

Eye movements as a measure of syntactic and semantic incongruity in globally anomalous sentences

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Research Question: If the first step in a garden path experience is anomaly detection, are there different patterns of eye movements depending on whether the anomaly is syntactic or semantic?

Step 1: Detect a problem in the analysis

[The millionaire [knew the answer]] **was...**
[James [saw [the agent] [with galoshes]]]

Step 2: Reanalyze

[The millionaire [knew [the answer was...]]]
[James [saw [the agent [with galoshes]]]]

Traditional Assumptions

Certain eye movement patterns reflect anomaly detection and syntactic reanalysis:

- an increase in first pass reading times in the disambiguating (anomalous) region
- an increase in the probability of a regression out of the disambiguating (anomalous) region

These patterns have been used as evidence for a serial parser in which only one syntactic structure is assigned to the ambiguous region of a garden path sentence (e.g., Ferreira & Henderson, 1990; Frazier & Rayner, 1982; Rayner, Carlson, & Frazier, 1983).

Reasons to Question These Assumptions

- There are conflicting reports in the literature: Ni, Fodor, Crain, & Shankweiler (1998) and Pearlmuter, Garnsey, & Bock (1999) found no evidence of increased first pass RTs for syntactically anomalous sentences.
- The stimuli in most garden path studies require other cognitive processes, such as ambiguity detection and resolution. It is important to use globally anomalous sentences to learn about eye movements and anomaly detection.
- Increased RTs could result from competition between parallel structures – not from anomaly detection and reanalysis (Spivey & Tanenhaus, 1998; MacDonald, Pearlmuter, & Seidenberg, 1994).

Local Dependent Measures

- **Transformed first pass reading times** are calculated as deviations from predicted RTs if length is the only controlling factor. We use this measure in Experiment 1 (following Ni et al., 1998; Pearlmuter et al., 1999; and others) to adjust for differences in length in the anomaly region across conditions and in Experiments 2 and 3 to facilitate comparisons to Experiment 1.
- **Probability of a first pass regression out of a region**

Global Dependent Measures

- **Go-past times or regression path durations** are calculated by adding together all fixations starting from when a given region is first entered until a later region is fixated.
- **Total reading times**

Experiment 1

We manipulated syntactic and semantic congruity in a 2 X 2 design using globally anomalous sentences and well-formed controls. The vertical bars in (1) delimit regions of analysis for critical items.

- **Syntactic anomaly = phrasal category violation:** The verb requires a PP in the anomaly region.
- **Semantic anomaly = thematic role violation:** Need an animate indirect object in the anomaly region.

(1) Kim recommended Shakespeare | **(anomaly region)** | after she | saw Hamlet.

to everyone	(congruent condition)
everyone	(syntactic anomaly)
to signs	(semantic anomaly)
signs	(double anomaly)

Syntactic and semantic anomalies elicited different patterns of eye-movements when it came to first pass RTs (See Figure 1) and the probability of a regression (See Figure 2). Whereas syntactic anomaly effects were strong and immediate, semantic anomaly effects were weaker or started later.

As expected, both types of anomalies increased total times and go-past times – the more global measures of processing difficulty. When go-past times were analyzed by region, semantic anomalies were reflected at the anomaly region, and both types of anomalies were reflected in the following region.

Fig. 1. Transformed first pass RTs from Exp. 1

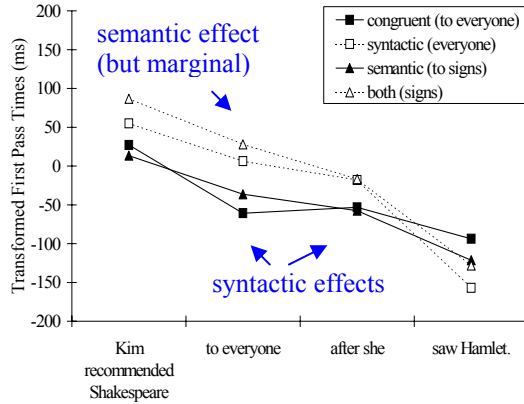
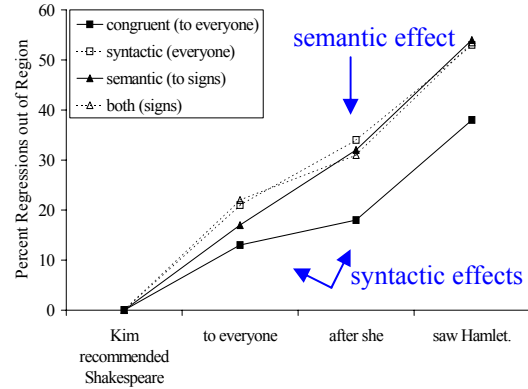


