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Eye movements reveal rapid concurrent access to factual and counterfactual interpretations of
the world

Heather J Ferguson

University of Kent

RUNNING HEAD: EYE MOVEMENTS AND COUNTERFACTUALS

Correspondence to:

Heather Ferguson
School of Psychology
Keynes College
University of Kent
Canterbury
Kent CT2 7NP
England, UK

email: h.ferguson@kent.ac.uk

Tel: +44 (0) 1227 827120

Fax: +44 (0) 1227 827030

Author Notes

This work was carried out with the support of a grant from the University of Kent's Faculty of Social Sciences. Thanks are due to Ruth Byrne and an anonymous reviewer for helpful comments on this work.

Abstract

Imagining a counterfactual world using conditionals (e.g. *If Joanne had remembered her umbrella...*) is common in everyday language. However, such utterances are likely to involve fairly complex reasoning processes to represent both the explicit hypothetical conjecture and its implied factual meaning. Online research into these mechanisms has so far been limited. The present paper describes two eye movement studies that investigated the time-course with which comprehenders can set up and access factual inferences based on a realistic counterfactual context. Adult participants were eye-tracked while they read short narratives, in which a context sentence set up a counterfactual world (*If...then...*) and a subsequent critical sentence described an event that was either consistent or inconsistent with the implied factual world. A factual consistent condition (*Because... then...*) was included as a baseline of normal contextual integration. Results showed that within a counterfactual scenario, readers quickly inferred the implied factual meaning of the discourse. However, initial processing of the critical word led to clear, but distinct, anomaly detection responses for both contextually inconsistent and consistent conditions. These results provide evidence that readers can rapidly make a factual inference from a preceding counterfactual context, despite maintaining access to both counterfactual and factual interpretations of events.

Key Words: Counterfactuals, indicative conditionals, eye movements, discourse processing

Introduction

Understanding a counterfactual scenario, a hypothetical scenario that is counter to reality or false, involves an understanding of at least two possibilities: the explicit conjecture and its implied meaning (Byrne & Tasso, 1999; Fauconnier, 1994). For example, the counterfactual utterance, *If Victoria had told the truth she wouldn't have been in trouble with her boss*, invites the comprehender to represent the hypothetical possibility that Victoria told the truth and was not in trouble with her boss. However, it also implies the facts, that in reality Victoria did not tell the truth and therefore was in trouble with her boss. Utterances such as this occur frequently in everyday conversations and do not appear difficult for healthy adults to make sense of. Indeed, even children respond correctly to counterfactual questions of the form, “If... then...”, from around the age of four years old (Riggs, Peterson, Robinson, & Mitchell, 1998). Interestingly, children’s success at counterfactual reasoning is also strongly correlated with the development of executive functions, which alludes to the involvement of complex reasoning abilities, particularly high-level language and inhibitory control (Beck, Riggs, & Gorniak, 2010). As such, the current paper employs a highly-sensitive eye-tracking analysis to identify the sophisticated cognitive processes that underlie adults’ counterfactual reasoning.

Theoretical speculations about how counterfactual worlds are constructed and represented in the mind typically involve the use of ‘mental spaces’ (e.g. Fauconnier, 1985; 1997) and are mostly supported by offline evidence that counterfactuals elicit a dual meaning, involving the counterfactual and factual representations (Byrne, 2002; 2005; Johnson-Laird & Byrne, 2002; Thompson & Byrne, 2002). The availability and exact relationship between these multiple representations remains under debate, with some recent models supporting the existence of multiple representations for counterfactuals and proposing that reasoners must keep track of the epistemic nature of both representations during comprehension (Byrne, 2005; Johnson-Laird & Byrne, 1991; 2002)¹. In contrast, others argue that people only construct one

mental model at a time (the ‘singularity principle’, see Evans, Over, & Handley, 2005; Evans & Over, 2004).

Despite a great deal of research on reasoning with conditionals such as the one above (e.g. Byrne & Johnson-Laird, 2009; Kahneman & Miller, 1986), the issue of how counterfactual scenarios are represented online during comprehension has only recently begun to attract research interest. Some of these studies have examined how conditionals, including counterfactual conditionals, are set up (e.g. Haigh & Stewart, in press; Stewart, Haigh, & Connell, 2010; Santamaría, Espino, & Byrne, 2005; Stewart, Haigh, & Kidd, 2009), while others have focussed on the mechanisms involved in anticipating or integrating the consequences of a counterfactual world (Ferguson & Sanford, 2008; Ferguson, Scheepers, & Sanford, 2010; Ferguson, Sanford, & Leuthold, 2008; de Vega, Urrutia, & Riffo, 2007). The current experiment will develop this work, looking at how the *consequences* of a counterfactual world are processed online.

Ferguson and colleagues investigated the comprehension of reality-violating counterfactuals such as, “If cats were vegetarians...”, and particularly how comprehenders make sense of a continuation that draws reference to this counterfactual world, as in, “Families could feed their cat a bowl of carrots...”. Ferguson and Sanford (2008; see also Ferguson et al., 2008) used an eye-tracked reading task to examine the time course with which a counterfactual consequence is integrated into an unfolding discourse. Here, participants read short passages that crossed real-world (e.g. “If cats are hungry...”) and counterfactual-world (e.g. “If cats were vegetarians...”) contexts with appropriate real-world (*feeding the cat fish*) and counterfactual-world (*feeding the cat carrots*) continuations. Results showed that readers can rapidly accommodate a novel counterfactual world, leading to a reversal of typical real-world anomaly detection effects when that information has been presented within an appropriate counterfactual context. In other words, “If cats were vegetarians... feed them a bowl of carrots” led to longer reading times and increased regressions out compared to “If cats were

vegetarians... feed them a bowl of fish". Complementary effects were found in Ferguson et al. (2010; Experiment 1) who used a visual world paradigm task to examine the build up of expectations within the same counterfactual contexts. In this experiment, participants listened to auditory scenarios, crossing real-world and counterfactual-world information. Participants' eye movements around a concurrent visual scene (depicting, among other things, a fish and some carrots) were monitored and time-locked to the onset of the disambiguating word ("fish" or "carrots"). Under these conditions, listeners anticipated reference to the contextually appropriate real-world or counterfactual-world objects at the same time point- 200ms before the auditory onset of "fish" or "carrots". Taken together, these results suggest that comprehenders are promptly able to construct a representation of a novel counterfactual world and use relevant information to predict subsequent events in the discourse. However, these studies also demonstrated that successful counterfactual reasoning is subject to interference from participants' own knowledge of reality, as continuations that violated real-world assumptions (i.e. cats eating carrots) led to disruptions during the early stages of critical word integration, regardless of a preceding counterfactual context.

To date, it remains unclear whether the early interference from real-world knowledge revealed in these studies was simply due to the counterfactual impossibilities that were employed. Thus, it could be that the initial disruption during integration was driven by participants' familiarity with established real-world norms compared to the novelty of the counterfactual alternative. On the other hand, it may be that this process of grounding incoming information in real-world knowledge is an integral part of comprehending counterfactuals generally, including counterfactual possibilities (see Byrne, 2005) that do not violate real-world assumptions. This question will be addressed directly here as we examine the processing of counterfactuals that do not violate reality. Consideration of this issue is particularly timely given recent evidence that readers evaluate the probability of a counterfactual scenario as they are reading, relating incoming information to their contextual

knowledge of the facts (see Stewart et al., 2010; Stewart et al., 2009).

In the current experiments, participants were eye-tracked while they read short narratives in which a counterfactual context set up a realistic hypothetical situation, and a subsequent critical sentence drew reference to the consequence of this event² (see (1)).

- (1) If Andy had revised diligently, he would have passed the exam first time round. Now Andy was preparing to celebrate over the Summer holidays.

In this example, a hypothetical scenario is described in which Andy revised diligently and passed his exam first time around. However, readers should make the inference from this counterfactual context that in fact, Andy did not revise diligently and hence did not pass his exam first time around. As such, his reported actions in the critical sentence (i.e. *celebrating*) are inconsistent with the context's meaning³. Using scenarios like this, the current paper will assess (i) the speed with which readers can infer the actual state of affairs from a counterfactual utterance, and (ii) whether they continue to suffer interference from the alternative interpretation during integration of realistic counterfactual situations. Passages depicting a factual scenario (established with the conjunction, "because") were included as a baseline of normal contextual integration.

Based on existing eye-tracking literature, it is expected that any difficulty integrating the critical word will be reflected in longer reading times and higher incidence of regressive eye movements (e.g. Braze, Shankweiler, Ni, & Palumbo, 2002; Ni, Fodor, Crain & Shankweiler, 1998; Rayner, Warren, Juhasz, & Liversedge, 2004). Therefore, we can make the following predictions. If readers have already established a full representation of the implied factual scenario, based on the preceding counterfactual context, then some processing difficulty should be revealed early on when readers encounter an inconsistent critical word (compared to a consistent continuation, such as 'resit'). Evidence for this inconsistency detection may be

elicited immediately in reading (i.e. increased reading times on the critical word), or at some later point (e.g. in a post-critical region). In contrast, if readers continue to represent the hypothetical counterfactual scenario rather than inferring its implied factual meaning, they are likely to suffer a delay in responding to a contextually inappropriate critical word. Such a delay might have the effect of eliciting early anomaly detection responses for consistent, rather than inconsistent, critical words (as seen in Ferguson & Sanford, 2008), or simply delaying the detection of inconsistent information until further downstream. Indeed, a lack of any interference would provide strong support for de Vega et al. (2007)'s update canceling hypothesis, which predicts that while a counterfactual scenario is briefly represented, access to information within it is suppressed at sentence wrap-up.

Importantly, it is hoped that the current study will inform on the temporal course of the dual representations involved in understanding a counterfactual scenario. In other words, do factual and counterfactual representations influence comprehension simultaneously or as part of a sequential two-stage process? Examining eye movements during reading provides an ideal way to tackle this issue for many reasons. First, tracking eye movements offers an online tool to study natural reading, as opposed to self-paced or automated word-by-word reading, with millisecond accuracy. Secondly, eye movement data can be broken down into consecutive regions for analysis and examined using a variety of reading behaviour measures, including early and late influences on fixations and regressions. Further, it is possible to examine whether such effects emerge at the critical word itself, or later in a 'spill-over' region. These measures have been integral to psycholinguistic research for over 30 years (see Rayner, 1998; 2009), meaning that a great deal is known about different eye movement patterns and the aspect of language processing that they represent.

Experiment 1

Method

Participants

Thirty six (22 females) native English speakers were recruited from the student population at the University of Kent. All had vision that they reported to be normal or corrected to normal (glasses or contact lenses) and none were dyslexic. The mean age was 20.3.

