Incremental prediction updating through consecutive cues: Evidence from eye-tracking and ERPs

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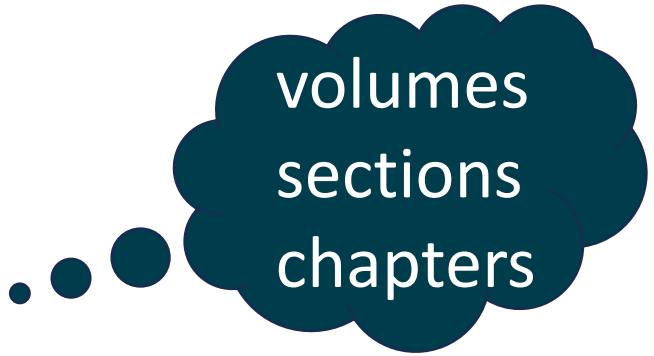
Introduction

This book has three _____



Introduction

This book has three hundred _____

Introduction

Prediction during language comprehension

Comprehenders can use rich contextual information to predict upcoming language (Altmann & Kamide, 1999; DeLong et al., 2005; Federmeier & Kutas, 1999; Kamide et al., 2003; Szewczyk & Schriefers, 2013; Wicha et al., 2004; see Kutas et al., 2011; Ryskin & Nieuwland, 2023 for reviews)

Moreover, recent studies indicate that upon encountering unexpected information, comprehenders can rapidly update their predictions (Chow & Chen, 2020; Fleur et al., 2020; Gussow et al., 2019; Szewczyk et al., 2022; Szewczyk & Wodniecka, 2020)

Introduction

Updating predictions based on incoming information

Chow and Chen (2020) examined listeners' sensitivity to cues that are inconsistent with their predictions by using nominal classifiers in Mandarin Chinese.

安娜 在 星巴克 买了 一 ……
Anna at Starbucks bought one ……

杯 / 些 很 美味的 咖啡 ← Expected N
CL_cup / CL_general very nice-tasting coffee.

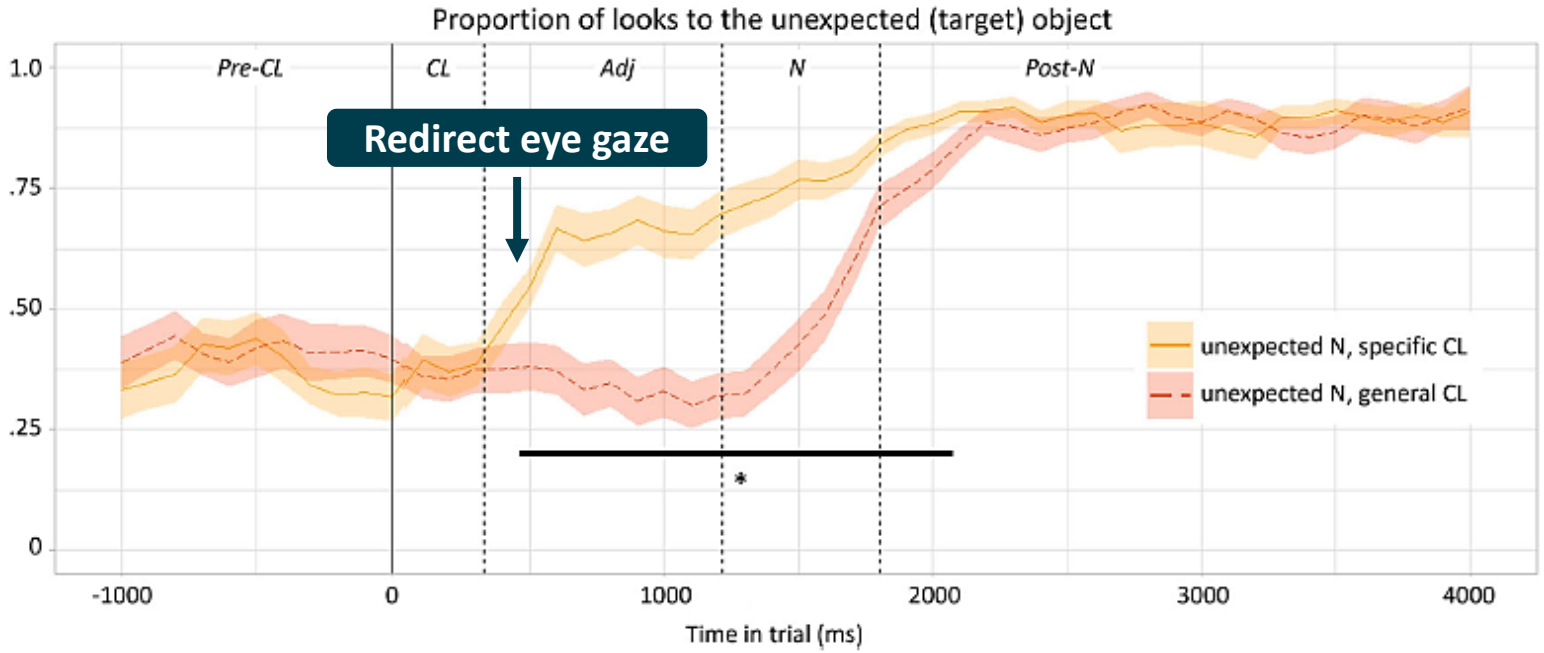
块 / 些 很 美味的 蛋糕 ← Unexpected N
CL_piece / CL_general very nice-tasting cake.

Specific CL　General CL

Introduction

Updating predictions based on incoming information

Chow and Chen (2020) found that Mandarin Chinese listeners were able to rapidly redirect their eye gaze towards a previously unexpected object upon hearing a prediction-inconsistent classifier.



Anna at Starbucks bought one CL_piece / CL_general very nice-tasting cake. **Unexpected N**

Introduction

Updating predictions based on incoming information

Szewczyk et al. (2022) found that English readers can use adjectives to dynamically adjust their expectations for upcoming nouns.

Supportive Adj

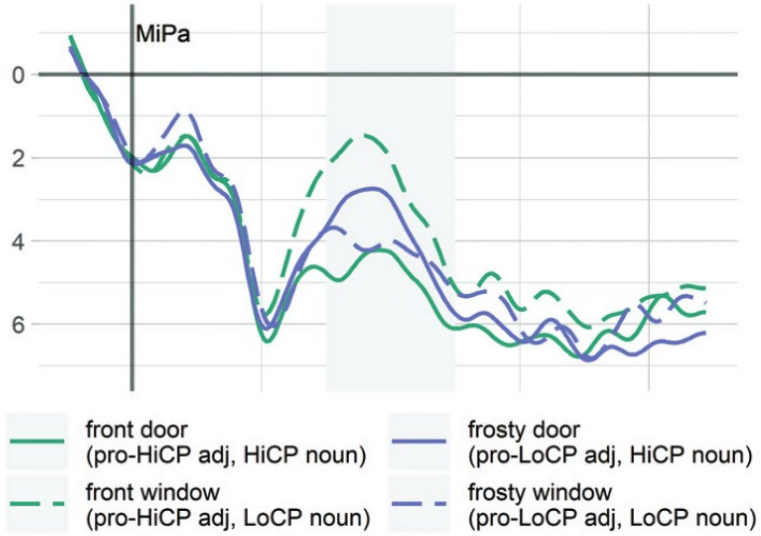
At night the old woman locked the **front** **door** ← **Expected N**

At night the old woman locked the **frosty** **window** ← **Unexpected N**

Unsupportive Adj

At night the old woman locked the **frosty** **door** ← **Expected N**

At night the old woman locked the **front** **window** ← **Unexpected N**



Introduction

How about consecutive cues?

Overload

Processing the first prediction-inconsistent cue may already overload the system

- Detecting conflicts between prediction and bottom-up input can disrupt subsequent processing (Husband & Bovolenta, 2020)
- Difficult to update existing predictions or make new ones

Resilient

The cost of prediction error seems very small or very short-lived

- Eye-tracking: redirect eye gaze without an extensive search for alternatives (Chow & Chen, 2020; Gussow et al. 2019)
- ERP: reduced N400 at the noun which is preceded by an informative cue (Szewczyk et al., 2022; Szewczyk & Wodniecka, 2020)

The present study

1st cue

We used ***prediction-mismatching classifiers*** to **signal a prediction error** (Chow & Chen, 2020).

