Over et al. calculated three statistically independent predictors that could be used to determine whether people base their belief in a conditional on the conditional probability, the conjunctive probability or the probability of the fully fleshed

out material conditional. Analyses revealed that P(q|p) was a strong predictor of subjective ratings of P(if p then q), thus providing support for a conditional probability hypothesis. There was some weak evidence for a conjunctive probability interpretation and no support for the fully fleshed out material conditional hypothesis.

Experiment: Reasoning as we read

While there is evidence that P(q|p) and, to a lesser extent, P(pq) inform belief in a conditional statement, little is known about the mechanisms that guide the fast-acting comprehension processes required to understand conditionals as they are processed in real time. Traditional measures of conditional reasoning (e.g., the deduction paradigm) rely on inferences or decisions that people make or endorse following a conditional statement. These tasks typically require sustained analytical processing, which is in contrast to the rapid and intuitive comprehension associated with conditional statements in everyday discourse. As a result, these offline techniques can only provide data based on the ultimate representation of a conditional. By focusing only on this final, fully formed representation, a number of distinct, incremental processes necessary for comprehension of a conditional statement may be overlooked.

In the experiment reported below, we employ a word-by-word self-paced reading paradigm to examine comprehension processes as the interpretation of a conditional is built in real time. A time-course approach has recently provided new insights into both the processing of conditional statements themselves (Espino, Santamaria & Byrne, 2009; Haigh & Stewart 2011; Stewart, Haigh & Kidd, 2009) and the processing of information following a conditional statement (e.g., Ferguson, 2012; Ferguson & Sanford, 2008; Haigh, Stewart, Wood & Connell, 2011; Rader & Sloutsky, 2002; de Vega, Urrutia, & Riffo, 2007).

Specifically, we examined the influence of P(p), P(q), P(pq), P(q|p) and P(not-p or q) on reading times to everyday causal conditionals that were embedded in vignettes. The dependent measure of interest was reading time to the critical region of text at the end of the consequent clause (i.e., the earliest point at which the conditional could be evaluated as a whole). Reading times to this region capture wrap-up processing, which occurs at the end of a clause as information is evaluated and integrated into the evolving discourse representation (Rayner, Kambe & Duffy, 2000). For our conditionals, the wrap-up region was always the final word of the consequent clause immediately preceding the end of a sentence (e.g. …if student tuition fees rise, then applications for university places will /fall./).

Reading times tend to be negatively associated with the subjective plausibility of a clause or sentence, with increased latencies as subjective plausibility decreases (Rayner, Warren, Juhasz & Liversedge, 2004). Evidence that ratings of P(q|p) negatively predict reading times to the wrap-up region would therefore provide support for the Suppositional Theory of Evans and Over (2004), who argue that processes approximating a Ramsey Test are engaged to rapidly establish the subjective conditional probability. In contrast, evidence that ratings of P(pq) or P(not-p or q) negatively predict wrap-up reading times would be consistent with the Mental Models theory of conditionals developed by Johnson-Laird and Byrne (2002). Specifically, finding that P(pq) predicts reading times would indicate that readers only represent an initial mental model during the early stages of comprehension, whereas an association with P(not-p or q) would indicate that readers rapidly flesh out their mental model.

Method

To ensure sufficient variance in reading times, the 128 conditionals used in our experiment were constructed from clauses that had either high or low subjective probability, as

determined by a pre-test of the materials (see below for details). These high and low

probability clauses were fully counterbalanced across items. Because P(if p then q) varies as

an interaction of P(p) and P(q) we also ensured that this variable was counterbalanced. For

example, a conditional with a high P(p) and high P(q) such as "if the cost of oil rises, then the

cost of petrol will rise" can have intuitively high P(if p then q). However, another conditional

with similarly high P(p) and high P(q) can have intuitively low P(if p then q) (e.g., "if more

money is spent annually on preventing heart disease, then levels of heart disease will

increase*"*). We counterbalanced all eight possible permutations of high and low P(p), P(q)

and P(if p then q) in a 2x2x2 design (see Figure 2).

(Figure 2 about here)

Pre-tests

Individual clause probability task

A rating task was carried out to generate conditional statements with antecedents and

consequents that had high versus low subjective probabilities of occurring over the next ten

years. Twenty-four students from the University of Manchester were presented with 64

statements (e.g., Over the next 10 years, student tuition fees will decrease) and asked to rate

the probability of these events on a scale of 0-100. All probability judgements were collected

in early 2009.

