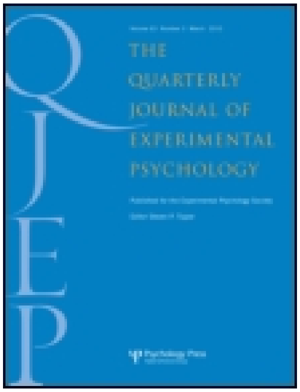

The Quarterly Journal of Experimental Psychology

Publication details, including instructions for authors and subscription information:
http://www.tandfonline.com/loi/pqje20

Because *there* was a cause for concern: An investigation into a word-specific prediction account of the implicit-causality effect

Cara R. Featherstone [a] & Patrick Sturt [b]

[a] Institute of Psychological Sciences, University of Leeds, Leeds, UK

[b] The School of Philosophy Psychology and Language Sciences, The University of Edinburgh, Edinburgh, UK

Available online: 30 Jun 2011

THE QUARTERLY JOURNAL OF EXPERIMENTAL PSYCHOLOGY
2010, 63 (1), 3–15

Rapid Communication

Because *there* was a cause for concern: An investigation into a word-specific prediction account of the implicit-causality effect

Cara R. Featherstone
Institute of Psychological Sciences, University of Leeds, Leeds, UK

Patrick Sturt
The School of Philosophy Psychology and Language Sciences, The University of Edinburgh, Edinburgh, UK

In Koornneef and Van Berkum's (2006) eye-tracking study of implicit causality (Caramazza, Grober, Garvey, & Yates, 1977), midsentence delays were observed in the processing of sentences such as "*David blamed Linda because she*$_{\text{(bias-congruent)}}$/*he*$_{\text{(bias-incongruent)}}$ ... " when the pronoun following *because* was incongruent with the bias of the implicit-causality verb. The authors suggested that these immediate delays could be attributed to participants predicting a bias-congruent pronoun after *because*. According to this explanation, any other word placed after *because* should cause processing delays. The present investigation aimed to test this explanation by using sentences of the form "*David blamed Linda because she*$_{\text{(bias-congruent)}}$/*he*$_{\text{(bias-incongruent)}}$/*there*$_{\text{(bias-neutral)}}$ ... ". Since significant immediate delays were observed in sentences containing a bias-incongruent pronoun (relative to a bias-congruent pronoun) but not in sentences containing *there*, the results of this study support an immediate integration effect but pose a problem to the word-specific prediction account of the implicit causality effect.

Keywords: Language; Implicit causality; Prediction; Focus.

The term implicit causality was first used by Caramazza, Grober, Garvey, and Yates (1977) to describe verbs such as *praise* and *amuse*, which "supply information about whose behaviour or state is the more likely immediate cause of the event at hand" (Koornneef & Van Berkum, 2006, p. 446). This information, intrinsic to the verb itself (Crinean & Garnham, 2006), is the basis upon which readers are able to assume that if John praised Mary, it was because of something Mary did, but that, on the other hand, if John amused Mary, it was because of something John

Correspondence should be addressed to Cara Featherstone, Institute of Psychological Sciences, University of Leeds, Leeds LS2 9JT, UK. E-mail: c.r.featherstone03@leeds.ac.uk
This experiment was funded by a University of Edinburgh UK/EU Master's Scholarship.

http://www.psypress.com/qjep
DOI:10.1080/17470210903134344

did. These lexical biases have been found to affect online comprehension behaviour: Sentences containing bias-incongruent pronouns (i.e., *John amused Mary because* she *had somehow always appreciated his strange sense of humour*) are read more slowly than sentences containing bias-congruent pronouns (i.e., *John amused Mary because* he *had somehow always had a good sense of humour*; Koornneef & Van Berkum, 2006; Stewart, Pickering, & Sanford, 2000).

There has been considerable debate about the time-course of the use of implicit causality information. According to the *integration* account (Garnham, 2001; Stewart et al., 2000), causality information is used relatively late in sentence processing, when the contents of the two relevant clauses are integrated into a unified interpretation. In contrast, according to the *focusing* account (Greene & Mckoon, 1995; Long & De Ley, 2000), causality information is used immediately by the comprehender to facilitate the processing of the rest of the sentence.

In a recent paper, Koornneef and Van Berkum (2006) report a self-paced reading experiment and an eye-tracking experiment, which both show evidence for an early use of implicit causality information. Their study compared Dutch equivalents of sentences such as 1a and 1b:

1a. David apologized to Linda because he according to the witnesses was the one to blame.
1b. Linda apologized to David because he according to the witnesses was not the one to blame.

In 1a and 1b, the verb *apologized* is an NP1-biased verb (where NP is noun phrase), meaning that in the active voice it has a bias for the cause to be interpreted in relation to the subject argument (i.e., *David* in 1a, or *Linda* in 1b). Thus, the gender of the pronoun is bias congruent in 1a and bias incongruent in 1b. In both experiments, readers slowed down at, or soon after, the pronoun in the incongruent condition relative to the congruent condition. For example, in the eye-tracking experiment, this slowdown was found on the pronoun itself for regression path time and three words after the pronoun for gaze duration. Koornneef and Van Berkum (2006) constructed their stimuli so that the five words immediately following the critical pronoun were identical across congruency conditions, and the end of the *because*-clause only occurred several words downstream of these five words. Kornneef and Van Berkum (2006) therefore argued against the integration account, which would have predicted much later effects of congruency.