- Nominal classifiers are obligatory in Mandarin Chinese when the noun is modified by a demonstrative or numeral.

Specific, matching	**Specific, mismatching**	**General**
一本书 (one CL_{ben} book)	一*块书 (one *CL_{kuai} book)	一些书 (some books)
一束花 (one CL_{shu} flower)	一*张花 (one *CL_{zhang} flower)	一些花 (some flowers)
一台相机 (one CL_{tai} camera)	一*份相机 (one *CL_{fen} camera)	一个相机 (one CL_{ge} camera)

2nd cue

We then used ***informative modifiers*** to **trigger potential updating of noun predictions**.

- We measured *cloze probabilities* of the target noun to ensure that an informative adjective can always make the noun more likely to follow even after a prediction-mismatching classifier (cf. Husband & Bovolenta, 2020)

EXP 1 the visual world study: Method

EXP 1 visual-world eye-tracking experiment (50 participants, 40 items)

Expected

Distractor

Target

Competitor

老家的院子里种了很多绿色植物，院子中央有…

The old house's courtyard is full of greenery, and in its centre, there is/are …

tree

Specific classifier

一 张 {下棋的/好看的} 桌子

one **CL$_{zhang}$** {chess-playing / good-looking} table

General classifier

一 些 {下棋的/好看的} 桌子

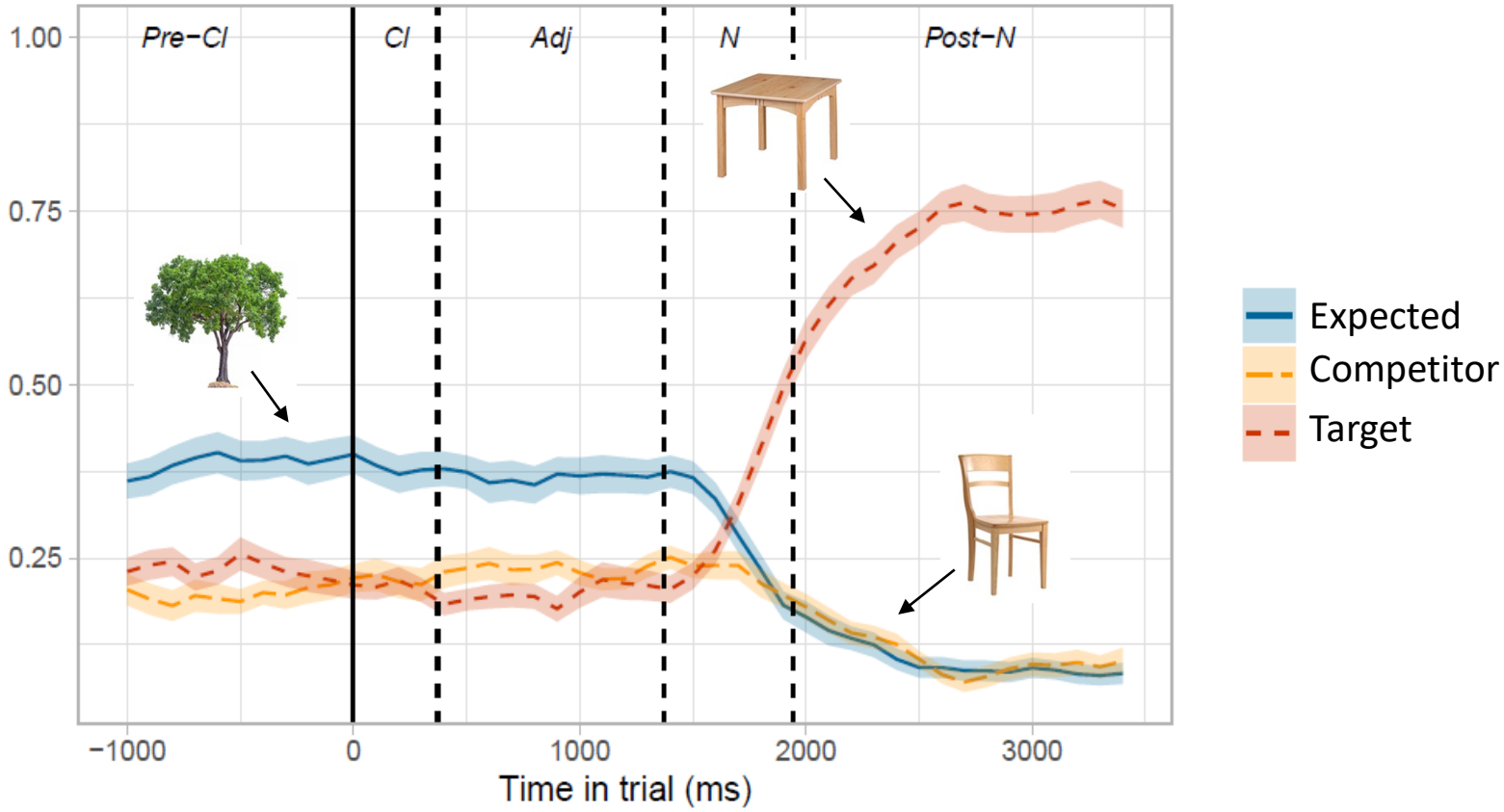
one **CL$_{xie}$** {chess-playing / good-looking} table

Informative modifier

Uninformative modifier

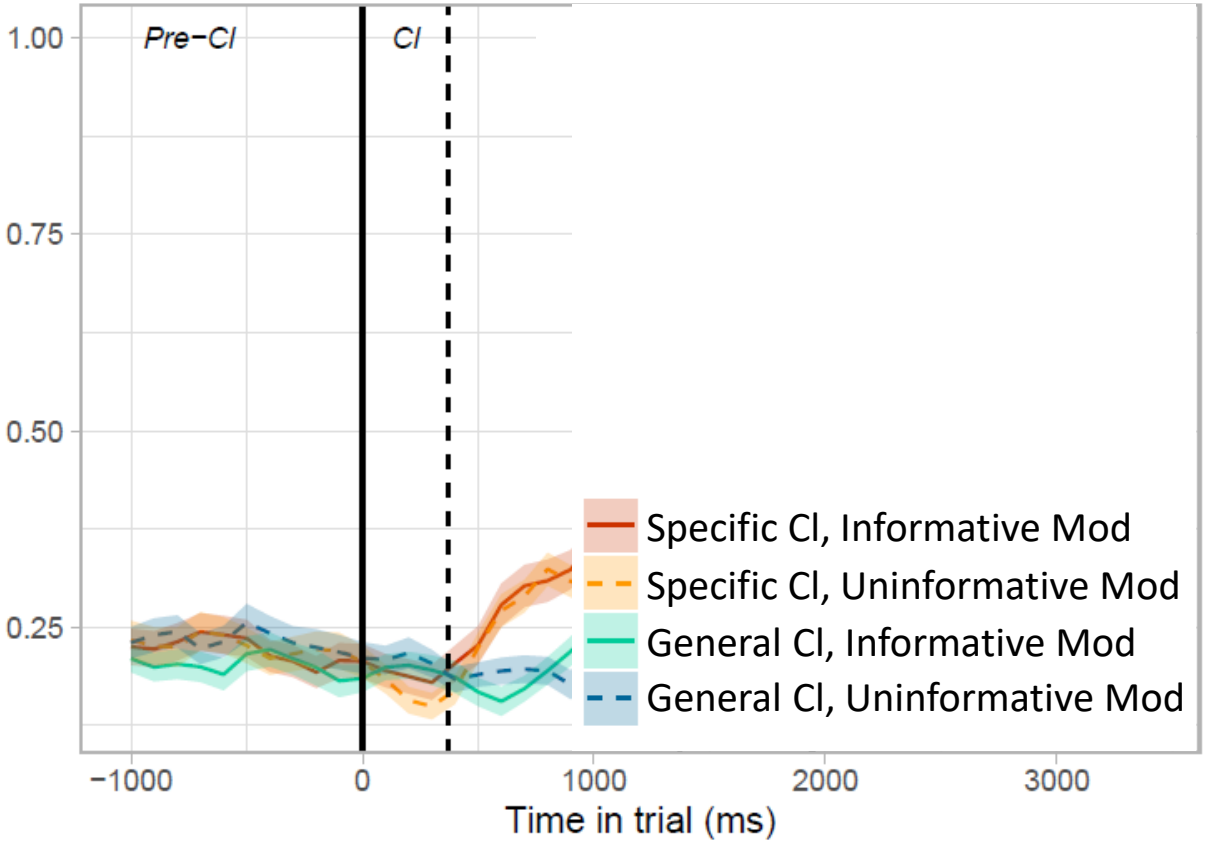
EXP 1 the visual world study: Results

Proportion of fixations to objects in the **General Cl-Uninformative Mod** condition