Materials and Design

Twenty four experimental items were created as in Table 1. Each item consisted of two sentences: Sentence one introduced a factual (“Because...”) or a realistic counterfactual (“If...”) scenario. The second sentence contained a continuation of this theme (“...Joanne’s hair was dry/ wet...”), where the critical word was either consistent or inconsistent with the preceding context. Note that within a counterfactual context, a consistent continuation is at odds with the hypothetical world described in sentence 1, and vice versa for inconsistent counterfactual continuations. This resulted in a 1-factor within-subjects design with three levels (factual-consistent, counterfactual-consistent and counterfactual-inconsistent).

“(Table 1 about here please)”

The critical nouns were matched across conditions for length and frequency (using the British National Corpus) and no significant differences were found (All $t_s < 1$). The nouns in the factual consistent and counterfactual inconsistent conditions averaged 6.83 (SD = 2.33) characters in length and a median frequency of 2230, while the nouns in the counterfactual consistent condition averaged 7.17 (SD = 2.26) characters in length and a median frequency of 2400. Hence, any difference in reading times between conditions should not to be due to discrepancies in length or frequency of the nouns.

Three presentation lists were then created, with each list containing twenty-four experimental items, eight in each of the three conditions. The twenty-four experimental items

in each list were interspersed randomly among 79 unrelated filler sentences to create a single random order and each subject only saw each target sentence once, in one of the three conditions. Twelve participants were randomly assigned to read each list. Comprehension questions followed half of the experimental (i.e., 12) and 40 of the filler trials. Participants did not receive feedback for their responses to these questions and all scored at or above 90% accuracy.

Procedure

Participants' gaze location and movement from the right eye was recorded using an EyeLink 1000 eye-tracker (viewing was binocular). All sentences were presented in size 14 Arial font style on a VDU screen, 60cm from the participants' eyes.

Prior to the experiment, the procedure was explained and participants were instructed to read at their normal rate. Participants were seated at the eye-tracker and a chin rest was used to stabilize participants' head position. The eye-tracker was calibrated using a series of nine fixed targets distributed across the display to establish the correlation between x/ y voltages and screen position. Before each sentence, participants performed a drift correction using a central fixation point, then fixated a marker at the top left of the screen- where the first character of the text would be displayed. Once this calibration check was completed accurately, the experimenter advanced the screen to display the next item. Adjustments to the calibration were made whenever necessary. After reading each sentence, participants clicked a button on the mouse that either led to the presentation of a comprehension question (after 50% of trials) or the next trial.

Results and Discussion

Methods of Analysis

The experimental passages were divided into six regions for analysis, as shown in Table 1.

Region 4 (critical) consisted of the consistent or inconsistent noun.

An automatic procedure pooled fixations shorter than 80ms with larger adjacent fixations, excluded fixations shorter than 40ms that were not within three characters of another fixation and truncated fixations longer than 1200ms. Trials where two or more adjacent regions had zero first-pass reading times were removed, which accounted for less than 3% of the data reported here.

Three early measures of language processing are reported here. *First fixation duration* is the duration of the first fixation in a region before going past that region (either a single fixation, or the first of multiple fixations). *First-pass reading time* is the sum of the duration of fixations made on first entering a region of text until an eye-movement exits the region to either the left or right. *First-pass regressions out* is the sum of regressive saccades made from the current most rightward fixation with a region of text, indicating the degree to which left to right movement was disrupted during the first sweep of the eyes through a region of text. These early measures provide an indication of the difficulty experienced when participants initially process a region of text. We also analysed two later measures. *Total reading time* is the sum duration of all fixations made within a region and provides an indication of the overall amount of time spent processing text in that region. Finally, *regressions in* inform us on the % of regressive movements from the right into each region and consequently provides details of the regions of text that readers need to revisit in order to make sense of a piece of text.

Table 2 displays mean values for each measure in each condition and region.

“(Table 2 about here please)”

The eye-movement data for each region was analysed using a within subjects 1-way ANOVA (factual consistent vs. counterfactual consistent vs. counterfactual inconsistent), allowing generalization to participants (F_1) and items (F_2). Post-hoc, Bonferonni comparisons

were used to examine the nature of significant effects. Given that the length of regions 1 and 2 differed naturally between factual and counterfactual contexts (i.e. “Because Joanne had remembered her umbrella, she had avoided the rain.” versus “If Joanne had remembered her umbrella, she would have avoided the rain.”), statistical analysis of reading time measures focused on the target sentence (but see Table 2 for means data).

First fixation: Statistical analyses revealed a significant difference between conditions in the critical region (“dry”/ “wet”; see Figure 1) [$F_1(2,34) = 3.93, p < 0.03$; $F_2(2, 22) = 5.35, p < 0.01$]. Further analyses using Bonferroni comparisons showed that first fixation durations were significantly longer in the counterfactual consistent condition compared to both the factual consistent ($t_1(35) = 2.56, p < 0.02$; $t_2(23) = 3.34, p < 0.005$) and counterfactual inconsistent ($t_1(35) = 2.54, p < 0.02$; $t_2(23) = 2.13, p < 0.05$) conditions, which did not differ from each other ($ts < 0.94$).

There were no significant effects at the post-critical or wrap-up regions [All $F_s < 2.5$].

First-pass Reading time: As with the first fixations data, a significant effect of condition was detected in the critical region [$F_1(2,34) = 3.8, p < 0.03$; $F_2(2, 22) = 4.39, p < 0.03$] (See Figure 1). Once again, planned contrasts revealed longer first-pass reading times in the counterfactual consistent condition compared to either the factual consistent ($t_1(35) = 2.3, p < 0.03$; $t_2(23) = 2.5, p < 0.02$) or counterfactual inconsistent ($t_1(35) = 2.6, p < 0.01$; $t_2(23) = 2.9, p < 0.008$) conditions. Factual consistent and counterfactual inconsistent conditions did not differ in this region ($ts < 1.06$).

Taken together, results from these two early reading measures (first fixation and first-pass reading time), showing increased reading times for counterfactual consistent compared to both factual consistent and counterfactual inconsistent critical words, may suggest that readers have not immediately noticed the anomalous event in the counterfactual inconsistent condition.

Thus, it is possible that they have processed the incoming information as though the context had been presented factually, as evidenced by the anomaly detection response (i.e. longer reading times) for counterfactual consistent continuations. This early interference is comparable to that reported in Ferguson and Sanford (2008), where initial reading time responses on the critical word were influenced by readers' own knowledge of reality, despite a preceding fictional counterfactual-world context.

No significant effects emerged during the post-critical and wrap-up regions [$F_s < 0.6$].

“(Figure 1 about here please)”

First-pass regressions out: Figure 2 plots the mean first-pass regressions out for each region and condition as the discourse progressed. As is apparent in this figure, no significant differences were found between conditions prior to the critical word onset [All $F_s < 0.29$]. However, during the critical region a significant difference emerged [$F_1(2, 34) = 4.05, p = 0.03$; $F_2(2, 22) = 4.6, p < 0.02$]. This difference reflected increased incidence of regressive eye movements in the counterfactual inconsistent condition compared to both the factual consistent ($t_1(35) = 2.86, p < 0.007$; $t_2(23) = 2.75, p < 0.01$) and the counterfactual consistent ($t_1(35) = 2.09, p < 0.04$; $t_2(23) = 2.94, p < 0.007$) conditions. Here, the two consistent conditions did not differ from one another (factual *vs.* counterfactual; $t_s < 0.81$). This suggests that immediately upon encountering a contextually inconsistent word (i.e. inconsistent within a counterfactual context), readers detected a processing difficulty that required them to regress back in the text. This effect explains the reduced reading times on earlier reading measures (detailed above) and demonstrates that participants have actually detected the inconsistent consequence of the counterfactual discourse immediately upon encountering the critical word, thus leading to shorter initial reading times prior to regressing back. As such, it is clearly not the case that readers were simply ignorant to the counterfactual status of the preceding context. Importantly,

within a counterfactual consistent scenario, readers did not show increased incidence of regressions back in the text, suggesting that the early increased reading time was sufficient to fully integrate the critical word into their representation of events.

The difference between conditions disappeared during the post-critical region [$F_s < 1.93$], but re-emerged by items (marginal by participants) during the sentence wrap-up [$F_1(2,34) = 1.98, p = 0.1; F_2(2, 22) = 8.5, p < 0.002$]. As in the critical region, this difference was characterised by increased regressive eye movements following a counterfactual inconsistent continuation compared to either a factual consistent ($t_1(35) = 1.86, p = 0.07; t_2(23) = 2.42, p < 0.02$) or a counterfactual consistent ($t_1(35) = 1.57, p = 0.12; t_2(23) = 3.56, p < 0.002$) continuation, which did not differ from one another ($ts < 0.68$). This effect provides further evidence that readers have detected and responded to an anomaly in inconsistent counterfactual continuations rather than consistent counterfactual continuations.

“(Figure 2 about here please)”

Total reading times: At the critical region, statistical analyses revealed a significant difference (marginal by items) in total reading times between the three conditions [$F_1(2,34) = 3.78, p < 0.03; F_2(2, 22) = 2.59, p = 0.09$] (see Figure 1). This difference reflected shorter total reading times on factually consistent critical words compared to both counterfactually consistent ($t_1(35) = 2.16, p < 0.04; t_2(23) = 2.1, p < 0.05$) and counterfactually inconsistent ($t_1(35) = 2.39, p < 0.02; t_2(23) = 1.71, p = 0.1$) critical words. These counterfactual conditions did not differ from each other ($ts < 0.85$).

Thus, this measure of later processing reveals that readers experienced a general difficulty at integrating the critical word within a counterfactual scenario, compared to a factual scenario. The increased total reading times for the counterfactual consistent condition is likely to reflect the initial difficulty that readers experienced when they first encountered the

critical word. In contrast, longer total reading times in the counterfactual inconsistent condition is likely to be manifest as a result of readers re-reading the critical information in order to make sense of the inconsistent event. As such, it seems that the overall difficulty experienced by readers in response to counterfactual scenarios represents two distinct sources of processing disruption.

There were no effects at the post-critical or wrap-up regions [All F s < 0.69].

Regressions in: Figure 3 shows the mean % of regressions into each region for each of the three conditions. A significant effect of condition was found immediately in Region 1 (“Because/ If Joanne had remembered her umbrella”) [$F_1(2,34) = 3.33, p < 0.05; F_2(2, 22) = 3.46, p < 0.05$]. Planned comparisons revealed that readers were significantly less likely to revisit region 1 when the context presented a factual scenario, compared to when the context depicted a counterfactual scenario (consistent: $t_1(35) = 1.99, p < 0.05; t_2(23) = 2.15, p < 0.04$; inconsistent: $t_1(35) = 2.57, p < 0.01; t_2(23) = 2.67, p < 0.01$). Interestingly, no significant difference was apparent between counterfactual consistent and counterfactual inconsistent conditions ($ts < 1.1$), which suggests that re-reading in this region reflects a general difficulty integrating counterfactual scenarios, and not as a result of having detected the inconsistent continuation.

