EEG correlates of covert dependency formation in Mandarin wh-questions

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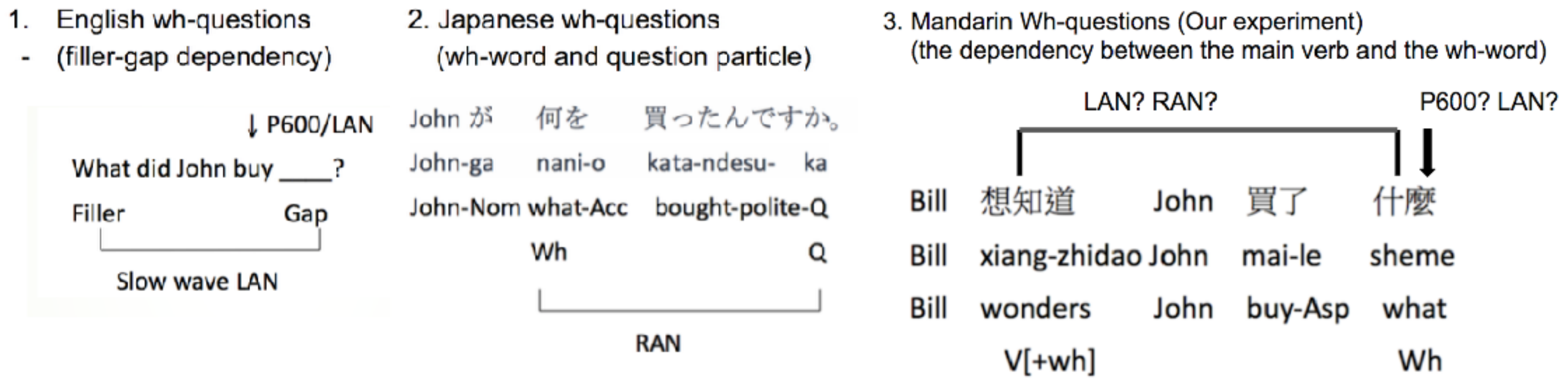
Introduction

- Event-related potential (ERP) components like the **P600** and **LAN** are sensitive to the processes underlying how questions are understood.
- However, prior data from English and Japanese are consistent with several different functional interpretations of these components.

- **P600** ERP component begins ≈600 ms post-stimulus on the posterior scalp [2], [3]. Linked to "syntactic integration" with debate about specific functional role:
  - reactivation of the *wh*-filler?
  - thematic role assignment?
  - semantic integration between the verb and the *wh*-filler?
- **LAN/RAN** ERP component is an increased negative voltage in 300-500 ms post-stimulus over the left or right anterior scalp. Associated with both storage and retention of information in working memory. [1], [4]

We use *in situ* Mandarin wh-questions to narrow down these different functional interpretations



1. English wh-questions
- (filler-gap dependency)

↓ P600/LAN
What did John buy ____?
Filler Gap
Slow wave LAN

2. Japanese wh-questions
(wh-word and question particle)

John が 何を 買ったんですか。
John-ga nani-o kata-ndesu- ka
John-Nom what-Acc bought-polite-Q
Wh Q
RAN

3. Mandarin Wh-questions (Our experiment)
(the dependency between the main verb and the wh-word)

LAN? RAN? P600? LAN?
Bill 想知道 John 買了 什麼
Bill xiang-zhidao John mai-le sheme
Bill wonders John buy-Asp what
V[+wh] Wh

- **P600 Predictions**
  - If it reflects integration between verb and filler, expect it at wh-word in indirect questions (IQs)
  - But, if it reflects re-activation of wh-filler, do not expect it with in situ Mandarin questions
- **Sustained LAN/RAN Predictions**
  - Expect to see if the question-selecting main verb served as a cue and needs to be stored expect
  - Do not expect if question-selecting verb imposes low demands on working memory

EEG Methods

Participant: N=37 native speakers of Mandarin Chinese read Chinese questions and declarative sentences word-by-word during EEG recording.