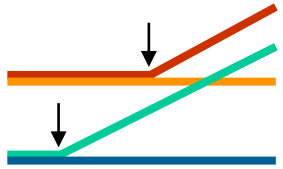


EXP 1 the visual world study: Results

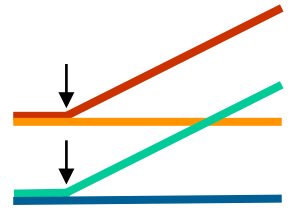
Proportion of fixations to the **target object** (e.g., table)



Overload

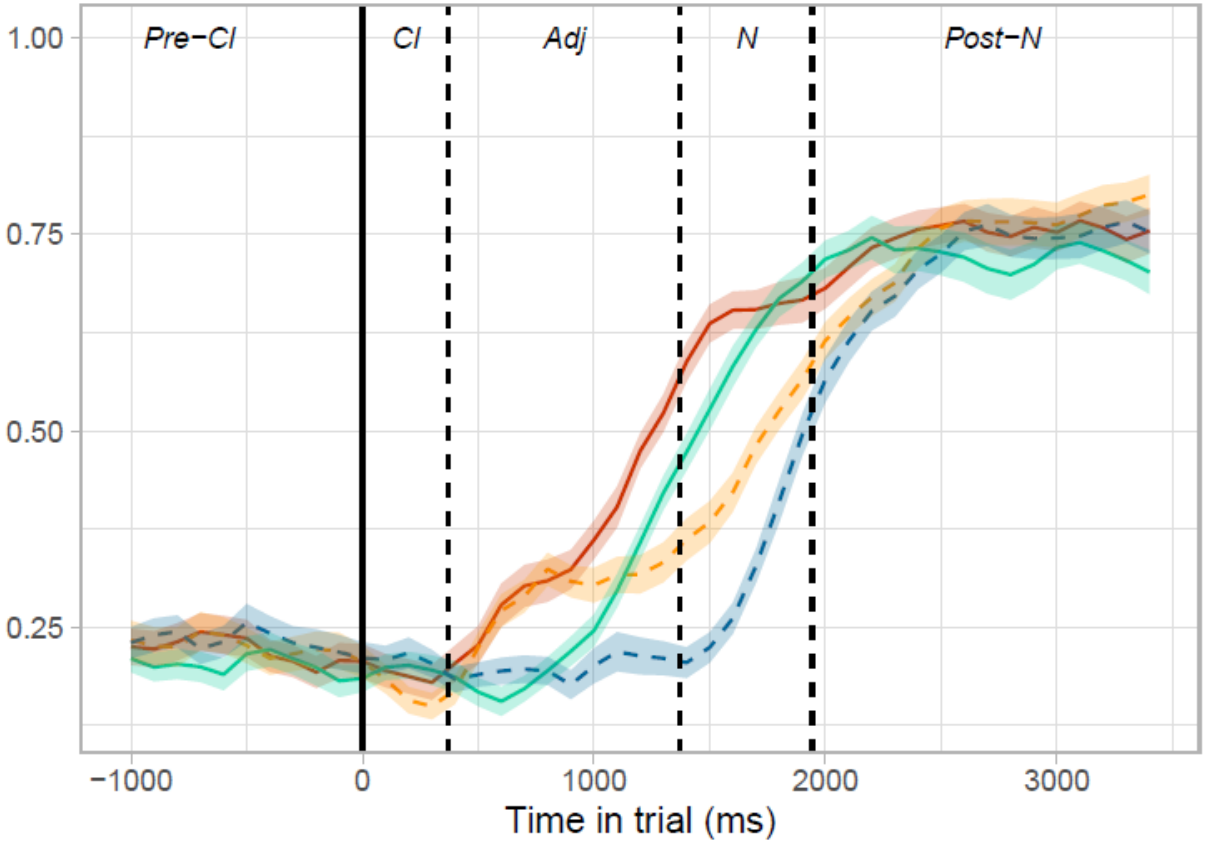


Resilient



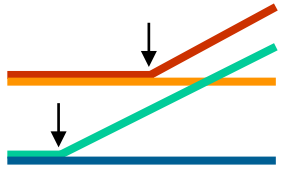
EXP 1 the visual world study: Results

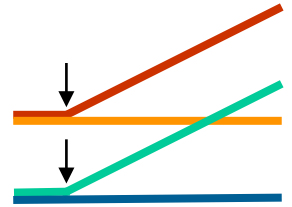
Proportion of fixations to the **target object** (e.g., table)



Overload

Resilient





Specific Cl, Informative Mod
Specific Cl, Uninformative Mod
General Cl, Informative Mod
General Cl, Uninformative Mod

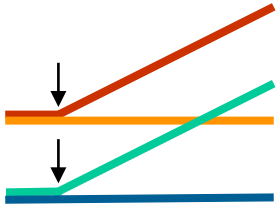
EXP 1 the visual world study: Results

Bootstrapping analysis
(Stone et al. 2021)

Following a specific classifier
819 ms, 95% CI = [740, 900]

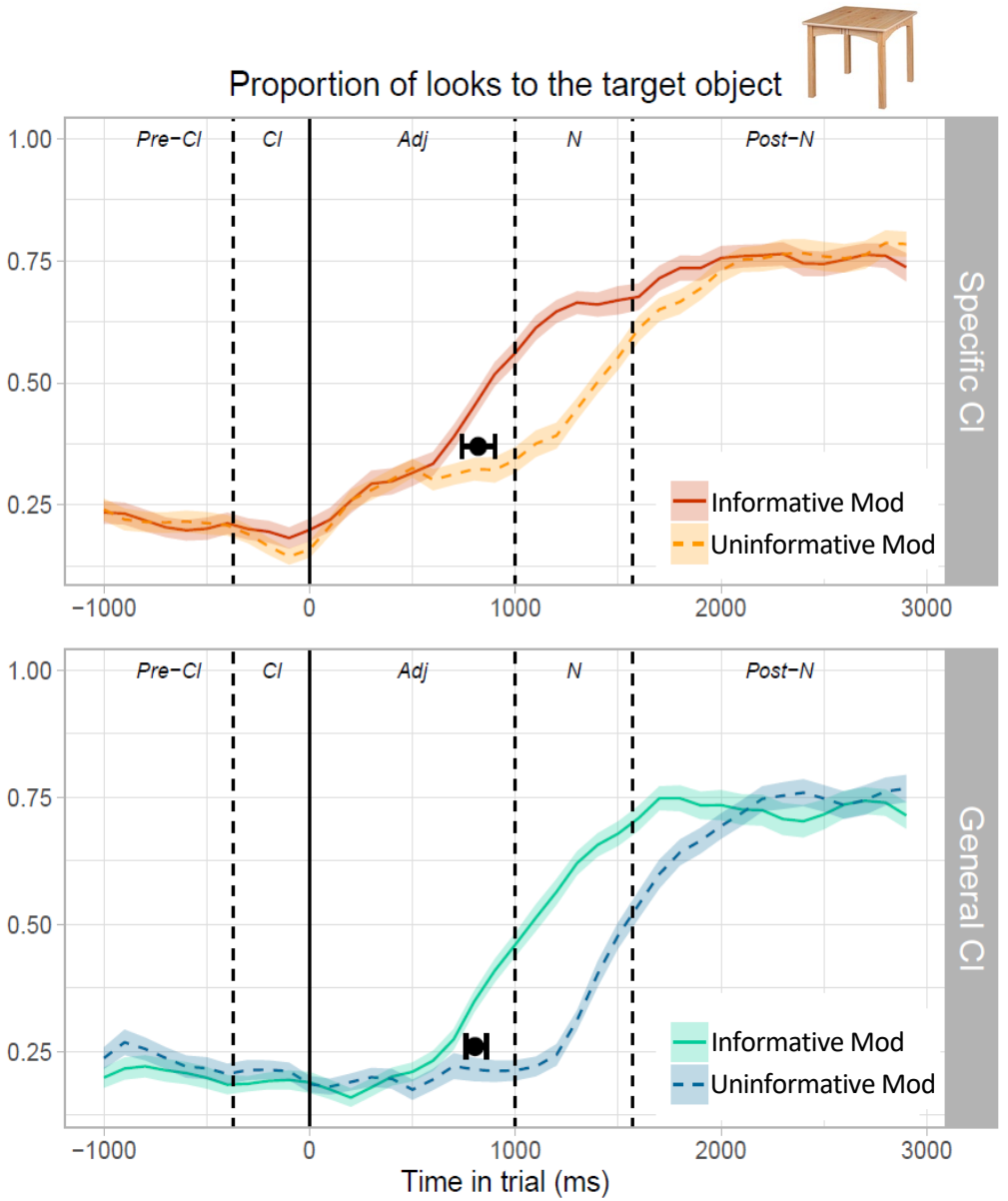
Following a general classifier
804 ms , 95% CI = [760, 860]