There were no differences between conditions in region 2 [F s < 1.43], but clear differences re-emerged during the pre-critical region (“By the time she arrived at school, Joanne’s hair was”) [$F_1(2,34) = 5.65, p < 0.008; F_2(2, 22) = 3.37, p < 0.05$]. More regressions were made into this region in the counterfactual inconsistent condition than the factual consistent ($t_1(35) = 3.28, p < 0.002; t_2(23) = 1.98, p = 0.06$) or counterfactual consistent ($t_1(35) = 2.48, p < 0.02; t_2(23) = 2.53, p < 0.02$) conditions, which did not differ from each other ($ts < 0.44$). This effect provides further evidence that readers detected and responded to the

counterfactual inconsistent continuation and returned to the start of the critical sentence in order to make sense of the incoherent event.

No significant effects were found in the remaining regions of analysis [All F 's < 3.03].

“(Figure 3 about here please)”

Taken together, these results suggest that readers have early access to both factual and counterfactual alternatives upon encountering the critical word, which leads to different processing and recovery strategies in each condition. Specifically, this study has revealed increased initial reading times when the continuation was consistent with the counterfactual context, but increased regressions back (coupled with shorter initial reading times) when the continuation was inconsistent with the counterfactual context. Importantly, both of these reading patterns differ from those shown for factually consistent stories, which suggests that understanding counterfactuals is generally more difficult than simple factual utterances.

However, there is a possible confound in the design of this experiment, which leads to a low-level explanation of the early increased reading time elicited in the counterfactual-consistent condition compared to the factual-consistent or counterfactual-inconsistent conditions. Recall that the critical word in a counterfactual-consistent item was different to the critical word used in both the factual-consistent and counterfactual-inconsistent items (e.g. “wet” vs. “dry”). As stated earlier, we attempted to control for lexical differences by matching word length and word frequency across these two critical words, and found no significant differences on these measures. However, it is possible that other factors, such as cloze probability (see McDonald & Shillcock, 2003), may have influenced reading times outwith the experimental manipulations, and thus may have driven the early effects on reading time found here. Indeed, previous eye-tracking research has demonstrated that the more predictable a word is given the preceding context, the faster it is read (Rayner & Well, 1996), with this

predictability effect emerging on both early and late measures of reading. As such, it is possible that the critical words used in the counterfactual-consistent condition (e.g. “wet”) were simply less predictable in the sentence context (e.g. “By the time she arrived at school, Joanne’s hair was”) than the factual-consistent and counterfactual-inconsistent conditions (e.g. “dry”).

In order to test this possibility, a second experiment was conducted that included a factual-inconsistent condition as a baseline measure of contextual anomaly detection responses in reading. Importantly, this condition included the same critical word as used in the counterfactual-consistent condition, thus allowing us to assess whether the early increased reading times were simply due to the lexical items used. Additionally, using this fully crossed context*consistency design, we aimed to determine how the disruptions to reading observed in the counterfactual conditions compare to clear violations of factual information.

Experiment 2

Method

Participants

Thirty six (20 females; mean age 21.7) native English speakers were recruited from the student population at the University of Kent. Selection criteria was the same as in Experiment 1, plus they had not participated in Experiment 1.

Materials and Design

The same twenty four experimental items as used in Experiment 1 were used in Experiment 2. However, this experiment included one additional experimental condition, a factual inconsistent condition to set up a fully crossed 2(factual vs. counterfactual) x2(consistent vs. inconsistent) within-subjects design (see Table 3).

“(Table 3 about here please)”

One version of each item was assigned to one of four presentation lists, with each list containing twenty-four experimental items, six in each of the four conditions. Thus, each participant only saw each target sentence once, in one of the four conditions. These experimental items were interspersed randomly among the same 79 filler items as in Experiment 1. Ten participants were randomly assigned to read each list. As in Experiment 1, comprehension questions followed half of the experimental and filler trials. Participants did not receive feedback for their responses and all scored at or above 90% accuracy.

Procedure

Experimental procedures were identical to those used in Experiment 1.

Results and Discussion

Methods of Analysis

Each experimental item was divided into six regions for analysis, as described in Experiment 1 and illustrated in Table 3. Data preparation and measures of language processing were also the same as detailed in Experiment 1.

Table 4 displays mean values for each measure in each condition and region.

“(Table 4 about here please)”

The eye-movement data for each region was analysed using a within subjects 2(context: factual vs. counterfactual) x2(consistency: consistent vs. inconsistent) ANOVA, allowing generalization to participants (F_1) and items (F_2).

First fixation: At the critical region, a significant interaction between context and consistency emerged in first fixation durations [$F_1(1,35) = 5.21, p < 0.03$; $F_2(1, 23) = 4.16, p < 0.05$]. Analysis of the simple main effects underlying this interaction revealed that first fixation durations were significantly longer in the inconsistent condition compared to the consistent condition at the factual context level ($t_1(35) = 2.78, p < 0.01$; $t_2(23) = 1.89, p = 0.07$), but not at the counterfactual context level ($ts < 0.3$). Additionally, first fixations on this critical word were significantly longer in the counterfactual-consistent condition compared to the factual-consistent condition ($t_1(35) = 1.98, p < 0.05$; $t_2(23) = 2.04, p < 0.05$), with no difference between factual and counterfactual context levels when the described event was inconsistent with the preceding context ($ts < 1.49$). These data are illustrated in Figure 4. Neither context nor consistency emerged as a main effect in this region [$F_s < 3.38$].

No differences in first fixation duration were found in the remaining regions of analysis [All $F_s < 0.72$].

“(Figure 4 about here please)”

First-pass Reading time: First-pass reading times at the critical region (see Figure 4) showed a main effect of consistency [$F_1(1,35) = 5.28, p < 0.03$; $F_2(1, 23) = 3.76, p = 0.06$]. This main effect reflected an overall increased first-pass reading time on the critical word (“dry” or “wet”) when that word was inconsistent with the preceding factual/ counterfactual context, compared to when it was consistent. However, more interesting was the presence of a significant interaction between the two variables [$F_1(1,35) = 6.68, p < 0.01$; $F_2(1, 23) = 3.71, p = 0.07$] in this region. Similar to the first fixation data, simple main effects revealed significantly longer first-pass reading times when the critical word was inconsistent, compared to when it was consistent with a preceding factual context ($t_1(35) = 3.05, p < 0.004$; $t_2(23) = 2.11, p < 0.05$). In contrast, consistency did not influence first-pass reading times on the

critical word within a counterfactual context ($ts < 0.27$). Further, on this measure, readers showed significantly longer reading times in the factual-inconsistent condition compared to the counterfactual-inconsistent condition ($t_1(35) = 2.24, p < 0.03$; $t_2(23) = 1.78, p = 0.09$), but no difference between factual- and counterfactual-consistent conditions ($ts < 0.27$). As such, it appears that the main effect of consistency was being driven solely by the substantially increased first-pass reading times for the factual-inconsistent condition, while reading times remained equivalent for the two counterfactual conditions.

Taken together, these early reading time measures (first fixation and first-pass reading time) indicate that the increased reading times found in Experiment 1 do genuinely reflect increased difficulty with integrating the critical word (“dry” or “wet”). This is evidenced by the significantly longer reading times in the factual-inconsistent condition compared to the counterfactual-consistent condition. It is also interesting to note that in contrast to Experiment 1, readers here spent as long integrating a counterfactually consistent word as a counterfactually inconsistent word, with both showing increased reading times relative to the factual-consistent baseline. We will consider the nature of this finding in more depth once all measures have been reported.

No further differences in first-pass reading times were found in the remaining regions [All $F_s < 3.02$].

First-pass regressions out: Figure 5 illustrates how each condition affected the mean first-pass regressions out of each region as the sentence progressed.

“(Figure 5 about here please)”

Similar to the first-pass reading time data, first-pass regressions out of the critical region showed both a main effect of consistency [$F_1(1,35) = 4.3, p < 0.05$; $F_2(1, 23) = 2.66, p = 0.1$]

and a significant interaction [$F_1(1,35) = 3.99, p < 0.05; F_2(1, 23) = 7.05, p < 0.01$]. However, on this measure, these effects were being driven by the significantly increased probability of making regressions out following a counterfactual-inconsistent item, compared to a counterfactual-consistent item ($t_1(35) = 2.71, p < 0.01; t_2(23) = 2.97, p < 0.007$) or even a factual inconsistent item ($t_1(35) = 1.56, p = 0.1; t_2(23) = 2.35, p < 0.03$). None of the remaining simple main effect comparisons revealed significant differences ($ts < 1.56$).

The post-critical region revealed a main effect of context [$F_1(1,35) = 10.31, p < 0.003; F_2(1, 23) = 5.65, p < 0.03$], with increased regressions out following a factual context compared to a counterfactual context. Given that no main effect of consistency or context*consistency interaction was present here [All F s < 0.81], we can assert that this context effect reflects readers' sensitivity to the clear anomalies among the factual items, which increased their likelihood of regressing back to double-check the context regardless of the consistency of the incoming information.

There were no effects in the wrap-up region [All F s < 2.87].

Total reading times: A significant main effect of consistency was found at the pre-critical region [$F_1(1,35) = 9.8, p < 0.004; F_2(1, 23) = 5.47, p < 0.03$]. This effect was characterised by increased total reading times when the target sentence included a contextually inconsistent continuation, compared to a contextually consistent continuation.

At the critical region, statistical tests revealed main effects of both context [$F_1(1,35) = 4.01, p < 0.05; F_2(1, 23) = 2.45, p = 0.1$] and consistency [$F_1(1,35) = 10.5, p < 0.003; F_2(1, 23) = 3.77, p = 0.06$]. These effects reflected increased overall reading times following a factual context compared to a counterfactual context, and increased reading times when the critical word was inconsistent with the preceding context compared to when it was consistent. However, as with earlier measures, the pattern of results in total reading times was dominated by a significant context*consistency interaction [$F_1(1,35) = 22.2, p < 0.001; F_2(1, 23) = 8.86, p$

< 0.007]. Examining the distribution of reading times in Figure 4, and running simple main effects analyses elucidates that this interaction is being driven by significantly longer total reading times following a factually inconsistent continuation compared to a factually consistent continuation ($t_1(35) = 5.25, p < 0.001$; $t_2(23) = 2.97, p < 0.007$). In contrast, consistency did not influence reading times at the counterfactual context level ($ts < 1.09$). Further, context influenced total reading times in opposing directions at each level of consistency, with factual-inconsistent conditions leading to increased reading times relative to counterfactual-inconsistent conditions ($t_1(35) = 4.77, p < 0.001$; $t_2(23) = 3.01, p < 0.007$), and counterfactual-consistent conditions eliciting increased reading times compared to factual consistent conditions ($t_1(35) = 2.31, p < 0.03$; $t_2(23) = 1.78, p = 0.08$).