The average rating for antecedent statements selected as high probability (M = 73, SE

= 1.21) was significantly higher than for antecedent statements selected as low probability (M

= 27, SE = 1.28), t1 (23) = 12.73, p < .001; t2 (31) = 21.57, p < .001. The average ratings for

consequent statements selected as high probability (M = 70, SE = 1.42) was significantly

higher than for consequent statements selected as low probability (M = 29, SE = 1.55), t1 (23) = 11.42, p < .001; t2 (31) = 15.37, p < .001).

Truth table task (Over et al., 2007)

To calculate P(q|p), P(pq) and P(not-p or q) for each conditional we asked participants to assign probabilities to the truth table conjunctions TT, TF, FT and FF occurring over the next 10 years. Participants were instructed that these four ratings should sum to 100 (see Over et al., 2007 for a full description of this method). The truth tables were rated by 17 participants. These participants did not take part in the individual clause rating task. Probabilities were calculated as follows:

P(pq) = P(TT)

P(q|p) = P(TT) / [P(TT) + P(TF)]

P(not-p or q) = P(TT) + P(FT) + P(FF)

The correlations between each of the five probabilities calculated in the pre-tests are reported in Table 1.

(Table 1 about here)

Comprehension task

We used the results of our two offline tasks to generate the 128 experimental items examined in the comprehension task.

Participants

Thirty-six volunteers from the University of Manchester population took part in the reading study. All participants were native English speakers and did not have a reading disability. They were each paid £5. Participants who took part in this comprehension task had not taken part in either of the offline ratings tasks.

Materials

One hundred and twenty eight experimental vignettes were used in this study. Each vignette consisted of four sentences (see Figure 2). The first two sentences provided context. Sentence 3 contained the indicative conditional. Sentence 4 provided additional contextual information. The full list of experimental vignettes with their associated probabilities can be found in Appendix 1. These vignettes were divided into four lists using a repeated measures Latin-square design, with each list containing 32 of the 128 items. Each list also contained 16 filler passages. These filler passages were each four sentences long and did not contain conditionals. All participants saw an equal number of passages across the eight counterbalanced conditions and 48 items in total (32 experimental plus 16 filler).

Procedure

Participants were informed that they would be presented with a number of vignettes to read on a word-by-word basis. To advance through the vignettes, they pressed the 'Next Word' button on a button box. Dashes were used to represent the rest of each passage. Only one

word was visible at a time. Comprehension questions appeared on 25% of the trials. The vignettes were presented in a different random order for each participant. Participants completed two practice trials before beginning the actual experiment. The experiment was run using E-Prime programming software and a button box recorded participants' reading times with millisecond accuracy.

Results

Comprehension accuracy was 94%. Individual word reading times were analysed at two points (see Example 1 below). The consequent wrap-up region (Region 1) was the earliest point at which the conditional could be evaluated as a whole. This was always the word or phrase immediately prior to the end of the consequent clause. We also measured reading times to the first word of the following sentence (Region 2) to reveal any residual (spill-over) processing load from Region 1 (Ehrlich & Rayner, 1983). Analysis on the reading time data was conducted using a linear mixed regression model with subjects and items as crossed random effects (see Locker, Hoffman & Bovaird, 2007). The fixed effects included in the model as continuous predictors were pre-test ratings of P(p), P(q), P(pq), P(q|p) and P(not-p or q).

Example 1

The Union argues that if student tuition fees are increased, then applications for university places will / rise. $_1$ / At $_2$ / present university tuition fees can cost up to £3000 per year.

Region 1 (wrap-up region)

The parameter estimates and p values (based on the t statistic) presented in Table 2 revealed

that P(p) and P(q|p) significantly predicted reading times to this region. These variables were

negative predictors, with decreased probability associated with increased reading time

latencies (and vice versa). There was no association between pre-test ratings of P(q), P(pq)[1]

or P(not-p or q) and reading times to this region.

Region 2 (spill over region)

The parameter estimates and p values (based on the t statistic) presented in Table 2 revealed

no significant effects of probability on reading time to this region.

(Table 2 about here)

---

[1] Because the product of P(p) and P(q|p) is logically equivalent to P(pq) (Over et al., 2007) we performed a
second analysis in which we entered P(p)*P(q|p) into our model in place of P(pq). As a validity check we
calculated the correlation between our pre-test ratings of P(pq) and P(p)*P(q|p), finding that they were highly
correlated (r = 0.92, p = <.001). Consistent with our main analyses, this proxy for P(pq) was not significantly
associated with reading times to either of our analysis regions. The correlation between P(p)*P(q|p) and P(q|p)
was 0.66 suggesting that colinearity was not an issue.