Given this support for early implicit causality effects, it is important to consider the various possible underlying cognitive mechanisms. The *focusing* account (e.g., Mckoon, Greene, & Ratcliff, 1993) explains the effect in terms of the relative salience of the two discourse referents. According to this explanation, when people process a clause that includes a causality-biased verb, the discourse referent congruent with that verb's bias is more prominent in the discourse representation than other arguments in the clause. Thus, for an NP1-biased verb in active voice, such as *apologized*, the subject of the clause (e.g., *David* in 1a) will be represented more prominently than the object (e.g., *Linda* in 1a); for an NP2-biased verb (such as *blamed*), the reverse will be true. The processing cost for a noncongruent pronoun can then be explained in terms of the difficulty of accessing the less prominent referent, or the cost of inhibiting the more prominent referent, or both.

However, Koornneef and Van Berkum (2006) argue that early causality effects could also be explained in other ways. One possible explanation that they discuss is based on the idea that discourse comprehension involves the active *prediction* of discourse referents, a claim that is consistent with Arnold's (2001) *expectancy hypothesis*. According to this explanation, when a reader processes a clause that includes a causality-biasing verb, a prediction is made that the individual corresponding to the preferred argument will be referred to in the subsequent clause. If an alternative individual is referred to instead, this will cause processing difficulty, due to the fact that the prediction is not satisfied. Kornneef and Van Berkum (2006) discuss two possible forms that such a prediction mechanism may take, which we call the *referential prediction account* and the *word-based prediction account*, respectively. According to the *referential prediction account* the processor predicts simply that a reference will be made to a particular individual, but no commitment will be made to the form that this reference may take, or where in the sentence this reference will occur. We return to discuss the referential prediction account in more detail in the Discussion section, where we argue that it is actually compatible with the focusing account. The second predictive account is the *word-based prediction account*, which involves a much stronger claim—namely, that an actual word form is predicted in a particular position in the sentence. So, for example in 1a the specific word form *he* would be predicted as the word following *because*, and any other word in this position in the sentence would be incompatible with this prediction.

The idea that the processor predicts specific words in specific sentence positions is consistent with recent evidence reported by DeLong, Urbach, and Kutas (2005), who recorded event-related potentials (ERPs) while people read sentences like 2a and 2b:

2a. The day was breezy so the boy went outside to fly a kite.
2b. The day was breezy so the boy went outside to fly an airplane.

A prior norming study had established a preferred continuation for *kite*, as in 2a. DeLong et al. (2005) predicted that processing difficulty should be found at the indefinite article *an* in 2b, because in English, this form of the article only occurs when the following word begins with a vowel, but the predicted word *kite* begins with a consonant. An N400 effect was indeed found at *an* in 2b compared with 2a, showing that participants were anticipating the phonological form of the expected word *kite*, when they were reading the indefinite article. Similar evidence of word-specific prediction has been found by manipulating gender congruency of articles in Spanish (Wicha, Bates, Morenoa, & Kutas, 2003) and adjectives in Dutch (Van Berkum, Brown, Zwitserlood, Koojman, & Hagoort, 2005). However, the DeLong et al. (2005) evidence is particularly striking as it shows that the expectation applies to a specific word position—namely, that of the word immediately following the article (the *a*/*an* alternation), which is specifically sensitive to the immediately following word.

In the light of this type of evidence, it is reasonable to hypothesize that implicit causality congruency effects may be driven by word-based prediction. However, as Koornneef and Van Berkum (2006) acknowledge, current available evidence does not allow us to decide whether causality effects arise as a result of focusing mechanisms, word-based prediction, or the more general prediction of referential mention. The experiment reported below aims specifically to test the strongest of these claims—namely, the word-based prediction hypothesis.

EXPERIMENT

The experiment reported here had two aims: first to replicate the early congruency effect reported by Koornneef and Van Berkum (2006), and secondly to establish whether or not this effect is driven by the word-specific prediction of a congruent pronoun. We assume that the word-specific prediction account involves the prediction of a congruent pronoun immediately following the word *because*, in a mechanism analogous to that reported by DeLong et al. (2005). Given this assumption, immediate processing difficulty should be found if any word other than a congruent pronoun is found immediately following *because*. To test the hypothesis, it is necessary to examine the effect of processing a word that is not only different from the predicted congruent pronoun, but also neutral with respect to referential processing and thus not predicted to cause difficulty according to the focusing account. The first three of our experimental conditions therefore include a causality-biasing context followed by a *because*-clause, in which the word immediately following *because* was manipulated by condition and could be a congruent pronoun, an incongruent pronoun, or the word *there* (as in 4a, 4b, and 4c).

Since the critical word in these three conditions always *follows* the biasing verb, we call these the *postbias* conditions.

4a. *Congruent pronoun/postbias*
Ryan charmed Emma, because he had recently been much more well-behaved, and seemed to have become a gentleman.

4b. *Incongruent pronoun/postbias*
Emma charmed Ryan, because he had recently been much more attracted to women with great personalities.

4c. *There/postbias*
Ryan charmed Emma, because there had recently been much more romance in their otherwise unremarkable relationship.