Procedure: Word-by-word reading task: yes/no comprehension question, breaks (Sessions lasted about 2 hrs)

Recording & Statistics: EEG data were recorded at 500 Hz from 61 active electrodes. Epochs around word onset were re-referenced to linked-mastoids, cleaned of artifacts with visual inspection and ICA, band-pass filtered from 0.1–30 Hz, and baseline-corrected. A non-parametric statistical analysis was conducted across all electrodes time-locked to (i) the *wh*-word, or (ii) the interval between the main verb and the *wh*-word

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Stimuli

Stimuli come from four conditions: (1) **indirect questions** (2) **direct questions** (3) **declarative sentences** (4) **yes/no embedded questions**. Each condition includes both short and long versions.

Indirect questions include a question-selecting main verb (e.g. wonder) that provides a cue for a subsequent wh-word, in contrast to **direct questions**, which include a non question-selecting main verb (e.g. think). **Declarative sentences** and **yes/no embedded questions** serve as controls.

Norming

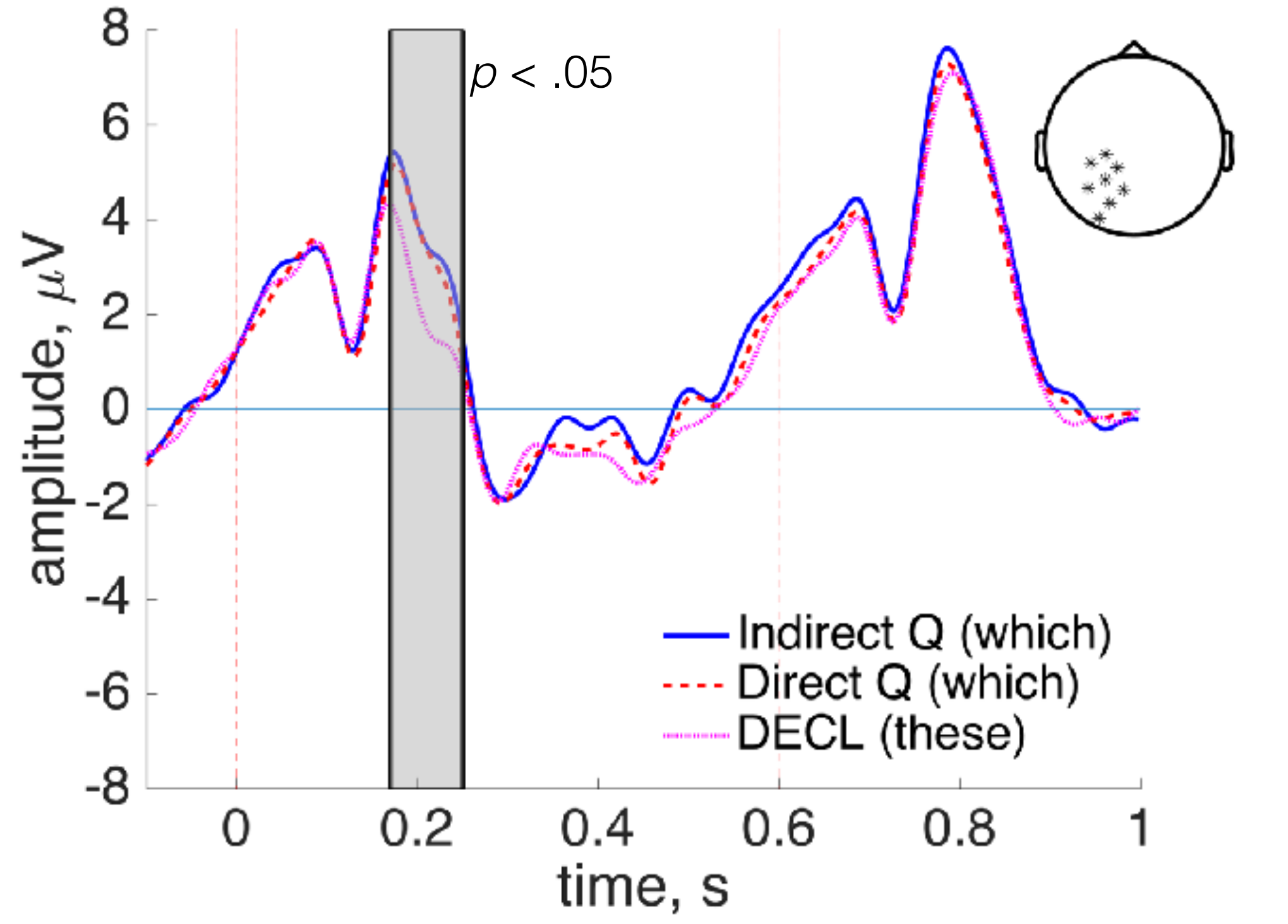
- The main verbs were matched based on the strokes of the word, the word frequency, and the frequency of the first and the second characters.
- 64 target sentence sets were selected based on the result of an acceptability judgement norming test.