General Discussion

In our reading time experiment wrap-up latencies were predicted by pre-test ratings of P(p) and P(q|p). There was no influence of P(q), P(pq) or P(not-p or q) on reading times to this region of text. Our results suggest that readers use the subjective conditional probability to rapidly guide their interpretation of a conditional as it is comprehended in real time. This is consistent with predictions made by the Suppositional Theory (Evans and Over, 2004). There was no evidence that during processing readers base their evaluation on an initial mental model representing the conjunction of p and q or on a fully fleshed out model represented by the probability of the material conditional.

In addition to the effect of P(q|p) we also found that P(p) predicted wrap up latencies. While this was not a primary prediction, it is nevertheless consistent with a version of the Ramsey test in which readers make a minimal change to their beliefs in order to hypothetically suppose the antecedent proposition (p) as true (Stalnaker, 1968). In Stalnaker's version of Ramsey Test beliefs about the actual world must be temporarily altered. For subjectively high probability antecedents this change in beliefs is likely to be negligible, but for low probability antecedents a much bigger and more cognitively demanding change in beliefs is required. Because P(p) was a negative predictor, this effect most likely reflects the relative difficulty in updating the discourse representation to suppose improbable events as though they were true (with low P(p) clauses associated with increased latencies).

Of the five sources of probability information that we manipulated, only P(p) and P(q|p) were associated with wrap-up reading times. For example P(q), did not predict latencies to the consequent (q) wrap-up region. In other words, readers processing the conditional "if student tuition fees are increased, then applications for university places will fall" were influenced by the probability of "tuition fees increasing" and the probability of

"applications falling given an increase in fees", but the probability of "university applications falling" in their own right did not matter. This suggests that not all sources of probability associated with conditionals are weighted equally in the mind of the reader.

Consistent with a number of previous studies we found that P(not-p or q) had no influence on the evaluation of a conditional (Evans et al., 2003; Over et al., 2007). This again shows that the material conditional of propositional logic does not influence the psychological representation of conditional information. Unlike a subset of previous studies (Evans et al., 2003; Oberauer & Wilhelm, 2003; Politzer et al., 2010), we found no evidence that P(pq) influenced the interpretation of our conditionals. This is unsurprising given the effect of P(pq) is not consistently replicated in the literature (Evans et al., 2008) and has only been shown in offline studies measuring the ultimate interpretation of a conditional. One speculative possibility is that the influence of P(pq) found in previous studies may be a remnant of sustained analytical processing. In contrast, the fast acting heuristic processes required to rapidly evaluate a conditional online may be more suited to a mechanism whereby if immediately triggers a supposition and the probability of q is evaluated only within this hypothetical world.

Our findings provide an initial insight into the processing of probabilistic information as readers rapidly establish their belief in indicative conditionals. Both the suppositional and mental models theories are well supported by evidence from offline tasks using abstract conditionals, but the offline techniques that have typically been employed within the reasoning literature have a limited capacity to advance our understanding of the processing of conditionals during incremental comprehension. Theoretical advances have recently been driven by a focus on the interpretation of everyday causal conditionals (e.g., Over et al., 2007). We believe that an examination of the online mechanisms associated with processing

conditionals is also essential for refining existing theories and posing questions that have not

previously been considered.

References

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.

Espino, O., Santamaria, C., & Byrne, R. M. J. (2009). People think about what is true for conditionals, not what is false: Only true possibilities prime the comprehension of "if". Quarterly Journal of Experimental Psychology, 62, 1072-1078.

Evans, J.St.B.T., Handley, S., Neilens, H., & Over, D. (2007). Thinking about conditionals: A study of individual differences. Memory & Cognition, 35, 1772-1784.

Evans, J.St.B.T., Handley, S.J., & Over, D.E. (2003). Conditionals and conditional probability. Journal of Experimental Psychology: Learning, Memory and Cognition, 29, 321-335.

Evans, J.St.B.T., Neilens, H., & Over, D. (2008). Understanding Causal conditionals: A study of individual differences. Quarterly Journal of Experimental Psychology, 61, 1291-1297.

Evans, J.St.B.T., & Over, D.E. (2004). If. Oxford: Oxford University Press.

Ferguson, H.J. (2012). Eye movements reveal rapid concurrent access to factual and counterfactual interpretations of the world. Quarterly Journal of Experimental Psychology, 65, 939-961.

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.