We note that any direct comparison between 4c and 4b (or between 4c and 4a) would be difficult to interpret, because lexical and semantic differences could affect processing between conditions, regardless of any word-specific predictions arising from the causality-biasing context. For example, the word *there* differs in length and frequency from the pronoun, and existential sentences might be processed differently from nonexistential sentences. For this reason, our experiment contained two baseline conditions, which presented the *because*-clause without a biasing context by preposing the *because*-clause into sentence-initial position (as in 4d and 4e). Since the critical word in these conditions comes before the biasing verb, we call these the *prebias* conditions.

4d. *Pronoun/prebias*
Because he had recently been much more well-behaved, and seemed to have become a gentleman, Ryan charmed Emma.

4e. *There/prebias*
Because there had recently been much more romance in their otherwise unremarkable relationship, Ryan charmed Emma.

These baseline conditions allowed us to test whether any slowdown for the *there* condition (4c) was due to the preceding biasing context (as would be predicted by the word-specific prediction account), or to irrelevant lexical or semantic characteristics of the *because*-clause.

Method

Participants

A total of 50 native speakers of British English (16 males), aged 16 to 43 years (mean age 22.47), recruited from the University of Edinburgh community, were paid to participate in the experiment. None had any diagnosed reading impairments or learning difficulties.

Materials and design

There were 50 experimental items, each of which appeared in the five conditions illustrated in 4a–4e above. Half of the items used an NP1-biased verb (e.g., *charmed*), and half used an NP2-biased verb (e.g., *fired*), and no verbs were repeated between items. The pronoun was kept identical across pronoun conditions, and the bias manipulation was made by changing the order of the two names in the main clause, one of which was always male, and the other always female. The main clause continuation in the prebias conditions was chosen so that the name in the main clause subject position agreed with the gender of the preceding pronoun. Thus, the pronoun prebias conditions were always congruent with the causality bias for the NP1-biased items and incongruent for the NP2-biased items. However, since the main focus of the current eye-movement study is on the first-pass measures, this difference could not affect the crucial results for the prebias conditions. As in Koornneef and Van Berkum's (2006) study, the five words following the pronoun were kept identical across all conditions, to accommodate for any spillover effects, but the ends of the main clause differed between the congruent, incongruent, and *there* conditions to allow for coherent sentences.

The 25 NP1- and 25 NP2-biased verbs were selected on the basis of a prior norming study administered to 50 native British English speakers (21 males) aged 16 to 32 years (mean age, 22.54). This study tested 120 candidate verbs, using a sentence completion task. Participants completed sentences such as "*John amused Mary because* . . .". Completions therefore started with a pronoun referring to the first NP (*John*), a pronoun referring to the second NP (*Mary*), or another continuation (e.g., . . . *because the joke was hilarious*).

Sentence continuations were analysed on a frequency basis, categorizing responses as "NP1 pronoun continuation", "NP2 pronoun continuation", and "other". The average percentages of types of continuations of the verbs retained for the eye-tracking experiment were as follows: preferred pronoun: 87.12% (NP1: 85.28%; NP2: 88.96%); nonpreferred pronoun: 6.24% (NP1: 7.52%, NP2: 4.96%); other: 6.64% (NP1: 7.04%, NP2: 6.24%). None of these thee response categories differed as a function of verb bias (Mann Whitney, all ps $> .1$).

In order to guarantee a meaningful analysis of the data across the five conditions, two different experimental designs were incorporated in the experiment. Koornneef and Van Berkum's (2006) crucial comparison would correspond in the current study to a comparison between the congruent and incongruent postbias conditions. We wanted to compare these two conditions alongside the postbias *there* condition, so the first design was equivalent to a one-way analysis of variance (ANOVA) comparing these three postbias conditions.

The second design was used to determine the source of any processing difficulty for *there* relative to the congruent pronoun in the prebias conditions. In cases where *there* was read slowly relative to the congruent pronoun in postbias conditions, the difference between *there* and the congruent pronoun was compared to the equivalent difference for the two prebias conditions. If *there* is difficult to process because of the causality-biasing context, as predicted by the word-specific prediction account, then the difference between *there* and the congruent pronoun should be greater in the postbias conditions than in the prebias conditions, where there has been no causality-biasing context. These differences were compared in the interaction test of a 2×2 ANOVA, treating clause position (prebias vs. postbias) and word (pronoun vs. *there*) as the two variables. Note that the main effect of word in this 2×2 ANOVA also allows us to test for any general differences between sentences containing *there* and sentences containing pronouns.

Procedure

A total of 100 filler sentences were added to the experimental stimuli, incorporating a wide range of sentence types. To ensure that participants paid attention to the sentences, simple comprehension questions were included after 20% of both experimental and filler items. Participants were required to choose between two potential answers displayed below each question on the same screen by pressing the appropriate button on a game pad. Subsequent analysis showed that comprehension performance was good, with a mean accuracy of 91% and all participants scoring over 81%.

The stimuli were distributed across five Latin-square counterbalanced lists, such that each list contained exactly one condition from each of the 50 items, and all conditions of all items were represented across the five lists. The stimuli were presented in a unique pseudorandom order for each participant, such that no two experimental items appeared adjacent to each other.