In the post-critical region, total reading times elicited a main effect of context [$F_1(1,35) = 8.14, p < 0.007$; $F_2(1, 23) = 2.88, p = 0.1$]. This effect was similar to that revealed in the first-pass regressions out data, where reading times were significantly longer for factual stories compared to counterfactual stories. There were no further effects in this post-critical region or in the wrap-up region [All $F_s < 2.05$].

Regressions in: Figure 6 shows the mean % of regressions into each region for each of the four conditions. In the critical region, a main effect of context [$F_1(1,35) = 4.71, p < 0.04$; $F_2(1, 23) = 6.93, p < 0.01$] and a main effect of consistency [$F_1(1,35) = 5.68, p < 0.02$; $F_2(1, 23) = 2.74, p = 0.1$] was found, which reflected increased likelihood of making a regressive eye movement into this region following a factual *versus* counterfactual context, and increased regressions in when this critical word was inconsistent *versus* consistent with the preceding context. No significant interaction was present [$F_s < 0.06$].

“(Figure 6 about here please)”

No significant effects were found in the other regions of analysis [All F s < 3.59].

Overall, the results from Experiment 2 replicate and develop the findings from Experiment 1. Importantly, they allow us to reject a low-level explanation of the increased initial reading times, since the clear violation in the factual-inconsistent condition led to significantly longer reading times compared to the counterfactual-consistent condition, despite involving the same critical word. As was found previously, readers here detected the counterfactually inconsistent word immediately upon encountering it, as reflected in increased first-pass regressions out from this region. However, in this experiment, readers spent longer initial reading time on the critical word in *both* counterfactual conditions compared to the factual-consistent condition. This effect contrasts with results from Experiment 1, which showed decreased initial reading time for counterfactual-inconsistent compared to counterfactual-consistent conditions. We explain this different pattern in terms of readers' sensitivity to the inclusion of obvious context violations (factual-inconsistent condition) in Experiment 2. Such an account is corroborated by the increased probability of regressing back in the text following both factual conditions and also by the relatively increased reading times for all conditions in Experiment 2 compared to Experiment 1.

As such, we can assert that for counterfactual-consistent sentences, as in Experiment 1, readers required longer initial reading time to fully integrate the critical word into their factual representation of events. Further, Experiment 2 demonstrates that when readers were aware of clear anomalous items among the sentences, they adapted their reading strategy to spend longer initial reading time on counterfactual-inconsistent critical words, prior to regressing back in the text to make sense of the mismatch. Therefore, these results can be taken as further evidence that readers maintain access to both possible interpretations of a counterfactual world.

General Discussion

Understanding a counterfactual scenario requires the comprehender to temporarily represent a version of the world that is at odds with the implied factual alternative (Fauconnier & Turner, 2003). However, for such language structures to be successful in everyday situations communicators need to be able to rapidly dissociate counterfactual and factual information, otherwise these contrasting sources of information would become confounded. That is, although the two ‘possible worlds’ are likely to be governed by the same basic constraints (e.g. gravity), each represents a distinct model of the world. Reasoners must then keep track of the epistemic state of these factual and counterfactual mental representations in order to interpret subsequent information appropriately (Byrne, 2005; Johnson-Laird & Byrne, 1991). At the outset of this paper, we proposed to investigate the time-course with which readers can set up and access factual inferences based on a counterfactual context and to examine whether such processes suffer interference from the counterfactual situation.

Results showed that within a counterfactual scenario, initial processing of the critical word led to anomaly detection responses for both contextually consistent and inconsistent information. These effects were characterized by distinct behavioural responses, as counterfactual consistent continuations prompted readers to spend longer during initial reading of a critical word, but counterfactual inconsistent continuations elicited a higher incidence of first-pass regressions back from that critical word. Indeed, as shown in Experiment 2, readers’ sensitivity to anomalous materials in the experiment modulated these effects further and prompted readers to increase their initial reading time on the critical word in both counterfactual conditions in order to verify the incoming information according to the inferred factual representation. However, even under these conditions, readers detected counterfactually inconsistent critical words immediately upon encountering them and attempted to recover by regressing back in the story. This was not the case for counterfactual-consistent items. Later measures of reading provided conclusive evidence that overall, readers favoured the implied factual meaning of the discourse, with increased total reading times in both counterfactual

conditions relative to the factual-consistent condition, and crucially, increased regressions for counterfactual inconsistent continuations compared to consistent ones. Taken together, these results demonstrate that readers can rapidly make a factual inference from a preceding counterfactual context, despite maintaining access to both counterfactual and factual interpretations of events.

These results fit well with previous online studies of counterfactual reasoning. Importantly, they replicate the rapid access to the factual alternative shown in de Vega et al. (2007), but extend this work to demonstrate that readers also maintain access to the hypothetical alternative. Such an account has been made previously by Santamaria and colleagues (2005), who observed that counterfactual utterances such as, “If it had rained, the plants would have bloomed” primed faster comprehension of both negative (i.e. factual; not p and not q) and affirmative (i.e. counterfactual; p and q) conjunctions. Moreover, we have established that understanding a counterfactual utterance may be more cognitively demanding than simply understanding a factual utterance. Evidence for this effect comes from the initial difficulty at integrating the critical word and the increased incidence of regressions into the antecedent clause region for both counterfactual continuations. Further, the finding from Experiment 2 that counterfactual inconsistencies do not elicit as strong anomaly detection effects as factual inconsistencies, suggests that representations of counterfactually-implied factual scenarios are not as robust as information that has been presented factually. It is possible that these effects are due to the increased demands on readers to set up multiple representations of the world following a counterfactual context and to evaluate the truth value of each, while factual contexts simply prompt the reader to simulate a single factual representation.

The results also offer an interesting comparison with Ferguson and Sanford’s (2008) studies of reality-violating counterfactuals. Although readers in all these studies suffered some initial interference from the alternative world representation, readers in Ferguson and Sanford

eventually favoured a counterfactual-world interpretation of the critical event, while readers in the current study favoured a factual-world interpretation of the critical event. These preferences were deliberately prompted by the language used in the critical sentence (i.e. modal verbs ‘could’ and ‘would’ in Ferguson and Sanford, *versus* factual cues (e.g. ‘That evening...’) used here). However, these differing effects raise several questions, including whether readers show any interpretation preference prior to encountering a biasing language cue. It would also be important to know how quickly these structures can trigger a reader to adopt one interpretation over the other and use that as the preferred model for parsing incoming information.

Since the current data have established that within a counterfactual narrative, the counterfactual representation does briefly interfere with readers’ online inferences about the implied factual situation (relative to factually consistent sentences), we can also assume that comprehenders do not actively suppress access to the hypothetical scenario. Such interference was not anticipated by previous research, which has proposed that readers are able to temporarily represent the false alternative when this fits with the counterfactual conditional framework (Byrne, 1997; Johnson-Laird & Byrne, 1991), or that they suppress access to the counterfactual events at sentence wrap-up and shift their attention back to the factual events in the story (de Vega et al., 2007). Thus, future accounts of counterfactual reasoning would need to allow for the fact that comprehenders continue to retain access to both factual and counterfactual representations of the world (as first suggested by Santamaria et al., 2005), and use these models to integrate incoming information, at least one sentence downstream of the counterfactual context. Indeed, it would be intriguing to examine how this effect proceeds over time when the constraints of the factual or counterfactual world are continually tested. For example, when reading a longer narrative that repeatedly supports the implied factual world, at what point does one stop representing the counterfactual world all together (therefore suffering no initial interference)? Conversely, if the narrative continues to develop the hypothetical counterfactual world, do readers gradually adopt this model as providing the constraints for

language comprehension, therefore eliciting anomaly detection responses to factually consistent input?

The data reported here offer new insights into the temporal course of the dual representations involved in understanding a counterfactual scenario. Although some models of counterfactual reasoning seem to endorse the involvement of multiple representations in some form (e.g. Byrne & Tasso, 1999; Fauconnier, 1994), there is currently no consensus on the exact time course with which each of these influences language processing. This is largely due to a lack of online evidence to examine such effects. Indeed, at face value, Ferguson and Sanford's (2008) previous online studies might be taken as evidence for a sequential mechanism, in which integrating the consequences of a counterfactual world suffer initial interference from the alternative world. However, these studies examined novel, reality-violating counterfactual scenarios, which were likely to require readers to make an extra inference to test incoming information against the true world. Using realistic counterfactual scenarios, the current study clearly demonstrates that incoming information is tested *simultaneously* against both the counterfactual and factual world for inference during the early stages of language comprehension. This finding argues against a sequential, two-stage process for understanding counterfactual conditional utterances in favour of a rapid, parallel process involving both the factual and counterfactual interpretations of events, from which readers can select the contextually appropriate continuation using cues from the evolving linguistic input.

A final interesting point to consider is the relative involvement of information provided by the antecedent and the consequent, which set up the counterfactual worlds to be tested here. A similar issue has recently been investigated by Stewart et al. (2010), who examined how online processing of a conditional statement of the form, *If p then q* (e.g. If student tuition fees rise then applications for university places will fall), is influenced by the conditional probability of [q given p], or the combined probability of [p and q]. In three experiments, Stewart et al. manipulated the subjective probability of p , q and [q given p] in various everyday

conditional statements. Results showed that during processing of the consequent clause, readers were sensitive to the probability of both p , and $[q \text{ given } p]$, meaning that readers do evaluate the real-world probability of a conditional statement online. In the current study, we examined how readers' understanding of a counterfactual world influences integration of a consequence in a subsequent critical sentence. Looking at the full set of experimental materials (see Appendix) shows that these critical consequences did not uniformly relate to the same aspect of the counterfactual context. Specifically, some of the critical events referred to information from the antecedent (as in (2)), others to the consequent (3) and still others to a combination of the two (4).

(2) If Karl had been wearing a jacket, he wouldn't have minded the long delay. After waiting outside for an hour he now felt cold as he watched the train approach.

(3) If it had rained this morning Susan would have rushed to get to work. In the end, Susan arrived at work late and her colleagues commented on it.

(4) If Bill had trained thoroughly, he would have completed this year's London marathon. The following day Bill felt frustrated with his efforts.