Fugard, J. B., Pfeifer, N., Mayerhofer, B., & Kleiter, G. (2011). How people interpret conditionals: Shifts towards the conditional event. Journal of Experimental Psychology: Learning, Memory, and Cognition, 37, 635-648.

Girotto, V., & Johnson-Laird, P.N. (2004). The probability of conditionals. Psychologica, 47, 207-225.

Haigh, M., & Stewart, A. J. (2011). The influence of clause order, congruency and

  probability on the processing of conditionals. Thinking and Reasoning, 17, 402-423.

Haigh, M., Stewart, A. J., Wood, J. S., & Connell, L. (2011). Conditional advice and

  inducements: are readers sensitive to implicit speech acts during comprehension? Acta

  Psychologica. 136, 419-424.

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

Johnson-Laird, P.N., & Byrne, R. M. J. (2002). Conditionals: A theory of meaning,

  pragmatics, and inference. Psychological Review, 109, 646-678.

Johnson-Laird, P.N., Legrenzi, P., Girotto, V., Legrenzi, M., & Caverni, J-P. (1999). Naïve

  probability: a mental model theory of extensional reasoning. Psychological Review, 106,

  62-88.

Locker, L., Hoffman, L., & Bovaird, J. A. (2007). On the use of multilevel modelling as an

  alternative to items analysis in psycholinguistic research. Behaviour Research Methods,

  39, 723-730.

Oberauer, K., & Wilhelm, O. (2003). The meaning(s) of conditionals: Conditional

  probabilities, mental models, and personal utilities. Journal of Experimental Psychology:

  Learning, Memory and Cognition, 29, 680-693.

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.

Politzer, G., Over, D. E., & Baratgin, J. (2010). Betting on conditionals. Thinking &

  Reasoning, 16, 172-197.

Rader, A. W., & Sloutsky, V. M. (2002). Processing of logically valid and logically invalid

  conditional inferences in discourse comprehension. Journal of Experimental Psychology:

  Learning, Memory and Cognition, 28, 59-68.

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.

Rayner, K., Kambe, G., & Duffy, S. A. (2000). The effect of clause wrap-up on eye movements during reading. Quarterly Journal of Experimental Psychology Section A: Human Experimental Psychology, 53, 1061-1080.

Rayner, K., Warren, T., Juhasz, B. J., & Liversedge, S. P. (2004). The effect of plausibility on eye movements in reading. Journal of Experimental Psychology: learning, Memory and Cognition, 30, 1290-1301.

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

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.

de Vega, M., Urrutia, M., & Riffo, R. (2007). Cancelling updating in the comprehension of counterfactuals embedded in narratives. Memory & Cognition, 35, 1410-1421.

Appendix 1

Experimental items with mean pre-test ratings of P(p), P(q), P(pq), P(q|p) and P(not-p or q).

	P(p)	P(q)	P(pq)	P(q|p)	P(¬p or q)
1. 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 rises, then the cost of petrol will rise.	0.88	0.87	0.58	0.88	0.92
...if the cost of oil rises, then the cost of petrol will fall.	0.88	0.11	0.08	0.12	0.77
...if the cost of oil falls, then the cost of petrol will rise.	0.12	0.87	0.11	0.32	0.42
...if the cost of oil falls, then the cost of petrol will fall.	0.12	0.11	0.23	0.68	0.89
Consumers need to be aware of these potential changes.					
2. With space at a premium in London 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 London increases, then more houses will be built.	0.81	0.85	0.46	0.67	0.77
...if the population of London increases, then fewer houses will be built.	0.81	0.31	0.23	0.33	0.78

...if the population of London decreases, then more houses will be built.	0.17	0.85	0.10	0.30	0.54
...if the population of London decreases, then fewer houses will be built.	0.17	0.31	0.22	0.70	0.90

The city currently has a population of over eight million.

3. 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 increases, then airport security checks will increase.	0.72	0.72	0.57	0.93	0.96
...if the threat of terrorism increases, then airport security checks will decrease.	0.72	0.22	0.04	0.07	0.84
...if the threat of terrorism decreases, then airport security checks will increase.	0.32	0.72	0.23	0.59	0.43
...if the threat of terrorism decreases, then airport security checks will decrease.	0.32	0.22	0.16	0.41	0.77

Officials will continue to monitor the situation on a daily basis.

4. With China striving to compete with the west, heavy industry has become a familiar sight along the banks of some of China's largest rivers. Campaigners have expressed concern over the pollution this may cause. They argue that...