Resilient



No difference in divergence points

Consecutive prediction updating without measurable cost



EXP 2 the ERP study: Method

! Candidate objects were already present on the screen

In the absence of a visual display, the target noun could receive higher competition with all other possible nouns, and prediction updating might be hindered.

In EXP 2 the ERP study (38 participants, 164 items), we used the same design. Participants read sentences presented word by word at a fixed rate, with **no pre-selected candidates available**.

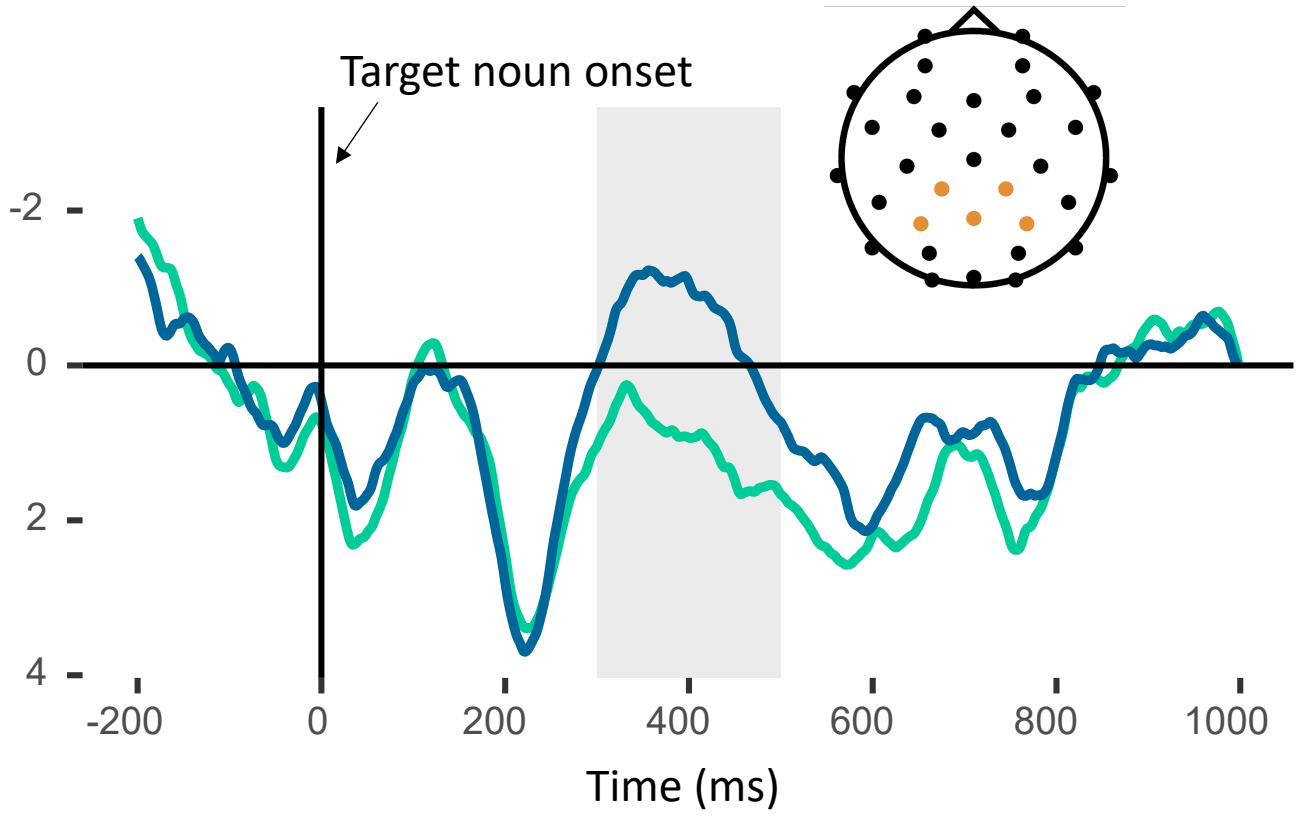
老家的院子里种了很多绿色植物，院子中央有…

The old house's courtyard is full of greenery, and in its centre, there is/are …

一	张	{下棋的/好看的}	桌子
one	**CL$_{zhang}$**	{chess-playing / good-looking}	table

一	些	{下棋的/好看的}	桌子
one	**CL$_{xie}$**	{chess-playing / good-looking}	table

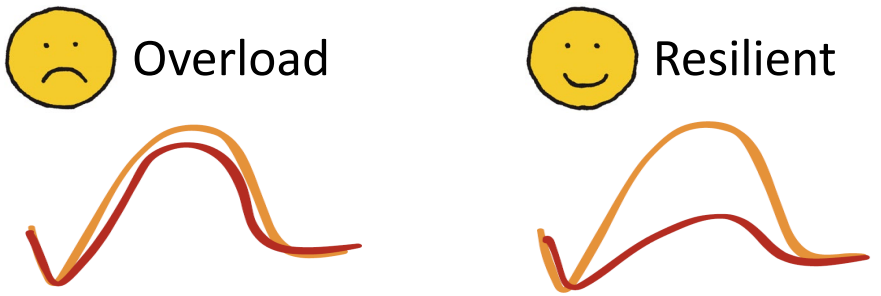
EXP 2 the ERP study: Results



The old house's courtyard is full of greenery, and in its centre, there is …

General Cl, Informative Mod: one CL_{xie} chess-playing table …

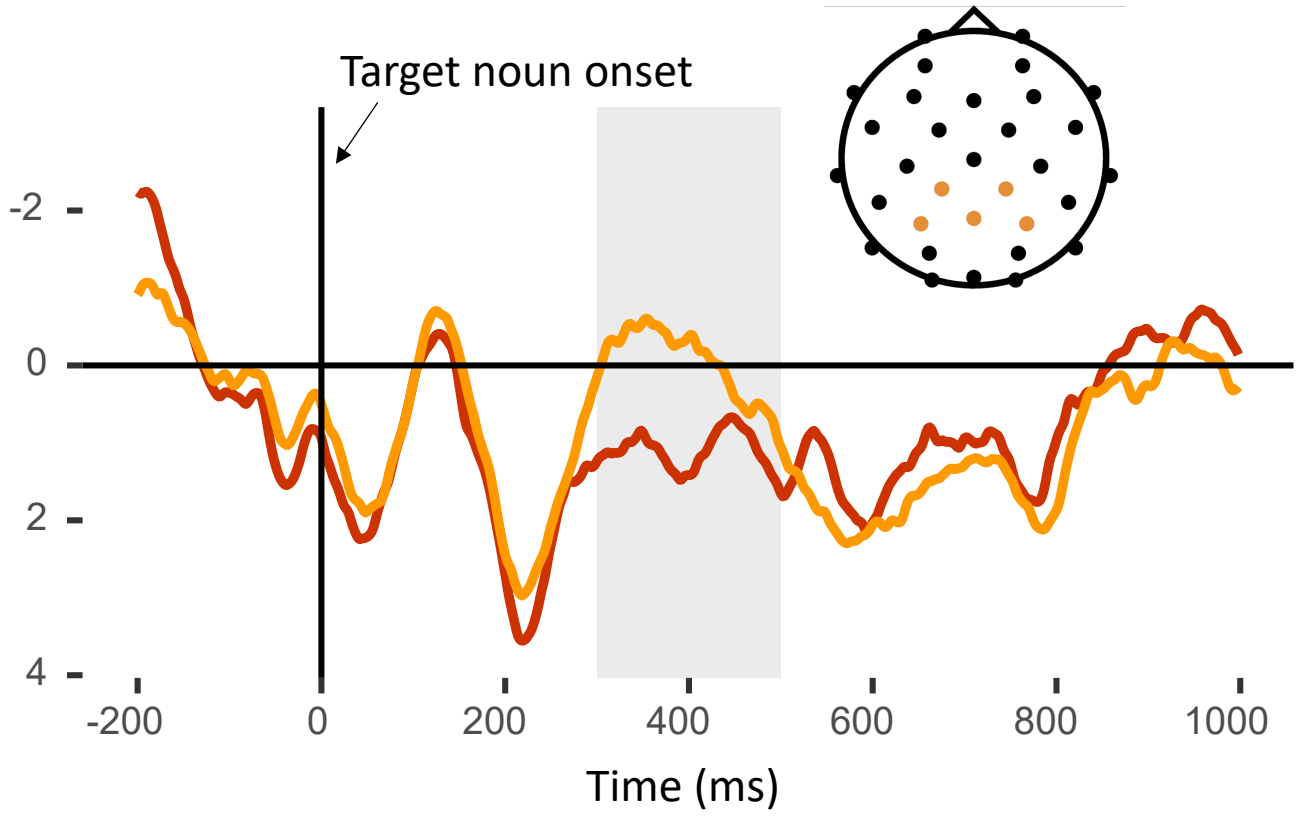
General Cl, Uninformative Mod: one CL_{xie} good-looking table …