Stimuli were presented on a 21-inch CRT display screen, and participants' eye movements were recorded using an SR Research Eyelink 1000 eyetracker. A chin-rest was used to minimize head movements. Eye movements were recorded from the right eye, although viewing was binocular. The monitor was situated 81 cm from the participants' eyes.

Sentences were displayed in Times New Roman 18 point on the screen with a maximum of two lines per sentence. Following a successful calibration, participants completed three practice trials before the experiment began. Each trial began with a gaze trigger box, which appeared in the position of the first character of the text. When the gaze box had been successfully fixated, it was replaced by the full stimulus text. If the gaze trigger became inaccurate, the participant was recalibrated. Participants pressed a button on the game pad to end the display. Each session lasted approximately 30 minutes.

Data analysis

An automatic procedure pooled short contiguous fixations. Fixations below 80 ms were merged with any adjacent fixations within a distance of one character. Any remaining fixations below 80 ms were deleted. Readers do not extract much useful information from such short fixations (Rayner & Pollatsek, 1989). Fixations above 1,200 ms were also deleted, as they usually indicate tracker loss. Together, these two cut-offs resulted in the removal of 2% of the fixations. Fixations of 120 ms or less were also deleted if they immediately preceded or followed a blink.

Eye-movement data for seven regions were analysed. The "because" region consisted of the word *because.* Note that in the prebias baseline conditions, this region corresponds to the first word of the sentence. The "critical" region (cr) consisted of the critical pronoun or *there*. Regions "critical + 1" to "critical + 5" consisted of the five words immediately following the critical region (see Table 1). These analysis regions were chosen to allow maximum comparability with Koornneef and Van Berkum's (2006) study, which also analysed each of the five words immediately following the pronoun.

Results

Below, we report data for *first-pass reading times* (the sum of fixation durations from the first entry into the region from the left to the first exit of the region, either to the left or to the right), and for *regression path times* (the sum of all fixations from the first entry into the region from the left, until the first fixation to a later region). These two measures are crucial for evaluating the word-specific prediction hypothesis, because they are informative about processing load immediately following the reader's first encounter of the relevant word. In cases where this relevant word differs from what is predicted, it is assumed that processing difficulty will manifest itself relatively early in processing. As well as the word-by-word measures of early processing described above, we also report *total times* for the single pooled region of text encompassing the critical word (pronoun or *there*), plus the following five words. This total time measure consists of the summed duration of all fixations in the region and serves as an indication of the general patterns of processing difficulty that readers encountered across the region. For all of these measures, trials where the analysis region did not receive any relevant fixation were not included in the analysis.

For each eye-movement measure, and for each analysis region, we computed two statistical comparisons, which are referred to below as the *main comparison* and the *baseline comparison*. The main comparison was an analysis of the three postbias conditions. The standard implicit causality effect should manifest itself in the postbias conditions as a processing cost for the incongruent pronoun relative to the congruent pronoun. Additionally, if the delays observed by Koornneef and Van Berkum (2006) are attributable to word-specific predictions, the *there* condition should also cause

Table 1. *Regions used per condition in the analysis of eye-tracking data*

	Region						
Condition	*because*	*critical*	*cr + 1*	*cr + 2*	*cr + 3*	*cr + 4*	*cr + 5*
Congruent/postbias	...because	he	had	recently	been	much	more
Incongruent/postbias	...because	he	had	recently	been	much	more
There/postbias	...because	there	had	recently	been	much	more
Pronoun/prebias	Because	he	had	recently	been	much	more
There/prebias	Because	he	had	recently	been	much	more

Note: Using Examples 4a–4e.

processing difficulty relative to the congruent pronoun condition.

The baseline comparison was designed to measure any relative difficulty for the postbias *there* condition, relative to a prebias baseline. This analysis compared four conditions: (a) the postbias congruent pronoun condition; (b) the postbias *there* condition; (c) the prebias pronoun condition; and (d) the prebias *there* condition. The conditions were analysed as a 2×2 design, with factors *word* (*there* vs. pronoun) and *position* (prebias vs. postbias). The processing of sentences including *there* may differ from sentences including pronouns for a number of reasons, including those that are unrelated to the question of prediction. However, by comparing the critical postbias conditions with the prebias baseline, we can determine which of these differences arise as a result of the causality context. The word-specific prediction account predicts an interaction in the baseline comparison: The difficulty for *there* relative to the (congruent) pronoun should be greater for the postbias conditions than for the prebias conditions, because only in the postbias case is there a preceding context that could lead to an unsatisfied word-specific prediction based on causality information.

In addition to the above, we also analysed the (between-items) factor of verb bias (NP1 vs. NP2), as well as all interactions of verb bias with the other factors. Thus, the main comparison resulted in a 3×2 design, Congruency (congruent vs. incongruent vs. *there*) $\times$ Bias (NP1 vs. NP2), and the baseline comparison resulted in a $2 \times 2 \times 2$ design, Word (pronoun vs. *there*) $\times$ Position (prebias vs. postbias) $\times$ Bias (NP1 vs. NP2).