8 Lists were created (48 sentences per condition plus 120 fillers).

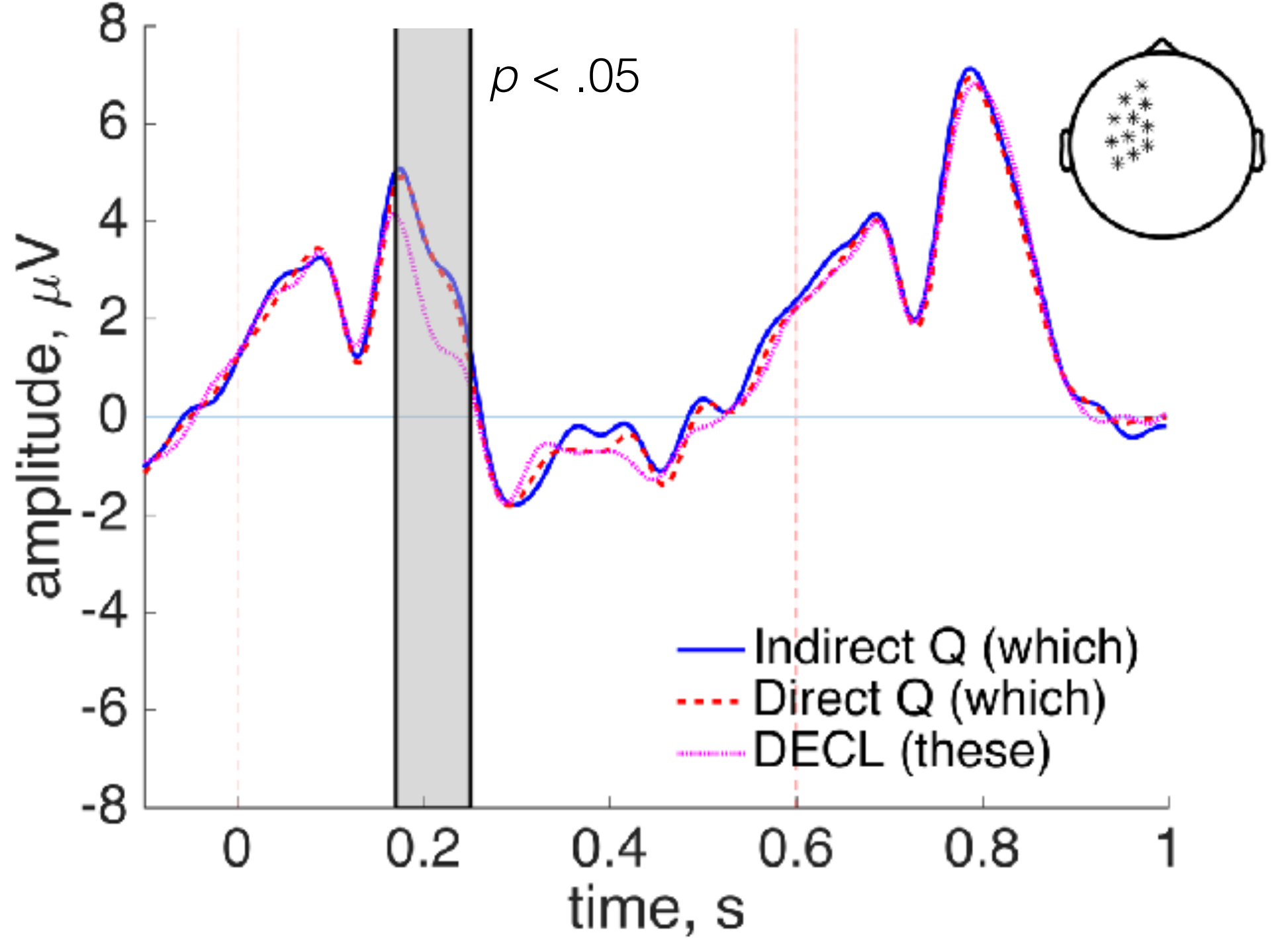
(a) Short indirect question:
張偉 詢問 前幾天 詠晴 開了 哪些 先例
Zhangwei ask few-days-ago Yongching create which precedent
'Zhangwei asked which precedents Yongching created a few days ago.'
(b) Long indirect question:
張偉 詢問 前幾天 詠晴 逼迫 錦華 開了 哪些 先例
Zhangwei ask few-days-ago Yongching force Chinghua create which precedent
'Zhangwei asked which precedents that Yongching forced Chinghua to create a few days ago.'
(c) Short direct question:
張偉 調查 前幾天 詠晴 開了 哪些 先例
Zhangwei investigate few-days-ago Yongching create which precedent
'Which precedents did Zhangwei investigate Yongching created a few days ago? '
(d) Long direct question:
張偉 調查 前幾天 詠晴 逼迫 錦華 開了 哪些 先例
Zhangwei investigate few-days-ago Yongching force Chinghua create which precedent
'Which precedents did Zhangwei investigate Yongching forced Chinghua to create a few days ago?'