As such, an intriguing question for future research is whether consequential information that draws upon these different sources (antecedent, consequent or a combination) leads to different patterns of online integration. Unfortunately, such a detailed analysis is not possible here since the experimental design did not explicitly manipulate this variable.

In conclusion, when a conditional context depicts a counterfactual scenario (e.g. 'If Andy had revised diligently...'), readers can rapidly make an appropriate inference about the factual alternative (that *Andy did not revise diligently*) and use this to interpret and predict subsequent events in the narrative. Importantly, this conjecture is established online during discourse comprehension, and represented (at least temporarily) in parallel with the

counterfactual version of events. This finding supports a model of counterfactual reasoning where comprehenders have rapid, concurrent access to both factual and counterfactual possibilities and use cues from the evolving linguistic input to guide their incremental interpretation of events. Finally, these studies have demonstrated that inferring information from a counterfactual context may be more cognitively effortful than simply making an inference from a factual context.

References

- Beck, S.R., Riggs, K.J., & Gorniak, S.L. (2010). The effect of causal chain length on counterfactual conditional reasoning. *British Journal of Developmental Psychology, 28*, 505-521.
- Braze, D., Shankweiler, D., Ni, W., & Palumbo, L.C. (2002). Readers' eye movements distinguish anomalies of form and content. *Journal of Psycholinguistic Research, 31*, 25-44.
- Byrne, R.M.J. (2005). *The Rational Imagination: How People Create Alternatives to Reality*. Cambridge, M.A.: MIT Press.
- Byrne, R.M.J. (2002). Mental models and counterfactual thoughts about what might have been. *Trends in Cognitive Sciences, 6*, 426-431.
- Byrne, R.M.J. (1997). Cognitive processes in counterfactual thinking about what might have been. *The Psychology of Learning and Motivation, Advances in Research and Theory*. Vol 37. San Diego, CA: Academic Press. pp.105-154.
- Byrne, R.M.J., & Johnson-Laird, P.N. (2009). 'If' and the problems of conditional reasoning. *Trends in Cognitive Sciences, 13*, 282-287.
- Byrne, R.M.J., & Tasso A. (1999). Deductive reasoning with factual, possible, and counterfactual conditionals. *Memory & Cognition, 27*, 726-740.
- Evans, J.St.B.T., & Over, D.E. (2004). *If*. Oxford, England: Oxford University Press.

- Evans, J.St.B.T., Over, D.E., & Handley, S.J. (2005). Suppositions, Extensionality, and Conditionals: A Critique of the Mental Model Theory of Johnson- Laird and Byrne (2002). *Psychological Review*, *112*, 1040-1052.
- Fauconnier, G. (1997). *Mappings in thought and language*, Cambridge University Press.
- Fauconnier, G. (1994). *Mental Spaces*. Cambridge, UK: Cambridge University Press.
- Fauconnier, G. (1985). *Mental Spaces: Aspects of Meaning Construction in Natural Language*, Cambridge, MA: MIT Press.
- Fauconnier, G., & Turner, M. (2003). *The Way We Think: Conceptual Blending and the Mind's Hidden Complexities*. New York: Basic Books.
- Ferguson, H.J., & Sanford, A.J. (2008). Anomalies in real and counterfactual worlds: An Eye-Movement Investigation. *Journal of Memory & Language*, *58*, 609-626.
- Ferguson, H.J., Sanford, A.J., & Leuthold, H. (2008). Eye-movements and ERPs reveal the time-course of processing negation and remitting counterfactual worlds. *Brain Research*, *1236*, 113-125.
- Ferguson, H.J., Scheepers, C., & Sanford, A.J. (2010). Expectations in counterfactual and theory of mind reasoning. *Language and Cognitive Processes*, *25*, 297-346.
- Haigh, M., & Stewart, A.J. (in press). The influence of clause order, congruency and probability on the processing of conditionals. *Thinking and Reasoning*.
- Johnson- Laird, P.N., & Byrne, R.M.J. (2002). Conditionals: a theory of meaning, pragmatics, and inference. *Psychological Review*, *109*, 646-678.
- Johnson- Laird, P.N., & Byrne, R.M.J. (1991). *Deduction*. London: Erlbaum.
- Kahneman, D., & Miller, D.T. (1986). Norm Theory - Comparing reality to its alternatives. *Psychological Review*, *93*, 136-153.
- McDonald, S.A. & Shillcock, R.C. (2003). Eye movements reveal the on-line computation of lexical probabilities during reading. *Psychological Science*, *14*, 648-652.

- Ni, W., Fodor, J.D., Crain, S., & Shankweiler, D.P. (1998). Anomalous strings: Eye movement patterns. *Journal of Psycholinguistic Research*, 27, 515-539.
- Rayner, K. (1998). Eye movements in reading and information processing: 20 years of research. *Psychological Bulletin*, 124, 372-422.
- Rayner, K. (2009). Eye movements and attention in reading, scene perception, and visual search. *Quarterly Journal of Experimental Psychology*, 62, 1457-1506.
- Rayner, K., Warren, T., Juhasz, B., & Liversedge, S. (2004). The effects of plausibility on eye movements in reading. *Journal of Experimental Psychology: Learning, Memory and Cognition*, 30, 1290-1301.
- Rayner, K., & Well, A. D. (1996). Effects of contextual constraint on eye movements in reading: A further examination. *Psychonomic Bulletin & Review*, 3, 504-509.
- Riggs, K. J., Peterson, D. M., Robinson, E. J., & Mitchell, P. (1998). Are errors in false belief tasks symptomatic of a broader difficulty with counterfactuality? *Cognitive Development*, 13, 73-90.
- Santamaria, C., Espino, O., & Byrne, R.M.J. (2005). Counterfactual and semifactual conditionals prime alternative possibilities. *Journal of Experimental Psychology: Learning, Memory and Cognition*, 31, 1149-1154.
- Stewart, A.J., Haigh, M., & Connell, L. (2010). Evaluating the probability of indicative conditionals as they are read. Presented to the 51st annual meeting of the Psychonomics Society, St. Louis, 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.
- Thompson, V., & Byrne, R.M.J. (2002). Reasoning about things that didn't happen. *Journal of Experimental Psychology: Learning, Memory, and Cognition*. 28, 1154-1170.

de Vega, M., Urrutia, M., & Rizzo, B. (2007). Cancelling Updating in the Comprehension of Counterfactuals embedded in narratives. *Memory and Cognition*, 35, 1410-1421.

Footnotes

¹ This model predicts that readers can represent the false alternative to a counterfactual utterance when that information is true within the counterfactual remit.

² Note that in contrast to Ferguson and Sanford (2008), the critical sentence used here prompted readers to infer the factual interpretation of the counterfactual context.

³ Note that this critical word would not be semantically anomalous without the preceding context sentence, thus we are examining inferences based on *local* contextual manipulations and not more global reality-violations (as in Ferguson & Sanford, 2008).

Figure 1:

Mean reading times at the critical region (e.g. “dry”/ “wet”) for first fixation duration, first-pass reading time and total reading time (Experiment 1). Error bars show standard errors.

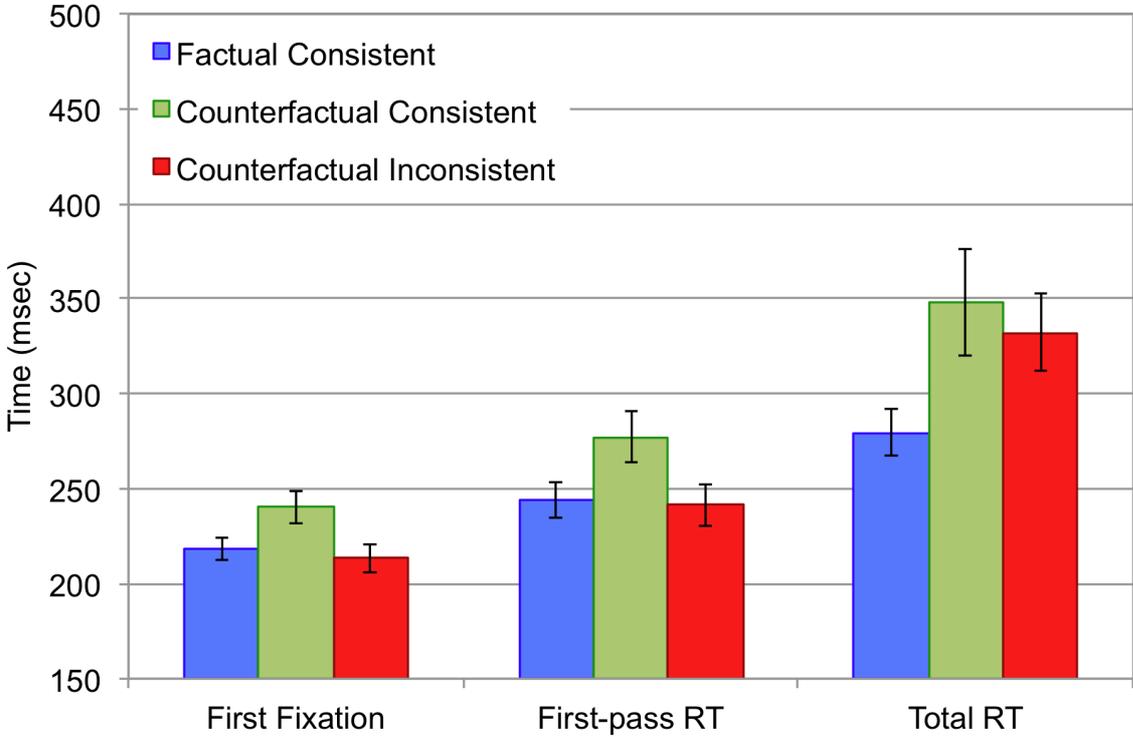


Figure 2:

Mean % first-pass regressions out per region, showing standard error bars (Experiment 1).