The above analyses were conducted using linear mixed effects regression (LMER; Baayen, 2008; Baayen, Davidson, & Bates, 2008). The advantage of LMER is that it is relatively robust against sparse data. This is an important consideration in eye-tracking data involving single word regions, where high skipping rates can often lead to missing design cells, a situation that leads to problems in ANOVA and related techniques. Significance levels for main effects and interactions are evaluated using a log-likelihood χ^2 test, measuring the decrease in goodness of fit associated with removing the relevant effect from the LMER model. All analyses reported below include crossed random intercepts for participants and items.[1] Where relevant and of theoretical interest, tests of main effects and interactions were followed up with pairwise comparisons based on 95% confidence intervals derived from the LMER model.[2]

Reliable fixation data are not available for the prebias conditions in the precritical region (i.e., the word *because*). This was the first word of the sentence in those conditions, and the first fixation of the trial (which overlaps with the display of the gaze trigger) is not recorded by the software. Thus, we report neither means nor statistical analyses involving this word in the prebias conditions.

First-pass reading times

Mean first-pass reading times for all analysis regions are reported in Table 2, and results of significance tests are reported in Table 3.

In the main comparison, the only significant effect was a main effect of congruence in the word immediately following the pronoun (cr + 1). Replicating previous studies, the incongruent condition received longer reading times than the congruent condition (estimated mean difference = 17 ms; 95% confidence interval, CI = $\pm$15 ms; $p < .05$). However, the difference between the congruent pronoun and *there* was not reliable (estimated mean difference = 8 ms; 95% CI = $\pm$16 ms). This congruency effect did not interact with verb bias. Moreover, there were no reliable interactions between word and position in the baseline comparison.

[1] The pattern of results was not changed by adding random slopes to the model. Moreover, in nearly all cases, the added complexity of such models failed to result in a significant improvement in model fit. Thus the present analyses are based on random intercepts only.

[2] Confidence intervals were computed in R using the pvals.fnc function provided in the LanguageR package (see Baayen, 2008; Baayen et al., 2008).

Table 2. *Means for first-pass reading times*

		because (cr − 1)		*he* (cr)		*had* (cr + 1)		*recently* (cr + 2)		*been* (cr + 3)		*much* (cr + 4)		*more* (cr + 5)	
	Verb bias	*NP1*	*NP2*	*NP1*	*NP2*	*NP1*	*NP2*	*NP1*	*NP2*	*NP1*	*NP2*	*NP1*	*NP2*	*NP1*	*NP2*
Postbias	Congruent	252	239	244	236	234	252	271	268	245	252	274	241	255	241
	Incongruent	248	248	248	235	276	263	255	281	260	260	252	246	259	262
	There	255	252	244	223	245	238	257	256	255	253	244	256	264	239
Prebias	Pronoun			226	226	246	248	239	252	257	254	249	246	254	248
	There			215	224	223	229	239	241	243	253	248	245	252	265

Note: NP = noun phrase. Reading times in ms.

Table 3. *Results of statistical analysis for first-pass reading times*

Comparison			*because* (cr − 1)	*he* (cr)	*had* (cr + 1)	*recently* (cr + 2)	*been* (cr + 3)	*much* (cr + 4)	*more* (cr + 5)
Main	Congruency	$\chi^2(2)$	1.60	1.59	10.51**	2.29	2.08	0.89	0.98
	Verb bias	$\chi^2(1)$	1.40	3.37+	1.30	0.21	0.00	0.26	0.53
	Cong × Bias	$\chi^2(2)$	1.32	0.57	0.18	4.35	0.20	4.68+	2.73
Baseline	Word	$\chi^2(1)$		1.44	7.35**	2.56	0.09	0.40	0.45
	Verb bias	$\chi^2(1)$		0.07	0.00	0.04	0.02	0.46	0.55
	Position	$\chi^2(1)$		6.85**	2.47	11.86***	0.04	0.86	0.11
	Bias × Word	$\chi^2(1)$		0.01	0.00	0.15	0.08	2.00	0.39
	Bias × Position	$\chi^2(1)$		3.58+	0.58	1.09	0.13	0.01	2.60
	Word × Position	$\chi^2(1)$		0.05	1.51	0.29	1.16	0.39	0.11
	Word × Pos × Bias	$\chi^2(1)$		1.02	0.11	0.06	0.57	2.57	1.05

$^{+}p < .1$. $^{*}p < .05$. $^{**}p < .01$. $^{***}p < .001$.

Table 4. *Means for regression path times*

		because (cr − 1)		*he* (cr)		*had* (cr + 1)		*recently* (cr + 2)		*been* (cr + 3)		*much* (cr + 4)		*more* (cr + 5)	
	Verb bias	*NP1*	*NP2*	*NP1*	*NP2*	*NP1*	*NP2*	*NP1*	*NP2*	*NP1*	*NP2*	*NP1*	*NP2*	*NP1*	*NP2*
Postbias	Congruent	325	259	278	268	293	283	325	343	292	303	328	350	338	335
	Incongruent	299	285	274	267	317	295	319	384	321	339	302	335	307	401
	There	289	275	291	241	292	294	331	353	393	352	317	295	349	359
Prebias	Pronoun			240	242	278	274	310	341	290	317	302	379	344	331
	There			236	231	274	275	322	340	324	382	318	350	346	333

Note: NP = noun phrase. Path times in ms.