(e) Short declarative sentence:
張偉 調查 前幾天 詠晴 開了 這些 先例
Zhangwei investigate few-days-ago Yongching create these precedent
'Zhangwei investigated that Yongching created these precedents a few days ago.'
(f) Long declarative sentence:
張偉 調查 前幾天 詠晴 逼迫 錦華 開了 這些 先例
Zhangwei investigate few-days-ago Yongching force Chinghua create these precedent
'Zhangwei investigated that Yongching forced Chinghua to create these precedents a few days ago.'
(g) Short embedded yes/no question:
張偉 詢問 前幾天 詠晴 有沒有 開了 先例
Zhangwei ask few-days-ago Yongching have-not-have create precedent
'Zhangwei asked if Yongching created precedents a few days ago.'
(h) Long embedded yes/no question:
張偉 詢問 前幾天 詠晴 有沒有 逼迫 錦華 開了 先例
Zhangwei ask few-days-ago Yongching have-not-have force Chinghua create precedent
'Zhangwei asked if Yongching forced Chinghua to create precedents a few days ago.'

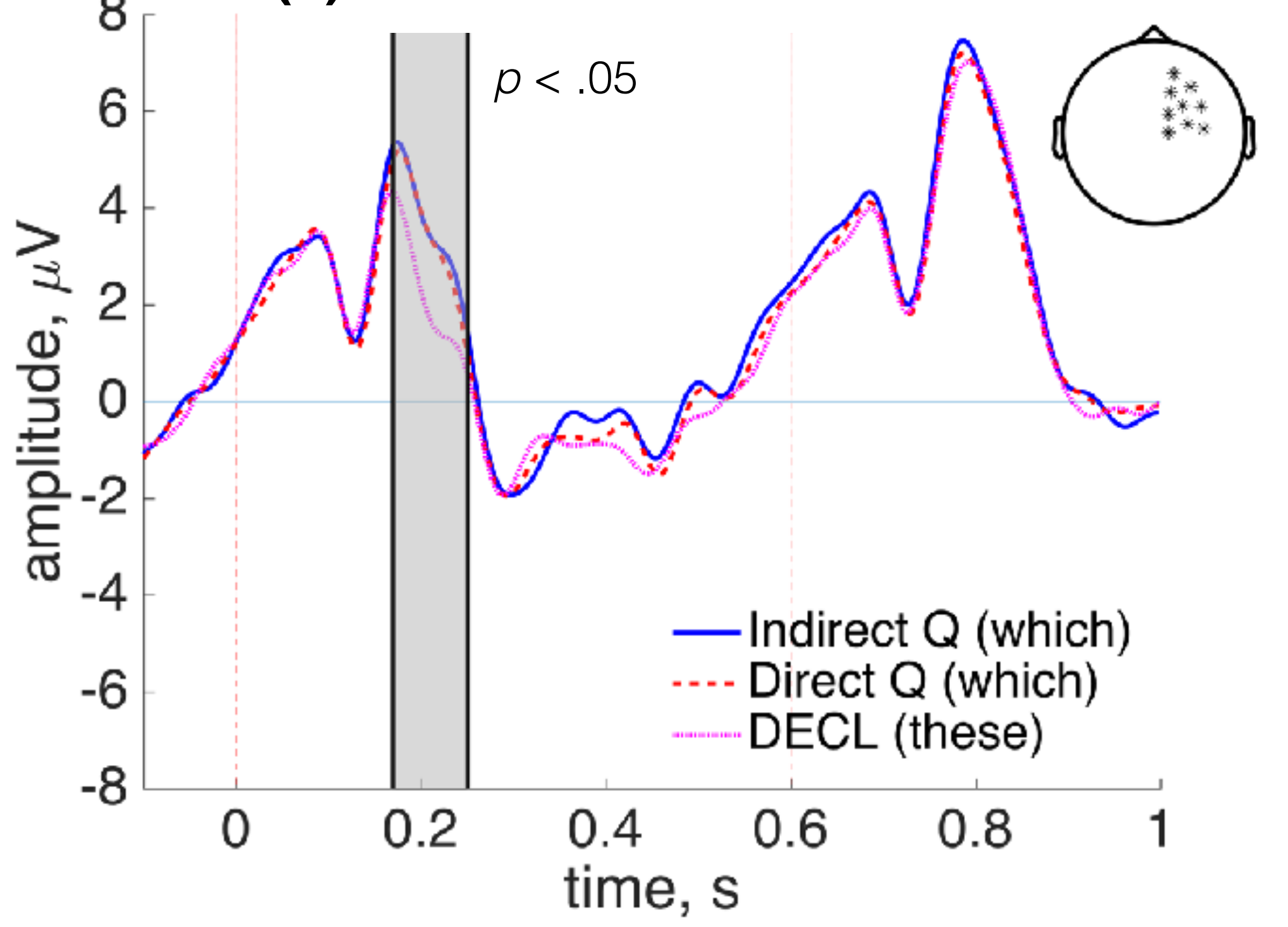
Results



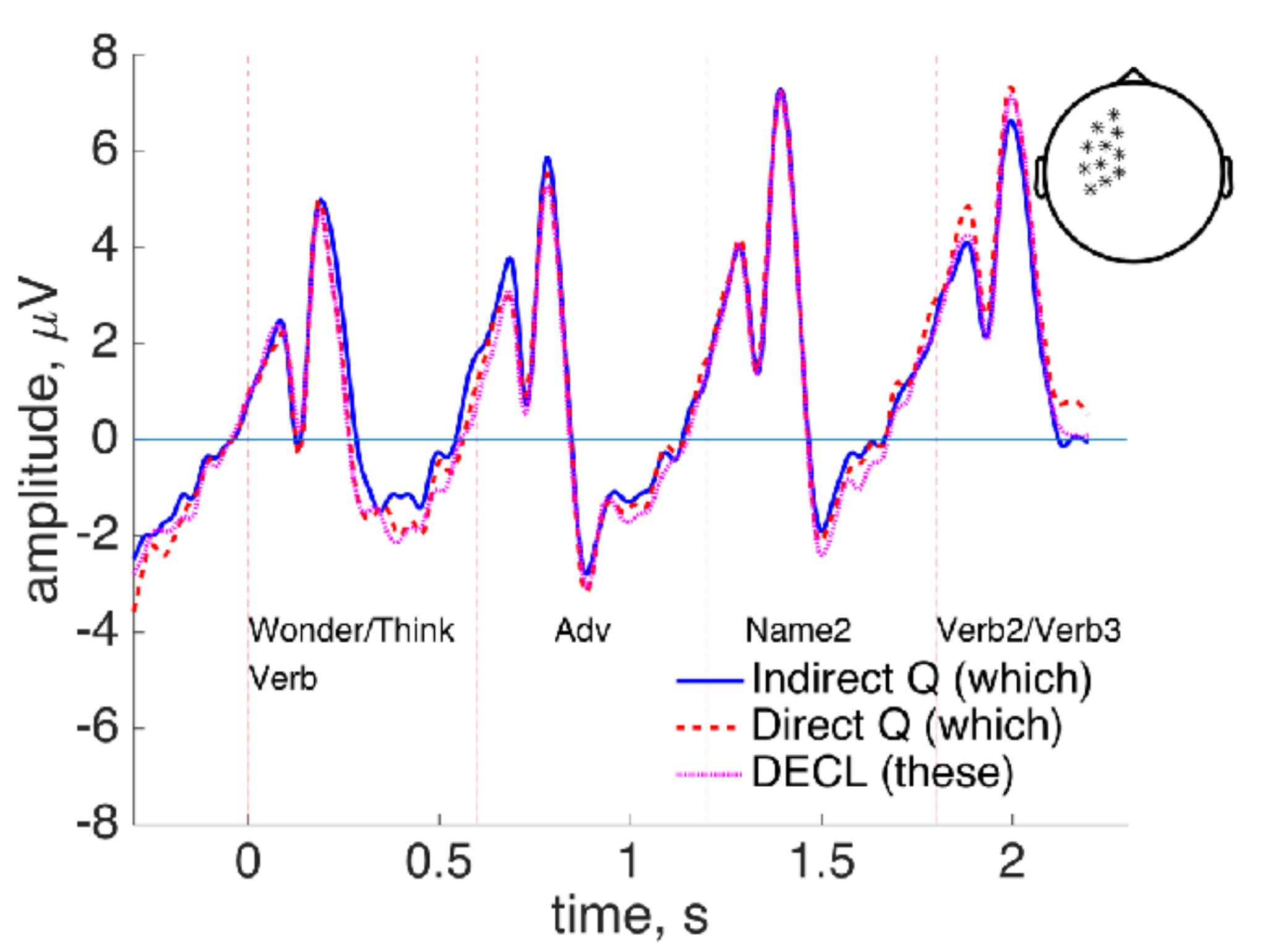
(1) No P600 at the wh-word



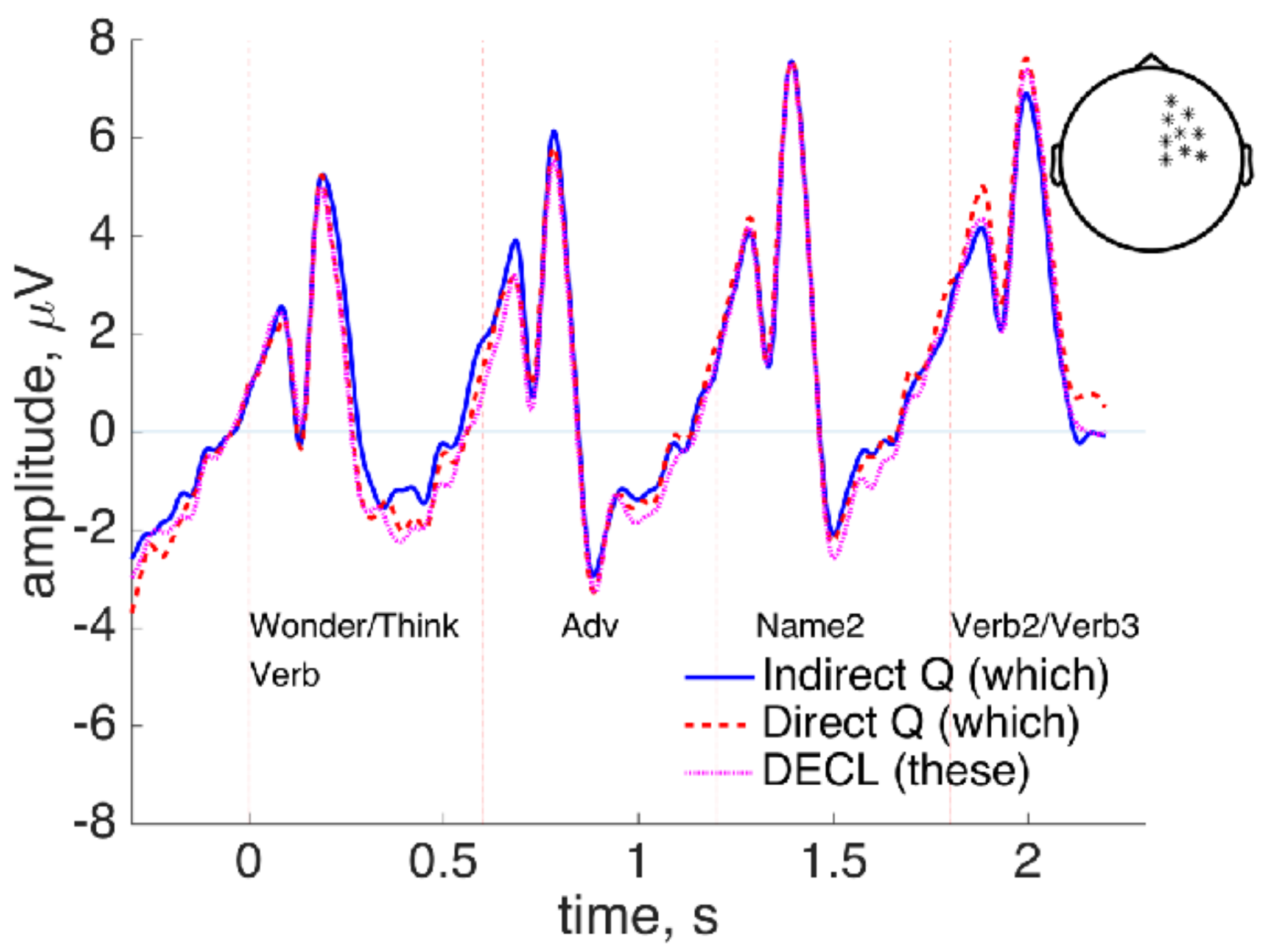
(2) No LAN at the wh-word



(3) No RAN at the wh-word



(4) No LAN between main verb and wh-word



(5) No RAN between main verb and wh-word

Conclusions

- Consistent with Japanese covert dependencies, no P600 was found at the gap site.
- An anterior negativity was also not found between the cue "wonder" verb and the *wh*-word in IQs.
- The absence of such a negativity suggests two possibilities:
  1. The question-selecting main verb is needed to be stored and retrieved but with lower processing cost.
  2. There is no need to store the *wh*-filler in memory when processing IQs.

References [1] Kluender, R., M. Kutas. 1993. Bridging the gap: evidence from ERPs on the processing of unbound dependencies. dependencies. *J. Cogn. Neurosci. 5*, 196–214. [2] Kaan, E.*et al*, 2000. The P600 as an index of syntactic integration difficulty. *Lang. Cogn. Processes 15*, 159–201. [3] Phillips, C. *et al*, 2005. ERP effects of the processing of syntactic long-distance dependencies. *Cogn. Brain Res. 22*, 407–428. [4] Ueno, M., R. Kluender. 2009. On the processing of Japanese wh-questions: an ERP study. *Brain Res. 1290*, 63-90.