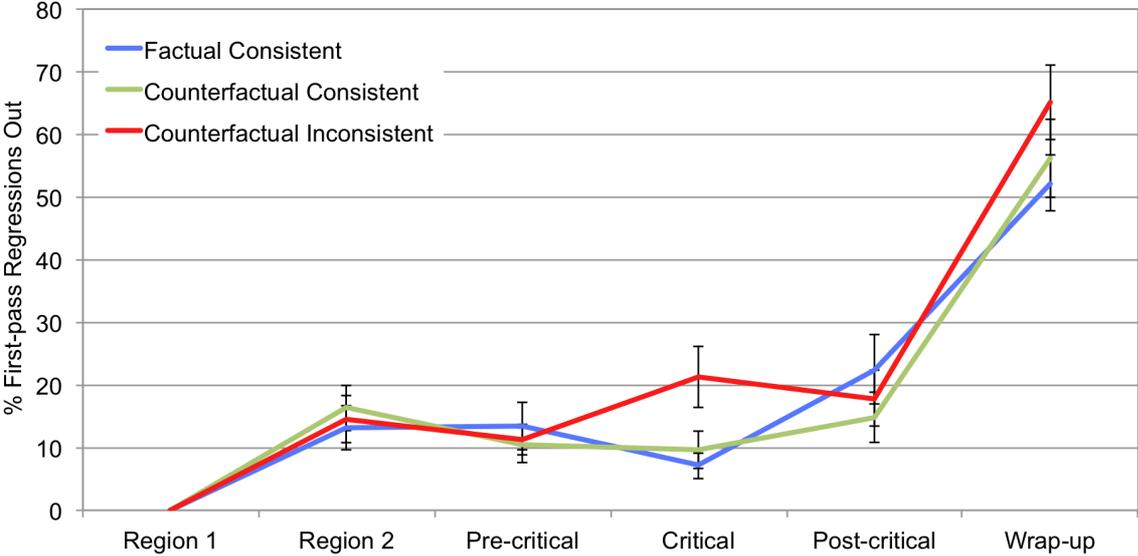


Figure 3:

Mean % regressions in per region, showing standard error bars (Experiment 1).

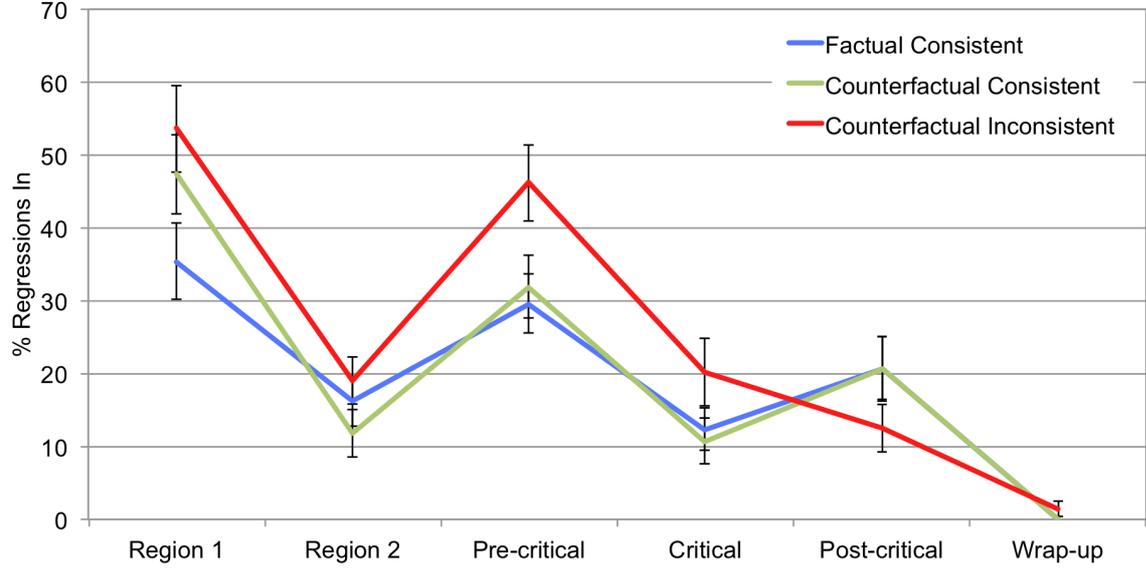


Figure 4:

Mean reading times at the critical region (e.g. “dry”/ “wet”) for first fixation duration, first-pass reading time and total reading time (Experiment 2). Error bars show standard errors.

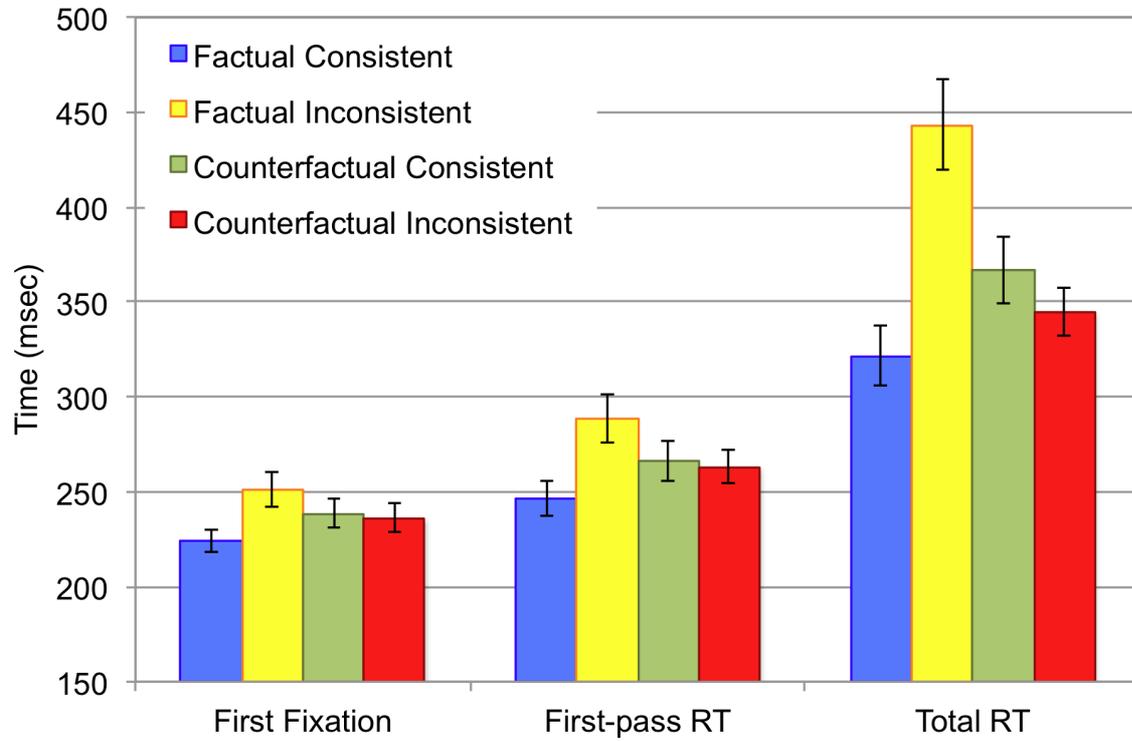


Figure 5:

Mean % first-pass regressions out per region, showing standard error bars (Experiment 2).

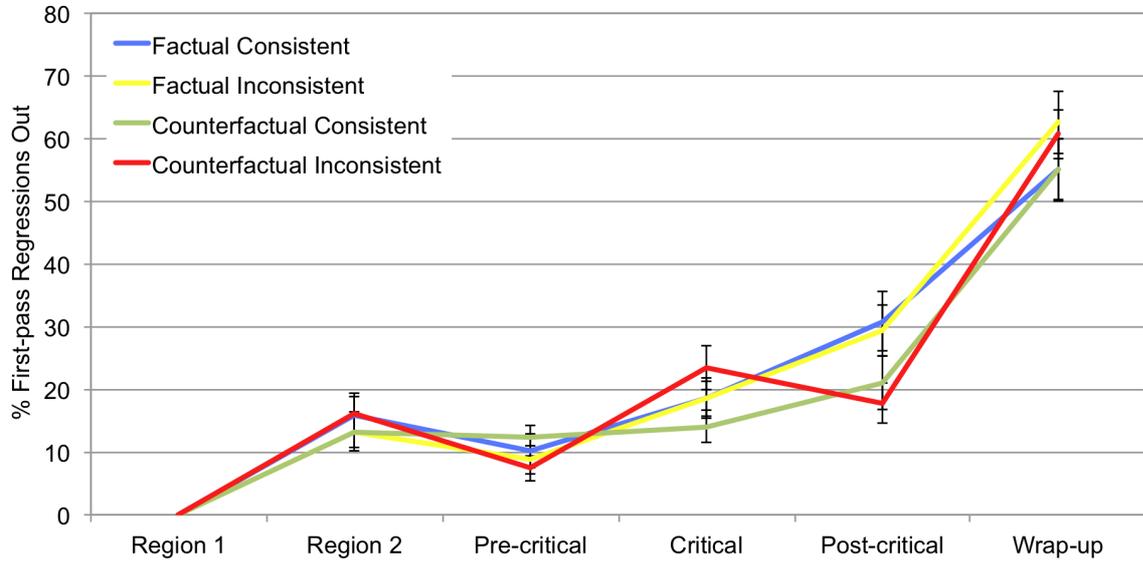


Figure 6:

Mean % regressions in per region, showing standard error bars (Experiment 2).

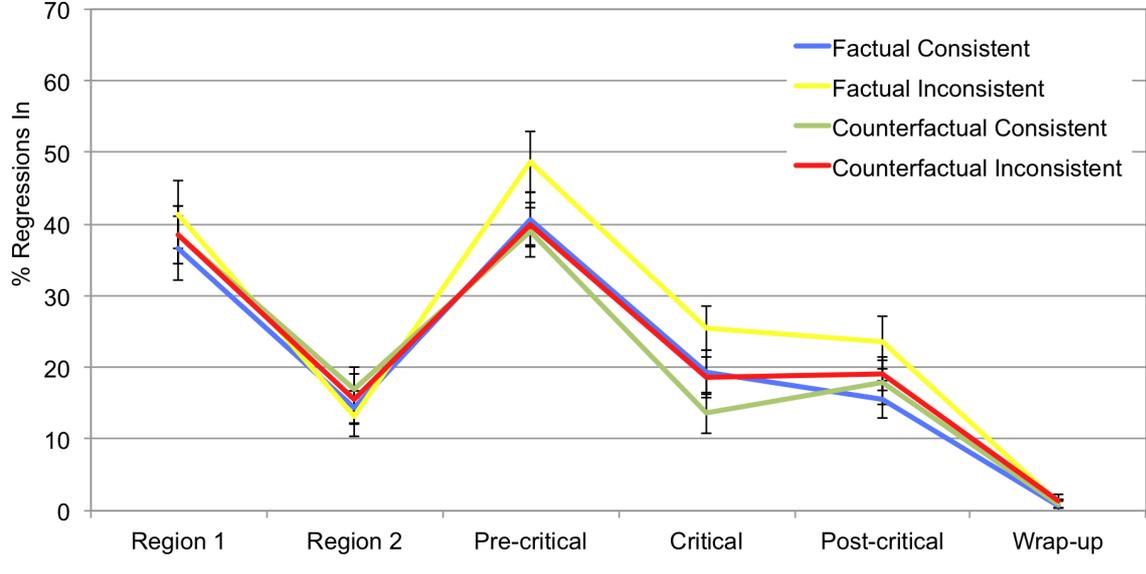


Table 1:

Example item showing regions of analysis (Experiment 1).