Regression path times

Table 4 shows mean regression path times per region, and Table 5 shows the statistical analyses.

In the regression path measure, there was a numerical trend consistent with the first-pass congruency effect at the word following the pronoun (cr + 1); however, this did not reach significance,

Table 5. *Results of statistical analysis for regression path times*

Comparison			*because* (cr − 1)	*he* (cr)	*had* (cr + 1)	*recently* (cr + 2)	*been* (cr + 3)	*much* (cr + 4)	*more* (cr + 5)
Main	Congruency	$\chi^2(2)$	0.44	0.35	1.37	1.76	11.18**	1.32	0.46
	Verb bias	$\chi^2(1)$	7.20**	5.85*	0.72	2.51	0.05	0.39	1.09
	Cong × Bias	$\chi^2(2)$	4.20	3.11	0.34	2.37	1.97	1.05	5.30+
Baseline	Word	$\chi^2(1)$		1.22	0.01	0.36	15.60***	0.57	0.15
	Verb bias	$\chi^2(1)$		2.82+	0.09	1.25	0.22	1.61	0.05
	Position	$\chi^2(1)$		16.09***	2.81 +	0.45	0.17	0.62	0.07
	Bias × Word	$\chi^2(1)$		1.29	0.43	0.01	0.10	1.81	0.28
	Bias × Position	$\chi^2(1)$		3.49+	0.04	0.22	4.99*	1.89	0.05
	Word × Position	$\chi^2(1)$		0.00	0.71	0.12	0.47	0.47	0.18
	Word × Pos × Bias	$\chi^2(1)$		0.74	0.03	0.00	1.56	0.01	0.22

$^+p < .1.$ $^* p < .05.$ $^{**}p < .01.$ $^{***}p < .001.$

probably due to the extra noise related to regressions out of this region. There was a main effect of congruence for the third word after the critical pronoun (cr + 3). The *there* condition had longer reading times than the congruent pronoun condition (estimated mean difference = 67 ms; 95% CI = ±39 ms; $p < .001$). The incongruent pronoun condition also led to slower reading times than the congruent pronoun, but this difference was not reliable (estimated mean difference = 30 ms; 95% CI = ±39 ms; $p = .14$). The baseline comparison yielded a reliable main effect of word (with *there* slower than the pronoun conditions), but no Position × Word interaction, indicating that the slowdown for *there* at this region is a general property of the sentences, rather than being due specifically to the causality-related context in the postbias conditions. The other reliable effect in this region was a Bias × Position interaction. For the NP1-biased sentences, reading times were marginally longer in the postbias conditions than in the prebias conditions (estimated mean difference = 36 ms; 95% CI = ±38 ms; $p = .06$), with a reversed, but nonsignificant tendency in the opposite direction for the NP2-biased sentences (estimated mean difference = −23 ms; 95% CI = ±38 ms; $p = .15$). Given that verb bias is a between-items factor, with a different set of sentences for verb bias, this interaction might simply indicate that the two sets of sentences differed in the degree of preference for the preposed adverbial order (prebias), relative to the main-clause-first order (postbias).

Total time on the combined region

Table 6 shows mean total times for the combined region consisting of the critical word plus the following five words. Table 7 shows the associated statistics.

The main comparison revealed a reliable main effect of congruence, which was moderated by an interaction with verb bias. This interaction reflects the fact that the slow-down for the incongruent pronoun (relative to the congruent pronoun) was greater for the NP2-biased sentences than for the NP1 sentences, and, measured against the 95% confidence interval, only the former of these

Table 6. *Means for total time, combining the critical word with the five following words*

		Mean total time	
	Verb bias	*NP1*	*NP2*
Post-bias	Congruent	1,249	1,162
	Incongruent	1,308	1,401
	There	1,411	1,318
Pre-bias	Pronoun	1,302	1,388
	There	1,405	1,440

Note: Mean total time in ms. NP = noun phrase.

Table 7. *Results of statistical analysis for total times on the combined region*

Main comparison	Congruency	$\chi^2(2)$	26.38***
	Verb bias	$\chi^2(1)$	0.19
	Cong × Bias	$\chi^2(2)$	9.07*
Baseline comparison	Word	$\chi^2(1)$	19.09***
	Verb bias	$\chi^2(1)$	0.04
	Position	$\chi^2(1)$	12.97***
	Bias × Word	$\chi^2(1)$	0.27
	Bias × Position	$\chi^2(1)$	7.72**
	Word × Position	$\chi^2(1)$	2.45
	Word × Position × Bias	$\chi^2(1)$	0.20

*$p < .05$. **$p < .01$. ***$p < .001$.

two differences was reliable (estimated mean differences: NP1-bias: 236 ms, $p < .001$; NP2-bias: 58 ms, $p = .24$, 95% CI = ±96 ms). The *there* conditions showed longer total times than the congruent pronoun conditions for each of the verb-bias levels, and both contrasts were reliable (estimated mean differences: NP1-bias: 164 ms; NP2-bias: 159 ms; 95% CI = ±94 ms). LMER contrast analyses showed that verb bias significantly modulated the magnitude of difference between congruent and incongruent pronouns ($p < .02$), but not the difference between congruent pronoun and *there* ($p = .99$).

