

## Not all Pronouns are Resolved Rapidly Online

Recent studies have used the phenomenon of implicit causality (IC) to demonstrate that pronoun resolution is rapidly influenced by pragmatic inferences about the causal structure of events.<sup>1-5</sup> For example, the P600 is greater when pronouns are congruent with the bias than incongruent (1-2).<sup>5</sup>

(1) Sally frightens/surprises/confuses John<sub>2</sub> because she<sub>1</sub>/he<sub>2</sub>\*...

(2) Sally<sub>1</sub> fears/likes/hates John<sub>2</sub> because she<sub>1</sub>\*/he<sub>2</sub>....

We explore whether these online IC-effects have a basis in lexical semantics and are more restricted than previously reported. Many commonly-tested IC-verbs fall into two semantic classes: Stimulus-subject psych-verbs (SS, 1) and stimulus-object psych-verbs (SO, 2).<sup>2</sup> Like transitive change-of-state verbs (*break*), SS-verbs – but not SO-verbs – have been analyzed as having an embedded casual predicate.<sup>7-8</sup> Thus for these verbs, early IC-effects could reflect direct use of the semantic structure, rather than global pragmatic constraints.

In Experiment 1, adult participants' (N=28) eye movements were tracked as they listened to SS (3) and SO (4) sentences and viewed corresponding images.

(3) Sally frightens Mary because she is such a strange girl.

(4) Sally fears Mary because she is such a strange girl.

Although the expected offline biases were observed for both conditions (as indicated by the subjects' pointing behavior; Table 1), the emergence of this bias was asymmetric. For SS-verbs there was a reliable target preference by 500ms but no early online effect was observed for SO-verbs (Table 2). This difference was significant by 600ms ( $p < .05$ ).

Were eye movements to the object in the object-biased contexts canceled out by the first-mention bias,<sup>6</sup> as suggested by previous authors<sup>3-4</sup>? Experiment 2 replicated Experiment 1, but with the first clause passivized. Participants (N=28) now assigned the pronoun to the surface object of SS-verbs and the surface subject of SO-verbs (Table 1). Again, for the SO-verbs target preference was reliable by about 600ms after pronoun onset, but not for stimulus-object verbs (with an effect in the *wrong* direction in an early window).

To confirm that this online asymmetry reflects semantically-encoded cause, rather than general processing advantage for SS-verbs, Experiment 3 tested utterances in which pronoun resolution requires an inference about the *effect* of an event (5-6). Prior work documents strong offline biases for these utterances.<sup>9</sup> But we predicted that these effects would be slow to emerge.

(5) Because Sally<sub>1</sub> frightens Mary<sub>2</sub>, she<sub>2</sub> is going to have trouble being friends.

(6) Because Sally<sub>1</sub> fears Mary<sub>2</sub>, she<sub>1</sub> is going to have trouble being friends.

Offline data confirmed that the sentences with SS-verbs were now more object-biased than those with SO-verbs (Table 1). However, neither condition showed significant eye-movement effects. Note: in all three experiments participants rapidly resolved pronouns in a control condition which were disambiguated by gender (*Sally fears John because s/he...*).

We re-examined the prior online data in light of these findings. The two studies that report separate analyses for subject-biased verbs and object-biased verbs found that effects were driven primarily by the subject-biased contexts.<sup>3-4</sup> We conclude that the online effects of IC-bias are more restricted than previously reported and may be semantically driven.

**Table 1**

	<u>Exp 1</u>	<u>Exp 2</u>	<u>Exp 3</u>
Stim-Subj	79% (4%)**	27% (6%)**	49% (5%)
Stim-Obj	38% (5%)*	76% (5%)**	83% (4%)

Percent choosing grammatical subject, with standard errors. Statistical difference from chance: \*  $p < .05$ , \*\*  $p < .01$ .

**Table 2**

	0	100	200	300	400	500	600	700	800	900	1000	1100
<u>Exp 1</u>												
Stim-Subj	49%	49%	45%	53%	57%	<b>62%*</b>	<b>68%**</b>	<b>68%**</b>	<b>68%**</b>	<b>64%**</b>	<b>66%**</b>	<b>65%**</b>
Stim-Obj	46%	46%	48%	46%	47%	51%	51%	51%	49%	47%	48%	48%
<u>Exp 2</u>												
Stim-Subj	49%	52%	53%	55%	57%	<b>62%*</b>	<b>68%**</b>	<b>68%**</b>	<b>68%**</b>	<b>64%**</b>	<b>66%**</b>	<b>65%**</b>
Stim-Obj	57%	61%	62%	<b>63%*</b>	59%	54%	52%	52%	52%	56%	56%	55%
<u>Exp 3</u>												
Stim-Subj	50%	50%	52%	54%	54%	47%	47%	49%	49%	52%	53%	53%
Stim-Obj	47%	50%	49%	50%	52%	51%	49%	48%	49%	51%	52%	51%

Looks to grammatical subject / (looks to either character) in 100 ms time windows from pronoun onset to adjective onset.

Table truncated at 1100ms for space, but subsequent time windows are similar.

Statistical difference from chance: \*  $p < .05$ , \*\*  $p < .01$

1. Garvey, C. & Caramazza, A. (1974). Implicit causality in verbs. *Linguistic Inquiry*, 5, 459-464.
2. Rudolph, U., & Forsterling, F. (1997). The psychological causality implicit in verbs: A review. *Psychological Bulletin*, 121, 192-218.
3. Koornneef, A.W. & van Berkum, J.J.A. (2006). On the use of verb-based implicit causality in sentence comprehension: Evidence from reading and eye tracking. *Journal of Memory and Language*, 54, 445-465.
4. Pyykkonen, P. & Jarvikivi, J. (2010). Activation and persistence of implicit causality information in spoken language comprehension. *Experimental Psychology*, 57, 5-16.
5. Van Berkum, J.J.A., Koornneef, A.W., Otten, M., & Nieuwland, M.S. (2007). Establishing reference in language comprehension: An electrophysiological perspective.
6. Arnold, J. E., Eisenband, J. G., Brown-Schmidt, S., & Trueswell, J. C. The rapid use of gender information: Evidence of the time course of pronoun resolution from eyetracking. *Cognition*, 76, B13-B26.
7. Levin, B. & Rappaport Hovav, M. (2005). *Argument realization*. Cambridge, UK: Cambridge University Press.
8. Pesetsky, D. (1995). *Zero syntax: Experiencers and cascades*. Cambridge, MA: The MIT Press.
9. Stewart, A.J., Pickering, M.J. & Sanford, A.J. (1998). Implicit consequentiality. In *Proceedings of the 20<sup>th</sup> Annual Conference of the Cognitive Science Society* (pp. 1031-1036). Mahwah, NJ: Lawrence Erlbaum Associates, Inc.