Factual Consistent

Because Joanne had remembered her umbrella,₁| she had avoided the rain.₂| By the time she arrived at school Joanne's hair was_{pre-critical}| dry_{critical}| and some_{post-critical}| of her friends laughed._{wrap-up}|

Counterfactual Consistent

If Joanne had remembered her umbrella,₁| she would have avoided the rain.₂| By the time she arrived at school Joanne's hair was_{pre-critical}| wet_{critical}| and some_{post-critical}| of her friends laughed._{wrap-up}|

Counterfactual Inconsistent

If Joanne had remembered her umbrella,₁| she would have avoided the rain.₂| By the time she arrived at school Joanne's hair was_{pre-critical}| dry_{critical}| and some_{post-critical}| of her friends laughed._{wrap-up}|

Table 2:

Mean eye-movement measures per region, showing standard errors in parentheses (Experiment 1).

	Region 1	Region 2	Pre-critical	Critical	Post-critical	Wrap-up
<i>First fixation (msec)</i>						
Factual Consistent	145 (4.7)	237 (9.3)	240 (8.2)	218 (5.8)	220 (11.0)	206 (8.4)
Counterfactual Consistent	153 (6.9)	230 (7.3)	224 (7.9)	240 (8.4)	204 (8.8)	221 (7.8)
Counterfactual Inconsistent	150 (5.4)	227 (6.2)	228 (7.7)	213 (7.2)	227 (8.3)	221 (10.2)
<i>First-pass reading time (msec)</i>						
Factual Consistent	1363 (64.5)	1015 (55.3)	1019 (62.2)	244 (9.4)	253 (18.3)	500 (26.2)
Counterfactual Consistent	1248 (53.3)	1069 (64.5)	985 (68.0)	277 (13.3)	246 (11.4)	490 (33.5)
Counterfactual Inconsistent	1200 (66.2)	1098 (67.9)	974 (60.8)	242 (11.1)	260 (13.4)	517 (29.1)
<i>First-pass regressions out (%)</i>						
Factual Consistent	0 (0)	13.1 (3.5)	13.4 (3.8)	7.1 (2.1)	22.5 (5.5)	52.2 (4.4)
Counterfactual Consistent	0 (0)	16.4 (3.7)	10.4 (2.8)	9.7 (3.1)	14.8 (3.9)	56.1 (6.3)
Counterfactual Inconsistent	0 (0)	14.6 (3.8)	11.2 (2.4)	21.3 (5.0)	17.9 (4.5)	65.1 (5.9)
<i>Total reading time (msec)</i>						
Factual Consistent	1601 (79.0)	1280 (62.8)	1335 (68.8)	280 (12.6)	312 (20.1)	660 (34.7)
Counterfactual Consistent	1623 (101.4)	1367 (72.8)	1338 (83.1)	348 (28.1)	315 (19.5)	615 (42.2)
Counterfactual Inconsistent	1645 (90.8)	1468 (72.0)	1447 (82.0)	332 (20.2)	332 (25.0)	655 (32.2)
<i>Regressions in (%)</i>						
Factual Consistent	35.4 (5.3)	16.2 (3.4)	29.6 (4.0)	12.4 (3.0)	20.7 (4.5)	0 (0)
Counterfactual Consistent	47.4 (5.4)	11.9 (3.3)	31.9 (4.3)	10.7 (3.2)	20.7 (4.4)	0 (0)
Counterfactual Inconsistent	53.6 (6.0)	19.0 (3.2)	46.2 (5.2)	20.2 (4.6)	12.5 (3.2)	1.4 (1)

Table 3:

Example item showing regions of analysis (Experiment 2).

Factual Consistent

Because Joanne had remembered her umbrella,₁| she had avoided the rain.₂| By the time she arrived at school Joanne's hair was_{pre-critical}| dry_{critical}| and some_{post-critical}| of her friends laughed._{wrap-up}|

Factual Inconsistent

Because Joanne had remembered her umbrella,₁| she had avoided the rain.₂| By the time she arrived at school Joanne's hair was_{pre-critical}| wet_{critical}| and some_{post-critical}| of her friends laughed._{wrap-up}|

Counterfactual Consistent

If Joanne had remembered her umbrella,₁| she would have avoided the rain.₂| By the time she arrived at school Joanne's hair was_{pre-critical}| wet_{critical}| and some_{post-critical}| of her friends laughed._{wrap-up}|

Counterfactual Inconsistent

If Joanne had remembered her umbrella,₁| she would have avoided the rain.₂| By the time she arrived at school Joanne's hair was_{pre-critical}| dry_{critical}| and some_{post-critical}| of her friends laughed._{wrap-up}|

Table 4:

Mean eye-movement measures per region, showing standard errors in parentheses (Experiment 2).

	Region 1	Region 2	Pre-critical	Critical	Post-critical	Wrap-up
<i>First fixation (msec)</i>						
Factual Consistent	146 (5.5)	240 (8.6)	241 (6.6)	224 (6.1)	236 (8.9)	243 (7.4)
Factual Inconsistent	147 (4.9)	250 (10.1)	252 (11.6)	251 (9)	235 (10.8)	250 (11.3)
Counterfactual Consistent	157 (6.7)	240 (7.9)	233 (7.6)	239 (7.9)	240 (13)	249 (11.2)
Counterfactual Inconsistent	160 (6.6)	243 (8)	234 (7.7)	236 (7.7)	235 (6.8)	240 (7.9)
<i>First-pass reading time (msec)</i>						
Factual Consistent	1594 (84.7)	627 (30.6)	981 (51.1)	246 (8.9)	286 (17.6)	515 (34.8)
Factual Inconsistent	1562 (60.5)	603 (26.8)	1041 (78.9)	289 (12.9)	305 (16.9)	530 (28.5)
Counterfactual Consistent	1531 (89.8)	656 (35.9)	984 (48.2)	266 (10.3)	266 (15.6)	542 (38.6)
Counterfactual Inconsistent	1455 (75.9)	664 (42.1)	1079 (69.2)	263 (9)	281 (12.7)	542 (40.6)
<i>First-pass regressions out (%)</i>						
Factual Consistent	0 (0)	15.9 (3)	10.1 (2.6)	18.6 (3.2)	30.9 (4.8)	55.1 (4.8)
Factual Inconsistent	0 (0)	13.2 (3.1)	8.8 (2.3)	18.5 (2.7)	29.4 (4.2)	62.6 (5)
Counterfactual Consistent	0 (0)	13.2 (2.5)	12.4 (2)	14.1 (2.6)	21.1 (4.3)	55.1 (5)
Counterfactual Inconsistent	0 (0)	16.1 (3.2)	7.4 (2)	23.5 (3.5)	17.8 (3.1)	60.7 (3.8)
<i>Total reading time (msec)</i>						
Factual Consistent	1863 (98.4)	733 (33.6)	1310 (56.6)	322 (15.9)	384 (25.9)	576 (38.3)
Factual Inconsistent	1922 (81.3)	786 (42.7)	1514 (76.6)	443 (23.6)	433 (25.3)	658 (30.9)
Counterfactual Consistent	1813 (95.9)	775 (53.4)	1299 (51.6)	367 (17.7)	354 (19.7)	658 (47)
Counterfactual Inconsistent	1743 (96.5)	851 (65.8)	1443 (77.7)	345 (12.8)	368 (20.3)	640 (47.7)
<i>Regressions in (%)</i>						
Factual Consistent	36.7 (4.5)	14.4 (2.3)	40.7 (3.7)	19.3 (3.1)	15.5 (2.6)	0.7 (0.7)
Factual Inconsistent	41.3 (4.7)	13.1 (2.7)	48.7 (4.2)	25.5 (3.1)	23.5 (3.7)	1 (0.7)
Counterfactual Consistent	38.5 (4.04)	17 (3.1)	38.9 (3.5)	13.6 (2.8)	17.9 (3.1)	0.9 (0.6)
Counterfactual Inconsistent	38.5 (4.04)	15.6 (3.4)	39.9 (3.1)	18.6 (2.8)	19.1 (2.3)	1.4 (1)

Appendix

Experimental items for Experiments 1 and 2. Note that for each of the items below, conditions are listed in the order: Factual Consistent, Factual Inconsistent (Experiment 2 only), Counterfactual Consistent, and Counterfactual Inconsistent.

1.

Because it had rained this morning Susan had rushed to get to work. In the end, Susan arrived at work early and her colleagues commented on it.

Because it had rained this morning Susan had rushed to get to work. In the end, Susan arrived at work late and her colleagues commented on it.

If it had rained this morning Susan would have rushed to get to work. In the end, Susan arrived at work late and her colleagues commented on it.

If it had rained this morning Susan would have rushed to get to work. In the end, Susan arrived at work early and her colleagues commented on it.

2.

Because Karl had been wearing a jacket, he hadn't minded the long delay. After waiting outside for an hour he now felt warm as he watched the train approach.

Because Karl had been wearing a jacket, he hadn't minded the long delay. After waiting outside for an hour he now felt cold as he watched the train approach.

If Karl had been wearing a jacket, he wouldn't have minded the long delay. After waiting outside for an hour he now felt cold as he watched the train approach.

If Karl had been wearing a jacket, he wouldn't have minded the long delay. After waiting outside for an hour he now felt warm as he watched the train approach.

3.

Because Helen had received her first student loan, her bank balance was now in credit. When she checked her bank balance today she was happy with her financial situation.

Because Helen had received her first student loan, her bank balance was now in credit. When she checked her bank balance today she was worried with her financial situation.

If Helen had received her first student loan, her bank balance would now be in credit. When she checked her bank balance today she was worried with her financial situation.

If Helen had received her first student loan, her bank balance would now be in credit. When she checked her bank balance today she was happy with her financial situation.

4.

Because the flight had been cancelled, all the passengers needed to rearrange their plans. The businessman called his office to say he would arrive late for the meeting.

Because the flight had been cancelled, all the passengers needed to rearrange their plans. The businessman called his office to say he would arrive on-time for the meeting.

If the flight had been cancelled, all the passengers would need to rearrange their plans. The businessman called his office to say he would arrive on-time for the meeting.

If the flight had been cancelled, all the passengers would need to rearrange their plans. The businessman called his office to say he would arrive late for the meeting.

5.

Because Susan had ordered the extra large pizza, she had felt satisfied after her meal. That evening, Susan left the restaurant feeling full and walked home to distract herself.