Specific Cl, Informative Mod

Specific Cl, Uninformative Mod

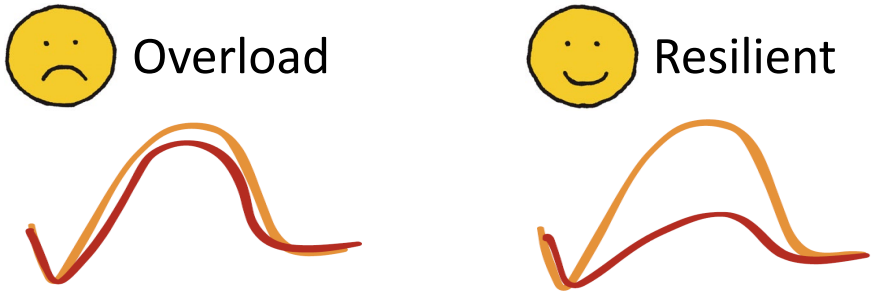
EXP 2 the ERP study: Results



The old house's courtyard is full of greenery, and in its centre, there is …

Specific Cl, Informative Mod: one CL_{zhang} chess-playing table …

Specific Cl, Uninformative Mod: one CL_{zhang} good-looking table …



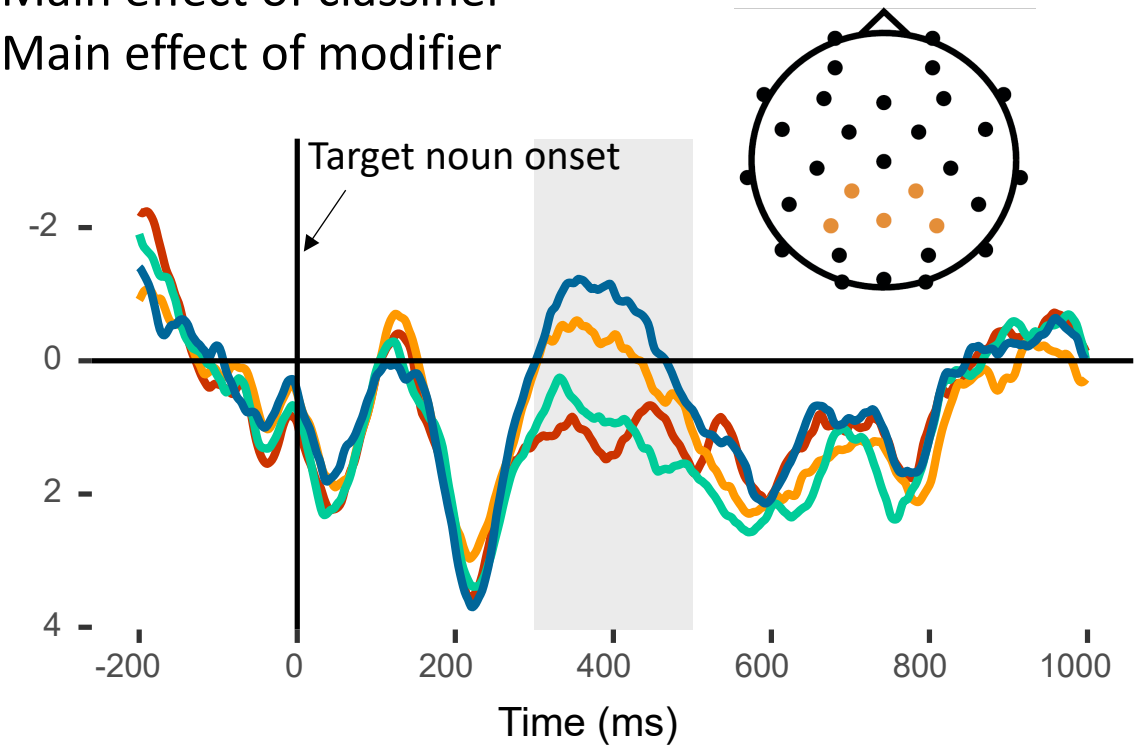
Specific Cl, Informative Mod

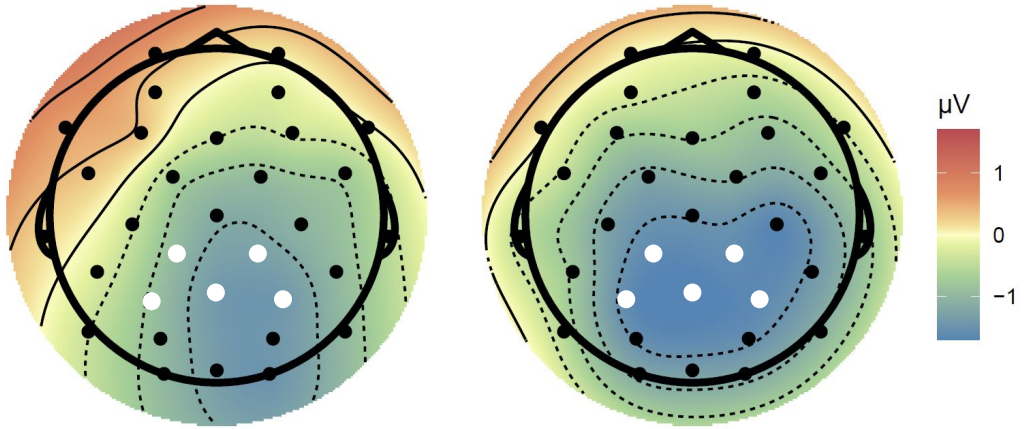
Specific Cl, Uninformative Mod

EXP 2 the ERP study: Results

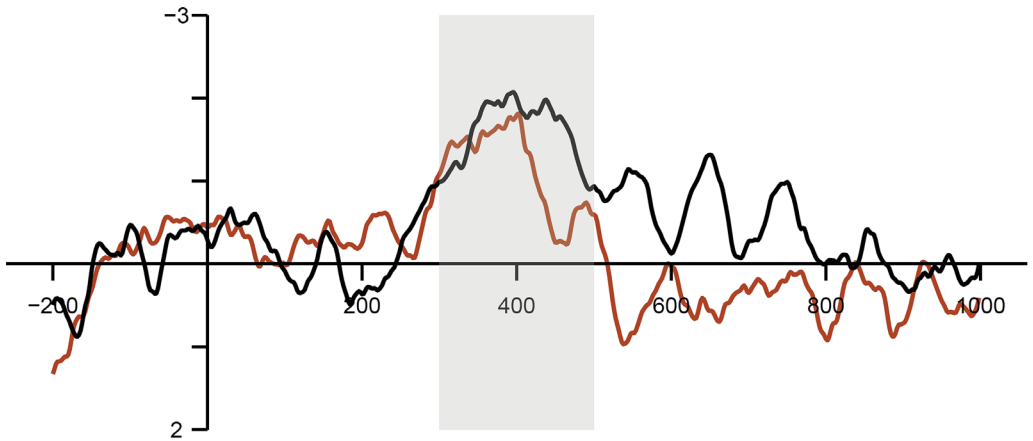
Centro-parietal Cluster, 300-500 ms

Main effect of classifier
Main effect of modifier





Specific Cl **General Cl**



The old house's courtyard is full of greenery, and in its centre, there is …

- Specific Cl, Informative Mod: one CL_{zhang} chess-playing table …
- Specific Cl, Uninformative Mod: one CL_{zhang} good-looking table …
- General Cl, Informative Mod: one CL_{xie} chess-playing table …
- General Cl, Uninformative Mod: one CL_{xie} good-looking table …

Specific Cl
General Cl

Difference wave:
Uninformative – Informative

Conclusion

EXP 1 Eye movements

- Listeners looked towards the unexpected target object upon hearing a specific classifier and informative modifier.
- The divergence points between the modifier conditions occurred at similar times following both specific and general classifiers.

EXP 2 ERP

- The N400 response to the critical unexpected noun was reduced when it was preceded by a specific classifier and an informative modifier.
- The modulation of the N400 amplitude due to the modifier was not affected by the preceding classifier.

An early sign of prediction error (i.e., a specific classifier) did not incur measurable costs that would affect subsequent semantic processing (i.e., the use of an informative modifier).

Comprehenders can use consecutive cues to update predictions effectively.

Conclusion

We are resilient comprehenders!

Resilience:

"an ability to recover from or adjust easily to misfortune or change"

– Merriam-Webster Dictionary

Thank You

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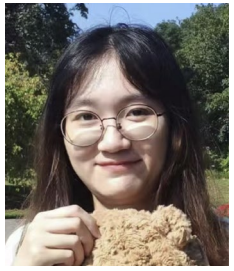

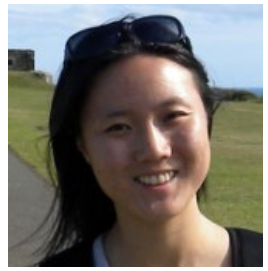

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Reference

Altmann, G. T. M., & Kamide, Y. (1999). Incremental interpretation at verbs: Restricting the domain of subsequent reference. Cognition, 73(3), 247–264. https://doi.org/10.1016/S0010-0277(99)00059-1

Chow, W.-Y., & Chen, D. (2020). Predicting (in)correctly: Listeners rapidly use unexpected information to revise their predictions. Language, Cognition and Neuroscience, 35(9), 1149–1161. https://doi.org/10.1080/23273798.2020.1733627

DeLong, K. A., Urbach, T. P., & Kutas, M. (2005). Probabilistic word pre-activation during language comprehension inferred from electrical brain activity. Nature Neuroscience, 8(8), 1117–1121. https://doi.org/10.1038/nn1504

Federmeier, K. D., & Kutas, M. (1999). A Rose by Any Other Name: Long-Term Memory Structure and Sentence Processing. Journal of Memory and Language, 41(4), 469–495. https://doi.org/10.1006/jmla.1999.2660