...if China increases the amount of carbon dioxide it produces, then the rivers of China will become more polluted.	0.65	0.72	0.57	0.84	0.89
...if China increases the amount of carbon dioxide it produces, then the rivers of China will become less polluted.	0.65	0.17	0.11	0.16	0.84
...if China decreases the amount of carbon dioxide it produces, then the rivers of China will become more polluted.	0.26	0.72	0.16	0.50	0.43
...if China decreases the amount of carbon dioxide it produces, then the rivers of China will become less polluted.	0.26	0.17	0.16	0.50	0.84

Many millions of people rely on these rivers for food and transport.

5. 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 more serious floods occur in Britain, then house insurance prices will rise.	0.71	0.71	0.52	0.83	0.89
...if more serious floods occur in Britain, then house insurance prices will fall.	0.71	0.35	0.11	0.17	0.83
...if fewer serious floods occur in Britain, then house insurance prices will rise.	0.31	0.71	0.20	0.54	0.48
...if fewer serious floods occur in Britain, then house insurance prices will fall.	0.31	0.35	0.17	0.46	0.80

House insurance is a major monthly expenditure for most households.

6. Computer technology has advanced rapidly over the past 20 years. For many it is difficult to imagine their lives without modern computer technology. Experts in computing predict that...

...if advances in computer technology speed up then people will become more dependent on computer technology in ten years time.	0.75	0.84	0.59	0.86	0.90
...if advances in computer technology speed up then people will become less dependent on computer technology in ten years time.	0.75	0.09	0.10	0.14	0.86
...if advances in computer technology slow down then people will become more dependent on computer technology in ten years time.	0.40	0.84	0.17	0.55	0.41

...if advances in computer technology slow down then people will become less dependent on computer technology in ten years time.	0.40	0.09	0.14	0.45	0.83

At present millions of people make use of computer technology each day.

7. 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 rises, then more new houses will be built.	0.84	0.87	0.44	0.83	0.76
...if the population of Manchester rises, then fewer new houses will be built.	0.84	0.29	0.09	0.17	0.77
...if the population of Manchester falls, then more new houses will be built.	0.17	0.87	0.24	0.51	0.56
...if the population of Manchester falls, then fewer new houses will be built.	0.17	0.29	0.23	0.49	0.91

The city currently has a population of 452,000.

8. 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 more people fly with budget airlines, then pollution caused by aeroplanes will increase.	0.76	0.75	0.51	0.81	0.88
...if more people fly with budget airlines, then pollution caused by aeroplanes will decrease.	0.76	0.31	0.12	0.19	0.76
...if fewer people fly with budget airlines, then pollution caused by aeroplanes will increase.	0.31	0.75	0.14	0.37	0.49
...if fewer people fly with budget airlines, then pollution caused by aeroplanes will decrease.	0.31	0.31	0.24	0.63	0.86

Environmental campaigns are now a familiar sight in the media.

9. 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 more violence is shown on television, then the amount of violent crime will rise.	0.62	0.65	0.38	0.64	0.79
...if more violence is shown on television, then the amount of violent crime will fall.	0.62	0.30	0.21	0.36	0.77
...if less violence is shown on television, then the amount of violent crime will rise.	0.24	0.65	0.18	0.44	0.62
...if less violence is shown on television, then the amount of violent crime will fall.	0.24	0.30	0.23	0.56	0.82

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, then the number of mobile phone shops on the High Street will increase.	0.75	0.66	0.40	0.59	0.72
...if mobile phone use increases, then the number of mobile phone shops on the High Street will decrease.	0.75	0.39	0.28	0.41	0.77
...if mobile phone use decreases, then the number of mobile phone shops on the High Street will increase.	0.21	0.66	0.10	0.30	0.60
...if mobile phone use decreases, then the number of mobile phone shops on the High Street will decrease.	0.21	0.39	0.23	0.70	0.90

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 Item Groups. Many people cannot afford to watch their local team. Some fans believe that...

...if footballers receive higher salaries, then ticket prices for games will rise.	0.76	0.76	0.58	0.84	0.89

...if footballers receive higher salaries, then ticket prices for games will fall.	0.76	0.34	0.11	0.16	0.83
...if footballers receive lower salaries, then ticket prices for games will rise.	0.28	0.76	0.14	0.45	0.42
...if footballers receive lower salaries, then ticket prices for games will fall.	0.28	0.34	0.17	0.55	0.86

Tickets at top clubs can cost as much as £50.