Fig. 2. Probability of a first pass regression in Exp. 1



Experiment 2

We again manipulated syntactic and semantic congruity in a 2 X 2 design using globally anomalous sentences and well-formed controls. The vertical bars in (2) delimit regions of analysis for critical items.

- **Syntactic anomaly = morpho-syntactic violation:** The subject and verb do not agree in grammatical number.
- **Semantic anomaly = thematic role violation:** The subject has the wrong agent properties for the verb.

(2)

(congruent)	The canary	in the large cage	sings	beautifully
(syntactic anomaly)	The canaries	in the large cage	sings	beautifully
(semantic anomaly)	The snake	in the large cage	sings	beautifully
(double anomaly)	The snakes	in the large cage	sings	beautifully

- **There was no evidence that morpho-syntactic or semantic anomalies increased first pass RTs (See Figure 3).** This was also true for regression-contingent analyses, which we calculated by excluding trials in which a participant made a first pass regression from the verb (19% of the data). We calculated regression-contingent first pass RTs once using all participants and (similar to Pearlmuter et al., 1999) once excluding data from the five participants who never made regressions from the verb.
- **There were more regressions out of the final region (*beautifully*) in the syntactically anomalous conditions (See Figure 4).** Although this effect was in the right direction at the verb, it was only marginally reliable and only by participants. Surprisingly, there was a small but reliable effect of agreement in the modifier region (*in the cage*) with more regressions in the syntactically congruent conditions.
- **Again, total times and go-past times increased in all anomalous conditions.** Go-past times were longer for syntactic anomalies in the anomaly region, and for syntactic and semantic anomalies in the following region.

Fig. 3. Transformed first pass RTs from Exp. 2

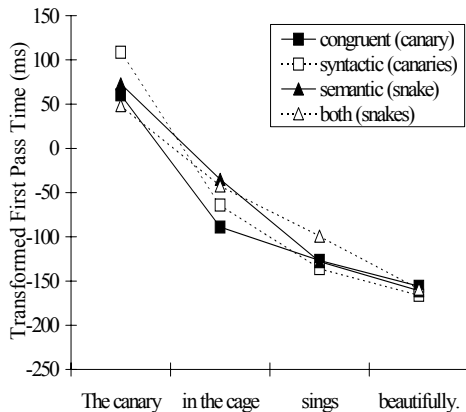
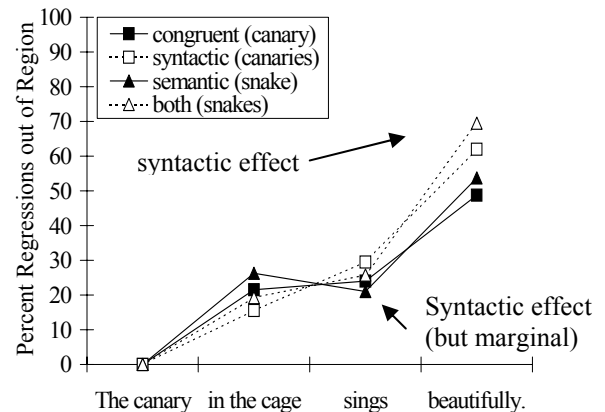


Fig. 4. Probability of a first pass regression in Exp. 2



Experiment 3

- **Semantic anomaly = thematic role violation** at the direct object. The vertical bars in (3) delimit regions of analysis for critical items.