Because Susan had ordered the extra large pizza, she had felt satisfied after her meal. That evening, Susan left the restaurant feeling hungry and walked home to distract herself.

If Susan had ordered the extra large pizza, she would have felt satisfied after her meal. That evening, Susan left the restaurant feeling hungry and walked home to distract herself.

If Susan had ordered the extra large pizza, she would have felt satisfied after her meal. That evening, Susan left the restaurant feeling full and walked home to distract herself.

6.

Because Emma had repaid her overdraft, her meeting at the bank had gone well. The bank manager told Emma that her account was in credit and she asked for advice on saving.

Because Emma had repaid her overdraft, her meeting at the bank had gone well. The bank manager told Emma that her account was in debit and she asked for advice on saving.

If Emma had repaid her overdraft, her meeting at the bank would have gone well. The bank manager told Emma that her account was in debit and she asked for advice on saving.

If Emma had repaid her overdraft, her meeting at the bank would have gone well. The bank manager told Emma that her account was in credit and she asked for advice on saving.

7.

Because Marc had got into Big Brother, he had been on the cover of all the big magazines. Back then, Marc was a celebrity but still enjoyed spending time with his friends.

Because Marc had got into Big Brother, he had been on the cover of all the big magazines. Back then, Marc was a no-one but still enjoyed spending time with his friends.

If Marc had got into Big Brother, he would have been on the cover of all the big magazines. Back then, Marc was a no-one but still enjoyed spending time with his friends.

If Marc had got into Big Brother, he would have been on the cover of all the big magazines. Back then, Marc was a celebrity but still enjoyed spending time with his friends.

8.

Because Victoria had been a fan of operas, her experience at the show was wonderful. Last night Victoria watched La Boheme and felt excited by the beautiful music.

Because Victoria had been a fan of operas, her experience at the show was wonderful. Last night Victoria watched La Boheme and felt bored by the beautiful music.

If Victoria had been a fan of operas, her experience at the show would have been wonderful. Last night Victoria watched La Boheme and felt bored by the beautiful music.

If Victoria had been a fan of operas, her experience at the show would have been wonderful. Last night Victoria watched La Boheme and felt excited by the beautiful music.

9.

Because Tony had been experienced at public speaking, he had enjoyed the international conference. Yesterday, when Tony gave his talk he felt confident and the audience could tell.

Because Tony had been experienced at public speaking, he had enjoyed the international conference. Yesterday, when Tony gave his talk he felt nervous and the audience could tell.

If Tony had been experienced at public speaking, he would have enjoyed the international conference. Yesterday, when Tony gave his talk he felt nervous and the audience could tell.

If Tony had been experienced at public speaking, he would have enjoyed the international conference. Yesterday, when Tony gave his talk he felt confident and the audience could tell.

10.

Because there hadn't been roadworks on the motorway, Bill's bus had arrived on time. Bill called a friend to say he would be punctual for their planned pub crawl.

Because there hadn't been roadworks on the motorway, Bill's bus had arrived on time. Bill called a friend to say he would be delayed for their planned pub crawl.

If there hadn't been roadworks on the motorway, Bill's bus would have arrived on time. Bill called a friend to say he would be delayed for their planned pub crawl.

If there hadn't been roadworks on the motorway, Bill's bus would have arrived on time. Bill called a friend to say he would be punctual for their planned pub crawl.

11.

Because Joanne had remembered her umbrella, she had avoided the rain. By the time she arrived at school Joanne's hair was dry and some of her friends laughed.

Because Joanne had remembered her umbrella, she had avoided the rain. By the time she arrived at school Joanne's hair was wet and some of her friends laughed.

If Joanne had remembered her umbrella, she would have avoided the rain. By the time she arrived at school Joanne's hair was wet and some of her friends laughed.

If Joanne had remembered her umbrella, she would have avoided the rain. By the time she arrived at school Joanne's hair was dry and some of her friends laughed.

12.

Because Martin is allergic to shellfish, he needs to avoid certain foods. When Martin eats in a restaurant he often chooses chicken and an expensive bottle of wine.

Because Martin is allergic to shellfish, he needs to avoid certain foods. When Martin eats in a restaurant he often chooses prawns and an expensive bottle of wine.

If Martin were allergic to shellfish, he would need to avoid certain foods. When Martin eats in a restaurant he often chooses prawns and an expensive bottle of wine.

If Martin were allergic to shellfish, he would need to avoid certain foods. When Martin eats in a restaurant he often chooses chicken and an expensive bottle of wine.

13.

Because Take That had been performing at Glastonbury, Edward had sold his ticket. In the end, Edward was happy to have missed the festival despite the weather.

Because Take That had been performing at Glastonbury, Edward had sold his ticket. In the end, Edward was happy to have been at the festival despite the weather.

If Take That had been performing at Glastonbury, Edward would have sold his ticket. In the end, Edward was happy to have been at the festival despite the weather.

If Take That had been performing at Glastonbury, Edward would have sold his ticket. In the end, Edward was happy to have missed the festival despite the weather.

14.

Because Sofia had told the truth she hadn't been in trouble with her boss. Now it looked like Sofia was going to be promoted and her colleagues were relieved.

Because Sofia had told the truth she hadn't been in trouble with her boss. Now it looked like Sofia was going to be fired and her colleagues were relieved.

If Sofia had told the truth she wouldn't have been in trouble with her boss. Now it looked like Sofia was going to be fired and her colleagues were relieved.

If Sofia had told the truth she wouldn't have been in trouble with her boss. Now it looked like Sofia was going to be promoted and her colleagues were relieved.

15.

Because the crime had been caught on CCTV, the prosecution had won the court case. The lawyers watched as the accused was imprisoned then discussed the situation with the press.

Because the crime had been caught on CCTV, the prosecution had won the court case. The lawyers watched as the accused was released then discussed the situation with the press.

If the crime had been caught on CCTV, the prosecution would have won the court case. The lawyers watched as the accused was released then discussed the situation with the press.

If the crime had been caught on CCTV, the prosecution would have won the court case. The lawyers watched as the accused was imprisoned then discussed the situation with the press.

16.

Because Stephen had been old enough, he had no problems buying alcohol. When Stephen went to his local off licence he was allowed to buy anything.

Because Stephen had been old enough, he had no problems buying alcohol. When Stephen went to his local off licence he was refused to buy anything.

If Stephen had been old enough, he would have had no problems buying alcohol. When Stephen went to his local off licence he was refused to buy anything.

If Stephen had been old enough, he would have had no problems buying alcohol. When Stephen went to his local off licence he was allowed to buy anything.

17.

Because Sally had been an accomplished skier, she hadn't had an accident. Now Sally boarded the flight home with no problems and hoped to fall asleep quickly.

Because Sally had been an accomplished skier, she hadn't had an accident. Now Sally boarded the flight home with crutches and hoped to fall asleep quickly.

If Sally had been an accomplished skier, she wouldn't have had an accident. Now Sally boarded the flight home with crutches and hoped to fall asleep quickly.

If Sally had been an accomplished skier, she wouldn't have had an accident. Now Sally boarded the flight home with no problems and hoped to fall asleep quickly.

18.

Because Andy had revised diligently, he had passed the exam first time round. Now Andy was preparing to celebrate over the Summer holidays.

Because Andy had revised diligently, he had passed the exam first time round. Now Andy was preparing to resit over the Summer holidays.

If Andy had revised diligently, he would have passed the exam first time round. Now Andy was preparing to resit over the Summer holidays.

If Andy had revised diligently, he would have passed the exam first time round. Now Andy was preparing to celebrate over the Summer holidays.

19.

Because Helen had watered her plants every day, they had bloomed throughout the Summer. Helen's neighbours commented that they were impressed with the garden.

Because Helen had watered her plants every day, they had bloomed throughout the Summer. Helen's neighbours commented that they were disappointed with the garden.

If Helen had watered her plants every day, they would have bloomed throughout the Summer. Helen's neighbours commented that they were disappointed with the garden.

If Helen had watered her plants every day, they would have bloomed throughout the Summer. Helen's neighbours commented that they were impressed with the garden.

20.

Because Elaine's car had passed its MOT, it had been deemed safe to be driven on the roads. Last week the police stopped Elaine in her car and were satisfied to let her continue home.

Because Elaine's car had passed its MOT, it had been deemed safe to be driven on the roads. Last week the police stopped Elaine in her car and were unwilling to let her continue home.

If Elaine's car had passed its MOT, it would have been deemed safe to be driven on the roads. Last week the police stopped Elaine in her car and were unwilling to let her continue home.

If Elaine's car had passed its MOT, it would have been deemed safe to be driven on the roads. Last week the police stopped Elaine in her car and were satisfied to let her continue home.

21.

Because Isobel had been on a diet for the last 6 months, she had lost a lot of weight. Isobel now buys her clothes in a size small but her husband gets upset at the cost.

Because Isobel had been on a diet for the last 6 months, she had lost a lot of weight. Isobel now buys her clothes in a size large but her husband gets upset at the cost.

If Isobel had been on a diet for the last 6 months, she would have lost a lot of weight. Isobel now buys her clothes in a size large but her husband gets upset at the cost.

If Isobel had been on a diet for the last 6 months, she would have lost a lot of weight. Isobel now buys her clothes in a size small but her husband gets upset at the cost.

22.

Because Alison had received a bonus, she had got very drunk at the office Christmas party. The next morning Alison had woken up feeling hungover and looked forward to the festive break.

Because Alison had received a bonus, she had got very drunk at the office Christmas party. The next morning Alison had woken up feeling refreshed and looked forward to the festive break.

If Alison had received a bonus, she would have got very drunk at the office Christmas party. The next morning Alison had woken up feeling refreshed and looked forward to the festive break.

If Alison had received a bonus, she would have got very drunk at the office Christmas party. The next morning Alison had woken up feeling hungover and looked forward to the festive break.

23.

Because Bill had trained thoroughly, he had completed this year's London marathon. The following day Bill felt delighted with his efforts.

Because Bill had trained thoroughly, he had completed this year's London marathon. The following day Bill felt frustrated with his efforts.

If Bill had trained thoroughly, he would have completed this year's London marathon. The following day Bill felt frustrated with his efforts.

If Bill had trained thoroughly, he would have completed this year's London marathon. The following day Bill felt delighted with his efforts.

24.

Because the racing driver had won the last race, he had won the season's championship title. That evening, the racing driver's team celebrated with him at the pub.

Because the racing driver had won the last race, he had won the season's championship title. That evening, the racing driver's team commiserated with him at the pub.

If the racing driver had won the last race, he would have won the season's championship title. That evening, the racing driver's team commiserated with him at the pub.

If the racing driver had won the last race, he would have won the season's championship title. That evening, the racing driver's team celebrated with him at the pub.