12. 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 the government increase their spending on school dinners, then school dinners will be healthier.	0.68	0.63	0.42	0.79	0.89
...if the government increase their spending on school dinners, then school dinners will be less healthy.	0.68	0.29	0.11	0.21	0.66
...if the government decrease their spending on school dinners, then school dinners will be healthier.	0.36	0.63	0.12	0.26	0.58
...if the government decrease their spending on school dinners, then school dinners will be less healthy.	0.36	0.29	0.34	0.74	0.88

Currently the majority of school children take school dinners at least three times a week.

13. The boom in online retail has commonly been linked to identity theft. Thieves often use these identities to launder money. Many experts ague that...

...if online shopping becomes more popular, then the risk of identity theft will increase.	0.82	0.60	0.49	0.71	0.80
...if online shopping becomes more popular, then the risk of identity theft will decrease.	0.82	0.27	0.20	0.29	0.81
...if online shopping becomes less popular, then the risk of identity theft will increase.	0.23	0.60	0.11	0.37	0.51
...if online shopping becomes less popular, then the risk of identity theft will decrease.	0.23	0.27	0.19	0.63	0.89

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 more money is spent annually on cancer research, then the amount of research on cancer treatment will increase.	0.79	0.74	0.50	0.78	0.86
...if the more money is spent annually on cancer research, then the amount of research on cancer treatment will decrease.	0.79	0.23	0.14	0.22	0.75

...if less money is spent annually on cancer research, then the amount of research on cancer treatment will increase.	0.24	0.74	0.12	0.32	0.50
...if less money is spent annually on cancer research, then the amount of research on cancer treatment will decrease.	0.24	0.23	0.25	0.68	0.88

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 more money is spent annually on AIDS research, then the amount of research into AIDS treatment will increase.	0.69	0.66	0.48	0.81	0.89
...if more money is spent annually on AIDS research, then the amount of research into AIDS treatment will decrease.	0.69	0.32	0.11	0.19	0.72
...if less money is spent annually on AIDS research, then the amount of research into AIDS treatment will increase.	0.29	0.66	0.14	0.33	0.52
...if less money is spent annually on AIDS research, then the amount of research into AIDS treatment will decrease.	0.29	0.32	0.28	0.67	0.86

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 more organic food is sold in shops, then organic food will become more popular.	0.74	0.72	0.39	0.68	0.82
...if more organic food is sold in shops, then organic food will become less popular.	0.74	0.34	0.18	0.32	0.74
...if less organic food is sold in shops, then organic food will become more popular.	0.31	0.72	0.16	0.38	0.61
...if less organic food is sold in shops, then organic food will become less popular.	0.31	0.34	0.26	0.62	0.84

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 increases, then motorway congestion at peak times will worsen.	0.82	0.64	0.37	0.61	0.76
...if the cost of petrol increases, then motorway congestion at peak times will improve.	0.82	0.38	0.24	0.39	0.88

...if the cost of petrol decreases, then motorway congestion at peak times will worsen.	0.16	0.64	0.26	0.68	0.63
...if the cost of petrol decreases, then motorway congestion at peak times will improve.	0.16	0.38	0.12	0.32	0.74

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 are increased, then applications for university places will rise.	0.71	0.65	0.33	0.49	0.66
..if student tuition fees are increased, then applications for university places will fall.	0.71	0.28	0.31	0.51	0.91
..if student tuition fees are decreased, then applications for university places will rise.	0.22	0.65	0.24	0.73	0.67
..if student tuition fees are decreased, then applications for university places will fall.	0.22	0.28	0.09	0.27	0.76

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 rises, then it will be harder for first time buyers to get on the property ladder.	0.83	0.61	0.24	0.51	0.77
...if the number of new houses built annually across the UK rises, then it will be easier for first time buyers to get on the property ladder.	0.83	0.34	0.23	0.49	0.81
...if the number of new houses built annually across the UK falls, then it will be harder for first time buyers to get on the property ladder.	0.40	0.61	0.34	0.64	0.76
...if the number of new houses built annually across the UK falls, then it will be easier for first time buyers to get on the property ladder.	0.40	0.34	0.19	0.36	0.66

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 increases, then the number of people who catch STDs each year will rise.	0.66	0.63	0.36	0.59	0.75
...if the amount of money spent annually on treating STDs increases, then the number of people who catch STDs each year will fall.	0.66	0.38	0.25	0.41	0.83
...if the amount of money spent annually on treating STDs decreases, then the number of people who catch STDs each year will rise.	0.29	0.63	0.23	0.58	0.64
...if the amount of money spent annually on treating STDs decreases, then the number of people who catch STDs each year will fall.	0.29	0.38	0.17	0.42	0.77