The baseline comparison corroborated the finding that the cost for *there* is independent of verb bias, as this analysis showed a main effect of word (with *there* slower than pronoun), but no interaction of word by position. In other words, clauses including *there* were read relatively slowly whether or not they were preceded by a biasing context.

This interaction between verb bias and congruence in our total time measure replicates a finding of Long and De Ley (2000) in a probe recognition experiment, where, for skilled readers, causality effects were found only for NP2-biased verbs. The source of this interaction is unclear, but one possibility is that there was a preference for the pronoun to refer to the most recently mentioned individual (i.e., to NP2), leading to a greater mismatch cost when the pronoun is incongruent with NP2.

This raises the question of whether the total time results show any evidence of an effect of causality, over and above the recency preference. To examine this question, we reanalysed the total time data, eliminating the *there* condition and relabelling the data, so that there were now two factors: verb bias (NP1 and NP2); and recency of gender-matching pronoun antecedent (first mention vs. second mention). In this design, an across-the-board preference for a recent antecedent predicts a main effect of recency, but a theory that involves causality information predicts that this should interact with verb bias, with a smaller (or reversed) recency preference for NP1-biased verbs than for NP2-biased verbs. The analysis showed a main effect of recency, $\chi^2(1) = 6.69$, $p < .01$, but this factor interacted with verb bias, $\chi^2(1) = 18.80$, $p < .001$, in the expected direction. Thus, although there does appear to have been a preference for the pronoun to refer to the more recent of the two antecedents, this preference alone cannot explain the implicit causality effect in the total time data.

The source of this interaction is unknown, but it may reflect a distributional bias in the language. In a corpus study, Long and De Ley (2000) found that NP2 bias verbs were better predictors of subsequent mention of the implied cause than were NP1 verbs. If this distributional information is used by readers online, it could explain the larger causality effect for the NP2 verbs than for the NP1 verbs.

It should also be noted that there was no such interaction in the first-pass data on the cr + 1 region, where, if anything, there was a greater numerical causality effect for the NP1-biased verbs than the NP2-biased verbs. Thus, there is evidence for an effect of causality both in early processing, and in a measure of more general processing. Moreover, any preference for reference to recently mentioned antecedents was late acting and independent of the earliest appearance of the causality congruence effect.

A second question raised by the results that deserves comment is why the early causality effect was found only on the word following the pronoun and not on the pronoun itself. Such delays of one word are typical of eye-tracking studies examining pronouns (see, e.g., Moxey, Sanford, Sturt, & Morrow, 2004) and are possibly related to the high skipping rates of pronouns. In our data, the pronoun was skipped on 65% of trials (compared with 43% for *there*). The relatively small number of observations contributing to fixation measures on the pronoun can be expected to reduce statistical power. Moreover, taking into account saccade durations, as well as the time required to programme an eye movement, the timing of our effect is consistent with Van Berkum, Koornneef, Otten, and Nieuwland's (2007) estimate (based on ERP data), that the bias-inconsistent pronoun affects processing within at most half a second of its appearance in the input.

Discussion

The experiment showed an early effect of causality congruency. Readers experienced increased processing difficulty on the word following the bias-incongruent pronoun in first-pass reading times. This finding fits well with Koornneef and Van Berkum's (2006) observation of elevated reading times in first-pass measures, although they found the difference one word earlier, on the pronoun itself, in the regression path measure. The congruency effect was also found in our measure of general processing, based on total time for the pooled region consisting of the pronoun plus the following five words.

In addition, the regression-path data showed that the *there* condition was also processed more slowly than the congruent pronoun condition on the region consisting of the third word following the pronoun, thus potentially offering support for the word-specific prediction account. However, a comparison with the prebias baseline data showed a general slowdown for the *there*-sentences in this region, and there was no evidence that this was modulated by the causality-biasing context. We can therefore conclude that, although bias-incongruent pronouns do exhibit a processing cost, this cost is unlikely to be due to an unsatisfied word-specific prediction.

In the introduction to this paper, we outlined three possible accounts of the early causality congruency effect—the focusing account, the referential prediction account, and the word-specific prediction account. As the present experiment found no evidence to support the word-specific prediction account, we need to consider which of the two alternative possibilities is most likely to be correct. However, although Koornneef and Van Berkum (2006) presented the referential prediction account as an alternative to the focusing account, we believe that these two hypotheses are in fact compatible with each other and that the best account of causality effects may well involve elements of both.

Indeed, a central feature of many theories of discourse processing is the tight link between discourse focus and the comprehender's prediction of what will be mentioned in the forthcoming text (see, e.g., Moxey, 2006). Moreover, recent theories that explicitly model the notion of expectation in language processing also provide a mechanism that could be thought of in terms of the claims of the focusing hypothesis. For example, Hale (2001) and Levy (2008) claim that processing difficulty in syntactic parsing is a function of the *surprisal* afforded by an incoming word. This corresponds to the degree to which the word forces a redistribution of the probability mass in the preference distribution. If applied to referential processing in our causality sentences, we can assume that such a model would encode a preference distribution that is heavily biased towards the expectation of reference to one of the two named individuals, following an appropriately biased verb. A subsequent incongruent pronoun would thus result in a large redistribution of the probability mass (and therefore, high surprisal), because it would disconfirm this expectation, while a congruent pronoun would result in only a small change to the preference distribution (and, therefore, low surprisal). Note, however, that the use of the word *there* as the subject of the main clause does nothing to disconfirm the expectation and is consistent with a continuation that does refer to the expected individual (e.g., *David apologized to Linda because there were spelling mistakes in* *his letter*). Thus, the preference distribution can be expected to remain largely unchanged at the point where *there* is processed, leading to a prediction of relatively low processing cost. This expected outcome is what we found in our experiment.