(3) The physics professor | trained | **(anomaly region)** | to observe | the process.

the kids	(congruent)
the paint	(semantic anomaly)

- **The apparent increase in transformed first pass RTs in the semantically anomalous condition was not statistically reliable (See Figure 5).**
- **There were more regressions out of the infinitive region (to observe) in the semantically anomalous conditions (See Figure 6).**
- **The anomaly effect was evident in go-past and total times.** Go-past times were elevated in the infinitive region.

Fig. 5. Transformed first pass RTs from Exp. 3

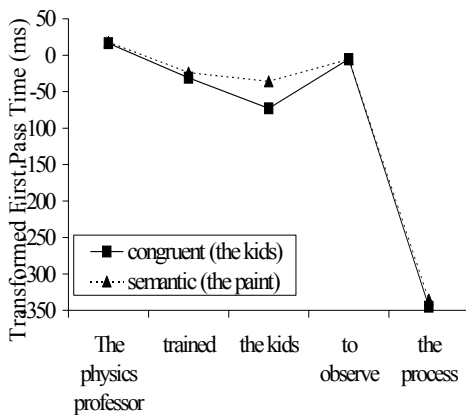
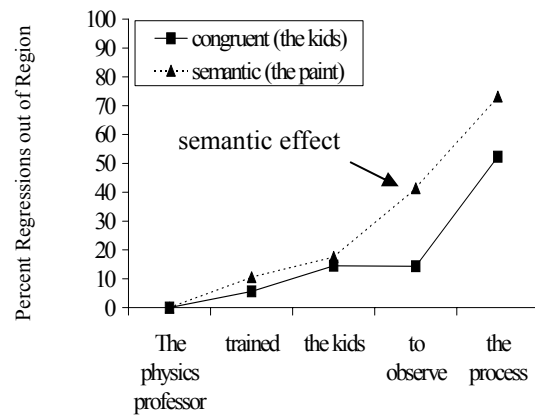


Fig. 6. Probability of a first pass regression in Exp. 3



Summary of Results

	First Pass RTs	Probability of a Regression	Go-Past Times	Total Times
Experiment 1				
Syntactic category anomaly	at anomaly	at anomaly	✓	✓
Semantic anomaly	at anomaly (but marginal)	post-anomaly	✓	✓
Experiment 2				
Morpho-syntactic anomaly	no effects	at anomaly (but marginal)	✓	✓
Semantic anomaly	no effects	no effects	✓	✓
Experiment 3				
Semantic anomaly	no effects	post-anomaly	✓	✓

Conclusions

- Detection of a syntactic category violation evokes a cognitively different response than detection of a morpho-syntactic violation.
- Syntactic category anomalies, but not morpho-syntactic anomalies, lead to longer first pass RTs.
- Morpho-syntactic anomalies elicit patterns that resemble those from semantic anomalies, rather than those from other syntactic anomalies.

Implications

- **The lack of first pass RT effects for agreement and semantic anomalies suggests that some garden path studies need to be re-evaluated.** For example, Rayner, Carlson, & Frazier (1983) interpreted longer first pass reading times to “The spy saw the cop with a revolver...” as evidence of semantic anomaly detection and reanalysis. Alternatively, the longer RTs might reflect competition between syntactic alternatives (Spivey & Tanenhaus, 1998; MacDonald, Pearlmutter, & Seidenberg, 1994).

- **The relevant contrast is not between syntactic and semantic anomalies, but between anomalies that affect computation of a well-formed tree structure and those that do not.** For example, the semantic information contained in the *wh*-phrases in (4) specifies the syntactic structure that should be built at the verb *recommend*. We predict that first pass RTs will increase at the anomalous region (*the book*) in (4d) when the syntactic structure is licensed (as in [4c]) but for different semantic content.

		NP	V	NP	PP
(4a)		The woman	recommended	the table	to Bill.
	NP-aux	NP	V	(gap)	PP
(4b)	Which table did	the woman	recommend	—	to Bill?
	NP-aux	NP	V	NP	(gap)
(4c)	Who did	the woman	recommend	the table	to ___?
	NP-aux	NP	V	NP	(gap)
(4d)	Which table did	the woman	recommend	the book	to ___?

- This distinction is important cross-linguistically, as well. We predict consistent first pass reading time effects for morphological anomalies in languages in which morphological information determines the syntactic structure (e.g., German).

References

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