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 people become more energy efficient, then their utility bills will rise.	0.65	0.78	0.33	0.52	0.69
...if people become more energy efficient, then their utility bills will fall.	0.65	0.21	0.31	0.48	0.89
...if people become less energy efficient, then their utility bills will rise.	0.30	0.78	0.25	0.69	0.67
...if people become less energy efficient, then their utility bills will fall.	0.30	0.21	0.11	0.31	0.75

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 rise, then pollution caused by aeroplanes will increase.	0.78	0.75	0.41	0.66	0.79
...if taxes on air travel rise, then pollution caused by aeroplanes will decrease.	0.78	0.31	0.21	0.34	0.85
...if taxes on air travel fall, then pollution caused by aeroplanes will increase.	0.13	0.75	0.22	0.59	0.59
...if taxes on air travel fall, then pollution caused by aeroplanes will decrease.	0.13	0.31	0.15	0.41	0.78

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 increases its spending on the environment, then inner city pollution will increase.	0.73	0.68	0.26	0.42	0.64
...if the government increases its spending on the environment, then inner city pollution will decrease.	0.73	0.32	0.36	0.58	0.89
...if the government decreases its spending on the environment, then inner city pollution will increase.	0.26	0.68	0.27	0.71	0.74
...if the government decreases its spending on the environment, then inner city pollution will decrease.	0.26	0.32	0.11	0.29	0.73

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 fewer people take up smoking each year, then government revenue from cigarette taxes will rise.	0.63	0.68	0.27	0.63	0.84
...if fewer people take up smoking each year, then government revenue from cigarette taxes will fall.	0.63	0.39	0.16	0.37	0.67

...if more people take up smoking each year, then government revenue from cigarette taxes will rise.	0.33	0.68	0.23	0.41	0.73
...if more people take up smoking each year, then government revenue from cigarette taxes will fall.	0.33	0.39	0.33	0.59	0.77

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 more money is spent annually on preventing heart disease, then levels of heart disease will increase.	0.67	0.59	0.23	0.38	0.63
...if more money is spent annually on preventing heart disease, then levels of heart disease will decrease.	0.67	0.36	0.37	0.62	0.87
...if less money is spent annually on preventing heart disease, then levels of heart disease will increase.	0.28	0.59	0.27	0.68	0.77
...if less money is spent annually on preventing heart disease, then levels of heart disease will decrease.	0.28	0.36	0.13	0.32	0.73

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 rises, then electricity consumption will rise.	0.76	0.76	0.41	0.59	0.72
...if the cost of electricity rises, then electricity consumption will fall.	0.76	0.22	0.28	0.41	0.87
...if the cost of electricity falls, then electricity consumption will rise.	0.24	0.76	0.18	0.58	0.59
...if the cost of electricity falls, then electricity consumption will fall.	0.24	0.22	0.13	0.42	0.82

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 harder, then car insurance prices for young drivers will rise.	0.66	0.71	0.40	0.66	0.79
...if driving tests are made harder, then car insurance prices for young drivers will fall.	0.66	0.18	0.21	0.34	0.87

...if driving tests are made easier, then car insurance prices for young drivers will rise.	0.31	0.71	0.26	0.67	0.60
...if driving tests are made easier, then car insurance prices for young drivers will fall.	0.31	0.18	0.13	0.33	0.74

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 raised, then more tap water will be used.	0.71	0.61	0.25	0.49	0.64
...if water bills are raised, then less tap water will be used.	0.71	0.38	0.36	0.51	0.88
...if water bills are cut, then more tap water will be used.	0.20	0.61	0.27	0.69	0.75
...if water bills are cut, then less tap water will be used.	0.20	0.38	0.12	0.31	0.73

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 rises, then the amount of waste buried in land fill sites will increase.	0.69	0.60	0.21	0.34	0.59
...if the rate of recycling rises, then the amount of waste buried in land fill sites will decrease.	0.69	0.41	0.41	0.66	0.87
...if the rate of recycling falls, then the amount of waste buried in land fill sites will increase.	0.21	0.60	0.26	0.67	0.79
...if the rate of recycling falls, then the amount of waste buried in land fill sites will decrease.	0.21	0.41	0.13	0.33	0.74

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 increases, then there will be more food shortages in third-world countries.	0.61	0.67	0.30	0.54	0.74