The preference distributions that are assumed by the surprisal account can be seen as a probabilistic way of modelling the allocation of activation to different alternatives. Viewed in this way, a situation of high surprisal corresponds to the need to reallocate activation (in the form of probability mass) from one referent to another. However, it is exactly this reallocation of activation that underlies the focusing account of the causality congruency effect. Therefore, we do not believe that the focusing account and the referential prediction account should necessarily be seen as opposing hypotheses.

Nevertheless, future work will need to make further investigations into the degree to which predictions might be made when people process causality-biased sentences and exactly what kind of predictions are made. In our opinion, these questions could be usefully addressed using a range of methodologies, possibly including the visual world paradigm as well as ERPs (see Van Berkum et al., 2007). However, the current study shows no evidence that people predict the actual form of the word following the connective *because* in implicit-causality sentences.

Original manuscript received 27 October 2008
Accepted revision received 16 June 2009
First published online 14 August 2009

REFERENCES

Arnold, J. E. (2001). The effect of thematic roles on pronoun use and frequency of reference continuation. *Discourse Processes*, *31*(2), 137–162.

Baayen, R. H. (2008). *Analyzing linguistic data: A practical introduction to statistics using R*. Cambridge, UK: Cambridge University Press.

Baayen, R. H., Davidson, D. J., & Bates, D. M. (2008). Mixed-effects modeling with crossed random effects for subjects and items. *Journal of Memory and Language*, *59*(4), 390–412.

Caramazza, A., Grober, E., Garvey, C., & Yates, J. (1977). Comprehension of anaphoric pronouns. *Journal of Verbal Learning and Verbal Behavior*, *16*(5), 601–609.

Crinean, M., & Garnham, A. (2006). Implicit causality, implicit consequentiality and semantic roles. *Language and Cognitive Processes*, *21*(5), 636–648.

DeLong, K., Urbach, T., & Kutas, M. (2005). Probabilistic word pre-activation during language comprehension inferred from electrical brain activity. *Nature Neuroscience*, *8*(8), 1117–1121.

Garnham, A. (2001). *Mental models and the interpretation of anaphora*. Hove, UK: Psychology Press.

Greene, S. B., & Mckoon, G. (1995). Telling something we can't know: Experimental approaches to verbs exhibiting implicit causality. *Psychological Science*, *6*(5), 262–270.

Hale, J. (2001). The information conveyed by words in sentences. *Journal of Psycholinguistic Research*, *32*(2), 101–123.

Koornneef, A. W., & Van Berkum, J. J. A. (2006). On the use of verb-based implicit causality in sentence comprehension: Evidence from self-paced reading and eye tracking. *Journal of Memory and Language*, *54*(4), 445–465.

Levy, R. (2008). Expectation-based syntactic comprehension. *Cognition*, *106*(3), 1126–1177.

Long, D. L., & De Ley, L. (2000). Implicit causality and discourse focus: The interaction of text and reader characteristics in pronoun resolution. *Journal of Memory and Language*, *42*(4), 545–570.

Mckoon, G., Greene, S. B., & Ratcliff, R. (1993). Discourse models, pronoun resolution, and the implicit causality of verbs. *Journal of Experimental Psychology: Learning, Memory, and Cognition*, *19*(5), 1040–1052.

Moxey, L. M. (2006). Effects of what is expected on the focussing properties of quantifiers: A test of the presupposition-denial account. *Journal of Memory and Language*, *55*, 422–439.

Moxey, L. M., Sanford, A. J., Sturt, P., & Morrow, L. I. (2004). Constraints on the formation of plural reference objects: The influence of role, conjunction, and the type of description. *Journal of Memory and Language*, *51*, 346–364.

Rayner, K., & Pollatsek, A. (1989). *The psychology of reading*. Hillsdale, NJ: Lawrence Erlbaum Associates.

Stewart, A. J., Pickering, M. J., & Sanford, A. J. (2000). The time course of the influence of implicit causality information: Focusing versus integration accounts. *Journal of Memory and Language*, *42*(3), 423–443.

Van Berkum, J. J. A., Brown, C. M., Zwitserlood, P., Koojman, V., & Hagoort, P. (2005). Anticipating upcoming words in discourse: Evidence from ERPs and reading times. *Journal of Experimental Psychology: Learning, Memory, and Cognition*, *31*(3), 443–467.

Van Berkum, J. J. A., Koornneef, A. W., Otten, M., & Nieuwland, M. S. (2007). Establishing reference in language comprehension: An electrophysiological perspective. *Brain Research*, *1146*, 158–171.

Wicha, N. Y. Y., Bates, E., Morenoa, E. M., & Kutas, M. (2003). Potato not Pope: Human brain potentials to gender expectation and agreement in Spanish spoken sentences. *Neuroscience Letters*, *346*, 165–168.