Fleur, D. S., Flecken, M., Rommers, J., & Nieuwland, M. S. (2020). Definitely saw it coming? The dual nature of the pre-nominal prediction effect. Cognition, 204, 104335. https://doi.org/10.1016/j.cognition.2020.104335

Gussow, A. E., Kapnoula, E. C., & Molinaro, N. (2019). Any leftovers from a discarded prediction? Evidence from eye-movements during sentence comprehension. Language, Cognition and Neuroscience, 34(8), 1041–1058. https://doi.org/10.1080/23273798.2019.1617887

Husband, E. M., & Bovolenta, G. (2020). Prediction failure blocks the use of local semantic context. Language, Cognition and Neuroscience, 35(3), 273–291. https://doi.org/10.1080/23273798.2019.1651881

Kamide, Y., Altmann, G. T. M., & Haywood, S. L. (2003). The time-course of prediction in incremental sentence processing: Evidence from anticipatory eye movements. Journal of Memory and Language, 49(1), 133–156. https://doi.org/10.1016/S0749-596X(03)00023-8

Kutas, M., DeLong, K. A., & Smith, N. J. (2011). A look around at what lies ahead: Prediction and predictability in language processing. In Predictions in the brain: Using our past to generate a future. Oxford University Press. https://doi.org/10.1093/acprof:oso/9780195395518.001.0001

Ryskin, R., & Nieuwland, M. S. (2023). Prediction during language comprehension: What is next? Trends in Cognitive Sciences, 0(0). https://doi.org/10.1016/j.tics.2023.08.003

Stone, K., Lago, S., & Schad, D. J. (2021). Divergence point analyses of visual world data: Applications to bilingual research. Bilingualism: Language and Cognition, 24(5), 833–841. https://doi.org/10.1017/S1366728920000607

Szewczyk, J. M., Mech, E. N., & Federmeier, K. D. (2022). The power of “good”: Can adjectives rapidly decrease as well as increase the availability of the upcoming noun? Journal of Experimental Psychology: Learning, Memory, and Cognition, 48(6), 856–875. https://doi.org/10.1037/xlm0001091

Szewczyk, J. M., & Schriefers, H. (2013). Prediction in language comprehension beyond specific words: An ERP study on sentence comprehension in Polish. Journal of Memory and Language, 68(4), 297–314. https://doi.org/10.1016/j.jml.2012.12.002

Szewczyk, J. M., & Wodniecka, Z. (2020). The mechanisms of prediction updating that impact the processing of upcoming word: An event-related potential study on sentence comprehension. Journal of Experimental Psychology: Learning, Memory, and Cognition, 46(9), 1714–1734. https://doi.org/10.1037/xlm0000835

Wicha, N. Y. Y., Moreno, E. M., & Kutas, M. (2004). Anticipating Words and Their Gender: An Event-related Brain Potential Study of Semantic Integration, Gender Expectancy, and Gender Agreement in Spanish Sentence Reading. Journal of Cognitive Neuroscience, 16(7), 1272–1288. https://doi.org/10.1162/0898929041920487

Cloze probability tasks

We did three rounds of offline cloze tasks.

- Before the classifier

  It's too dark. To read the words on the book, Jack brings one _____.

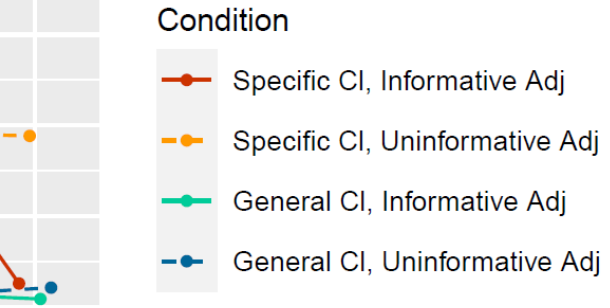
- After the classifier but before the adjective

  It's too dark. To read the words on the book, Jack brings one {CL_specific/CL_general} _____.