...if the amount of money spent annually on reducing third-world poverty increases, then there will be fewer food shortages in third-world countries.	0.61	0.32	0.26	0.46	0.84
...if the amount of money spent annually on reducing third-world poverty decreases, then there will be more food shortages in third-world countries.	0.35	0.67	0.29	0.64	0.70
...if the amount of money spent annually on reducing third-world poverty decreases, then there will be fewer food shortages in third-world countries.	0.35	0.32	0.16	0.36	0.71

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 increases, then levels of obesity will rise.	0.71	0.66	0.35	0.56	0.72
...if the amount of money spent annually on tackling obesity increases, then levels of obesity will fall.	0.71	0.43	0.28	0.44	0.86
...if the amount of money spent annually on tackling obesity decreases, then levels of obesity will rise.	0.35	0.66	0.24	0.63	0.65
...if the amount of money spent annually on tackling obesity decreases, then levels of obesity will fall.	0.35	0.43	0.14	0.37	0.76

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. They propose that...

...if cars become more fuel efficient, then people will need to spend more money on petrol.	0.71	0.78	0.25	0.37	0.58
...if cars become more fuel efficient, then people will need to spend less money on petrol.	0.71	0.14	0.42	0.63	0.88
...if cars become less fuel efficient, then people will need to spend more money on petrol.	0.30	0.78	0.21	0.64	0.75
...if cars become less fuel efficient, then people will need to spend less money on petrol.	0.30	0.14	0.12	0.36	0.79

Top car manufacturers spend millions of pounds each year developing new engines.

Figure 1: Truth table for if p then q

p	q	If p then q
p	q	True
p	not-q	False
not-p	q	True
not-p	not-q	True

Figure 2: Example materials showing all eight permutations of high and low P(p), P(q) and P(if p then q). We constructed four versions of 32 items (128 items in total).

Example of items 1-16 (1-64)

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...

a)...if the cost of oil rises, then the cost of petrol will rise. (high P(p), high P(q), high P(if p then q))

b)...if the cost of oil rises, then the cost of petrol will fall. (high P(p), low P(q), low P(if p then q))

c)...if the cost of oil falls, then the cost of petrol will rise. (low P(p), high P(q), low P(if p then q))

d)...if the cost of oil falls, then the cost of petrol will fall. (low P(p), low P(q), high P(if p then q))

Consumers need to be aware of these potential changes.

*****

Example of items 17-32 (65-128)

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...

a)...if more money is spent annually on preventing heart disease, then levels of heart disease will increase. (high P(p), high P(q), low P(if p then q))

b)...if more money is spent annually on preventing heart disease, then levels of heart disease will decrease. (high P(p), low P(q), high P(if p then q))

c)...if less money is spent annually on preventing heart disease, then levels of heart disease will increase. (low P(p), high P(q), high P(if p then q))

d)...if less money is spent annually on preventing heart disease, then levels of heart disease will decrease. (low P(p), low P(q), low P(if p then q))

Donations can be made to the British Heart Foundation through their website.

Table 1: Correlations between each of the five probabilities calculated in pre-tests

	P(p)	P(q)	P(pq)	P(q|p)	P(not-p or q)
P(p)	-	.001	.464*	.001	.374*
P(q)	.001	-	.441*	.479*	-.491*
P(pq)	.464*	.441*	-	.829*	.421*
P(q|p)	.001	.479*	.829*	-	.285*
P(not-p or q)	.374*	-.491*	.421*	.285*	-

*p= <.001

Table 2: Regression weights and Confidence Intervals (CI) in Linear Mixed Regression Model for each

Critical Region (parameter estimates and p values based on the t statistic).

	Region 1 (wrap-up region)						**Region 2 (spill over)**				
	Estimate	95% CI Lower	95% CI Upper	p	r		Estimate	95% CI Lower	95% CI Upper	p	r
Intercept	1163.6	514.3	1812.8	<.001	-		892.5	428.3	1356.7	<.001	-
P(p)	-4.4	-8.1	-0.7	.019	-.078*		0.74	-1.9	3.4	.589	-.011
P(q)	2.0	-2.5	6.7	.376	-.027		1.1	-2.2	4.4	.508	.015
P(pq)	5.2	-8.0	18.3	.443	-.131*		1.6	-11.1	8.0	.748	-.101*
P(q|p)	-10.6	-18.1	-3.1	.006	-.128*		-3.1	-8.6	2.3	.256	-.115*
P(not-p or q)	1.0	-6.9	8.9	.802	-.084*		-3.2	-8.9	2.5	.275	-.110*

*p = <.05

Note: Correlation coefficients (r) are zero order correlations between predictor variables and reading times to each analysis region.