Fine-graining structure prediction in sentence processing: Evidence from language mixing

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Does the parser predict upcoming syntactic structure? And if so: how far ahead and at which point in a sentence? Does it look for any cue to form a prediction? Or do only a small set of cues trigger structure generation? This study addresses these questions in two reading time experiments.

Introduction / Rationale

It is difficult to investigate the exact point at which final commitments are made regarding word order in sentence processing. For example, a sentence like *The boy has read the story* is preferred over *The boy has the story read*, but at which point in the input string is VO word order predicted? At *the boy*? At *has*?

To answer this type of question, we tested Dutch/English mixed sentences, varying
(a) which words were expressed in which language (Dutch vs. English)
(b) word order (OV vs. VO / - V_2 vs. + V_2)

Method: Sentence Matching

Participants were asked to indicate whether two sequentially appearing sentences formed an identical pair or not. Sentence 2 appeared on the screen 500ms after sentence 1. Both sentences remained on for 2400ms.

A monolingual pilot confirmed that pairs of sentences that violate VO/OV word order yield slower reaction times (RTs) than grammatical pairs.

Self-paced reading times did not reflect word order preferences.

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[sentence 1]
500ms
[sentence2]
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PARTICIPANTS **Pilot**: 21 native speakers of English + 22 native speakers of Dutch
Code-switching experiments: 32 Dutch - English 'balanced' bilinguals

Experiment 1: OV (Dutch) vs. VO (English)

What determines the position of the main verb relative to its direct object?

English has VO order e.g., ***The old woman will*** *[read]$_V$ [the paper]$_O$*
Dutch has OV order e.g., ***De oude vrouw zal*** *[de krant]$_O$ [lezen]$_V$*

Table 1 presents the design of Exp. 1: 2 (word order) x 2 (language) x 3 (switching point)

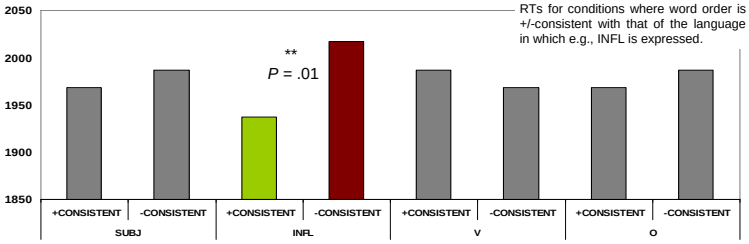
It was assumed that a preference for OV-order would indicate that those words expressed in Dutch in the condition under consideration were 'decisive' in determining VO/OV structure, and vice versa.

TABLE 1. DESIGN & RESULTS EXP. 1 Conditions and example stimuli

LEGEND: Dutch | English; FASTER < SLOWER

Subj	Infl	Obj	V		Subj	Infl	V	Obj
De oude vrouw	WILL	the paper	read	>	De oude vrouw	WILL	read	the paper
The old woman	ZAL	de krant	lezen	<	The old woman	ZAL	lezen	de krant
De oude vrouw	ZAL	the paper	read	<	De oude vrouw	ZAL	read	the paper
The old woman	WILL	de krant	lezen	>	The old woman	WILL	lezen	de krant
De oude vrouw	ZAL	de krant	read	<	De oude vrouw	ZAL	read	de krant
The old woman	WILL	the paper	lezen	>	The old woman	WILL	lezen	the paper

RESULTS - **Only the language of INFL was indicative of WO preferences**



These results suggest that

- **INFL forms the pivotal point in determining VO/OV word order**
  Importantly, this appears to be so irrespective of the language of V and/or O (see blue box)

It thus seems that only overt functional elements trigger structure generation. However:
- the conditions were confounded by linear precedence: INFL always appeared before to V.
- it remains unclear whether *any* prediction for upcoming structure is made on the basis of the sentence-initial NP (e.g., NP → INFL). **Exp. 2 addressed these points directly**

Experiment 2: +V_2 (Dutch) vs. -V_2 (English)

Do functional elements like Infl, enjoy special status in structure-prediction?

Exp. 2 asked whether, in the generation of syntax, the parser operates on ***any*** cue (by way of linear precedence) or rather relies solely on overt functional cues (e.g., INFL) in the generation of syntax.

Dutch is strict +V2: The inflected verb always occupies the second slot in main declarative sentences:

[de boer]$_{Subj}$ ***[verkocht]$_{INFL}$*** *[vandaag]$_{Adv}$* ***zijn paard***
[vandaag]$_{Adv}$ ***[verkocht]$_{INFL}$*** *[de boer]$_{Subj}$* ***zijn paard***

[See table 2 for glosses]

This difference between Dutch and English allow us to disentangle the following two hypotheses:

- Any element may be deterministic in structure generation (e.g., sentence-initial adverbs)
- Only certain functional elements can trigger structure generation (e.g., INFL)

TABLE 2. DESIGN & EXAMPLE STIMULI EXP. 2

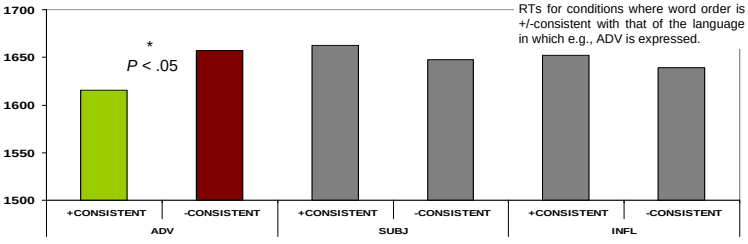
Adverb	Infl +V_2	S	O
Vandaag	sold	the farmer	zijn paard
Today	verkocht	de boer	his horse

Adverb	S -V_2	Infl	O
Vandaag	the farmer	sold	zijn paard
Today	de boer	verkocht	his horse

Subj	Infl +V_2	Adv	O
De boer	sold	today	zijn paard
The farmer	verkocht	vandaag	his horse

Subj	Adv -V_2	Infl	O
De boer	today	sold	zijn paard
The farmer	vandaag	verkocht	his horse

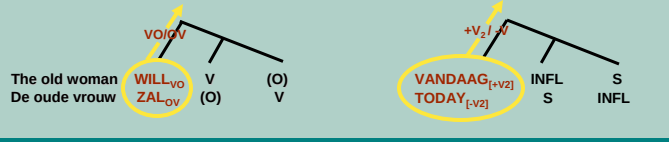
RESULTS - **Only the language of the adverb was indicative of WO preferences**



These results suggest that

- **structure prediction is not limited to overt functional triggers**
- **the parser does not treat all cues equally**
  Adverbs trigger + / - V_2 word order, but sentence-initial NPs do not (see blue box).
  It is not entirely clear *why* adverbs are 'better' cues than sentence-initial NPs.
  Possible explanations may be sought in frequency distributions: maybe temporal adverbs are more likely to be immediately followed by an inflected verb that DET-N sequences.

SUMMARY & CONCLUSIONS



The results of Exp. 1 & 2 suggest that

(1) **sentence-initial NPs remain 'underspecified' (in English and Dutch) they are not integrated into S-level structure until INFL is available**
(2) **sentence-initial temporal adverbs DO trigger the generation of S-level syntax**
(3) **INFL triggers the generation of VO/OV structure, i.e., at least two nodes ahead**

Together, these findings suggests that parsing mechanisms are driven by a balance between anticipating as much as possible and keeping options open, operating either in a ranked parallel or serial fashion. In addition, these studies show how experimental code-mixing can address architectural properties of the parser that are difficult to tap onto in monolingual contexts.