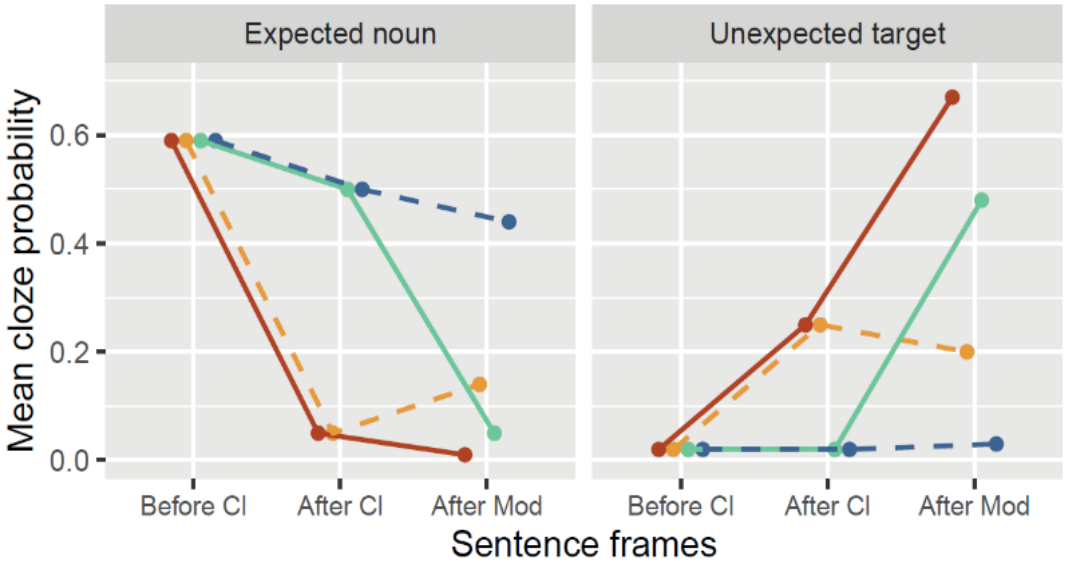
- After the adjective but before the noun

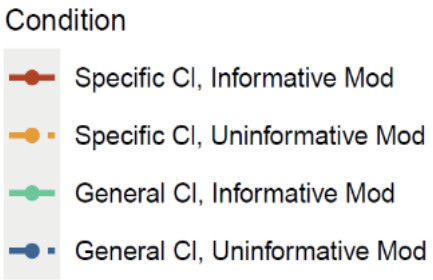
  It's too dark. To read the words on the book, Jack brings one {CL_specific/CL_general} {Mod_informative/Mod_uninformative} _____.

Cloze probability tasks



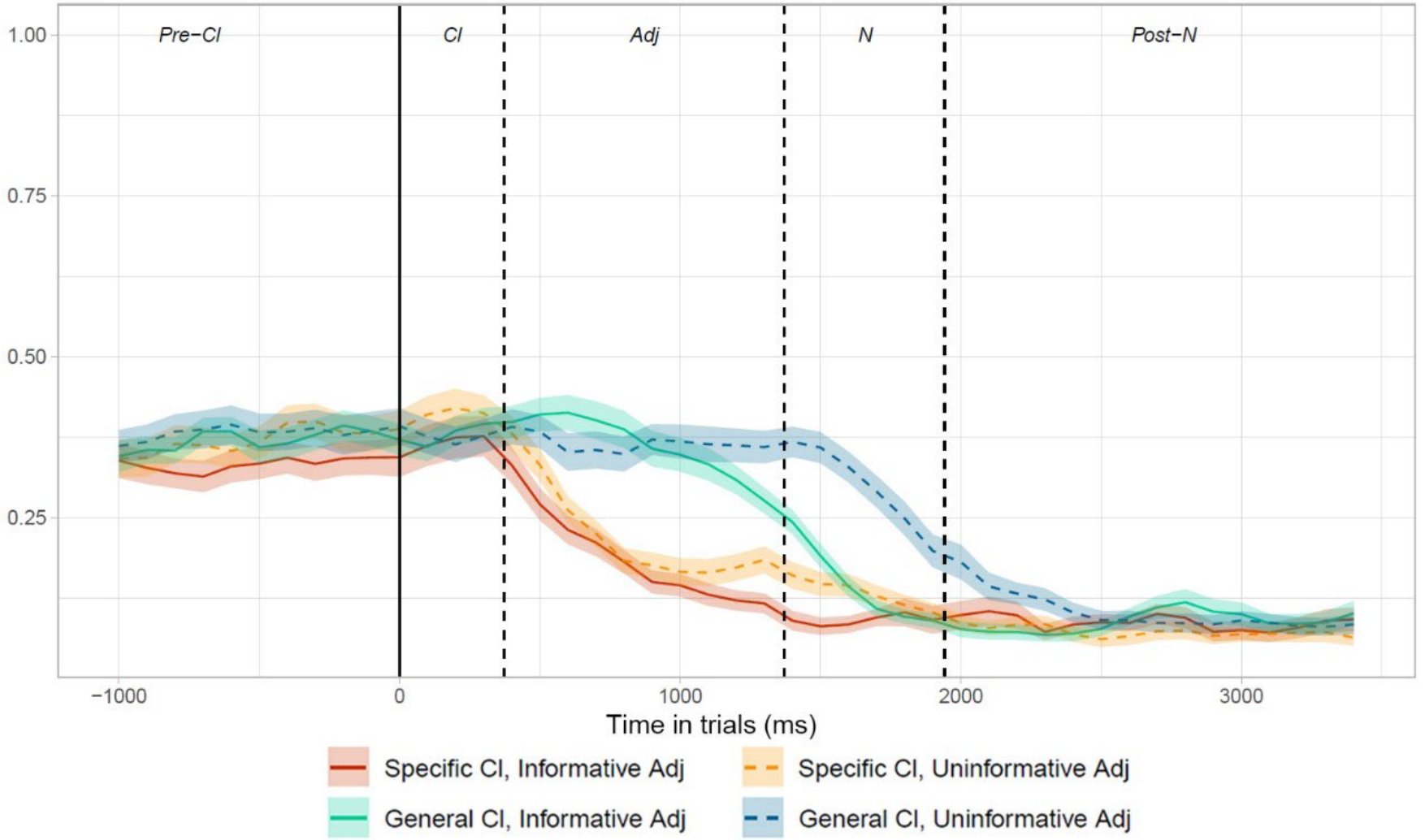
Visual-world study



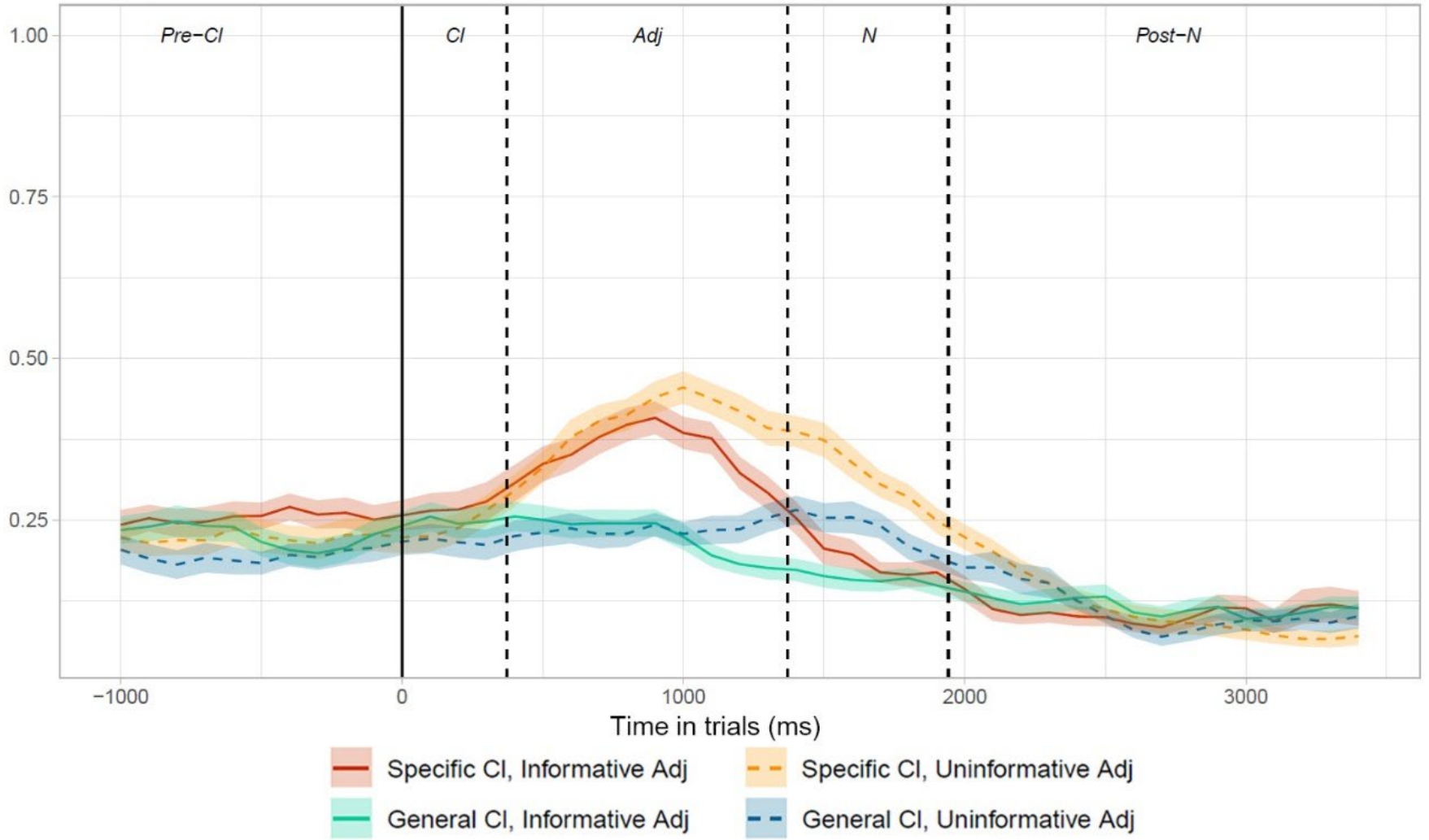


ERP study

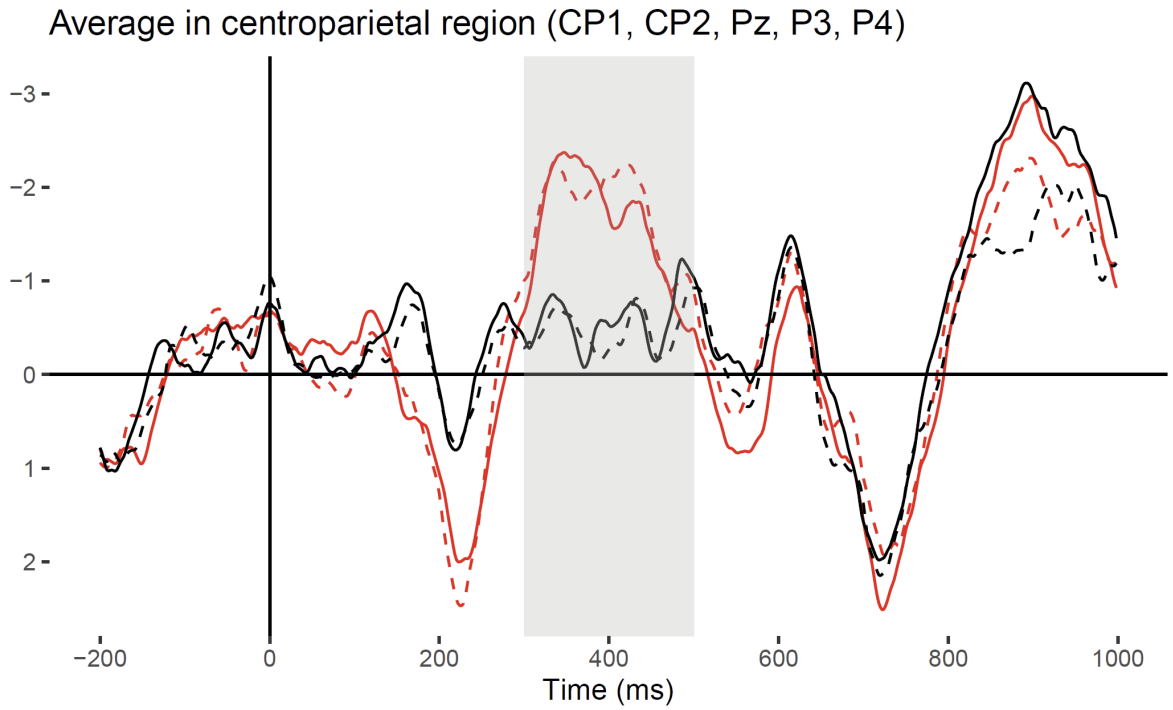
Looks to the expected object



Looks to the unexpected competitor



ERP at the classifier



Specific Cl, Informative Mod: one CL_{zhang} chess-playing table …

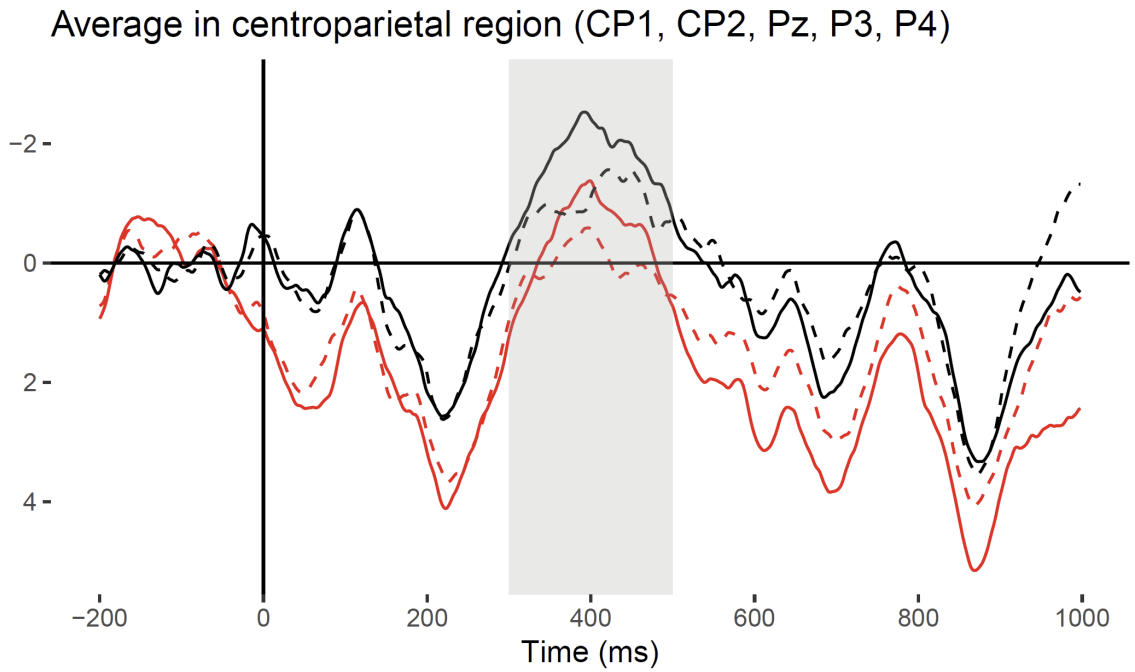
Specific Cl, Uninformative Mod: one CL_{zhang} good-looking table …

General Cl, Informative Mod: one CL_{xie} chess-playing table …

General Cl, Uninformative Mod: one CL_{xie} good-looking table …

Main effect of classifier
(collapsed over modifier conditions)

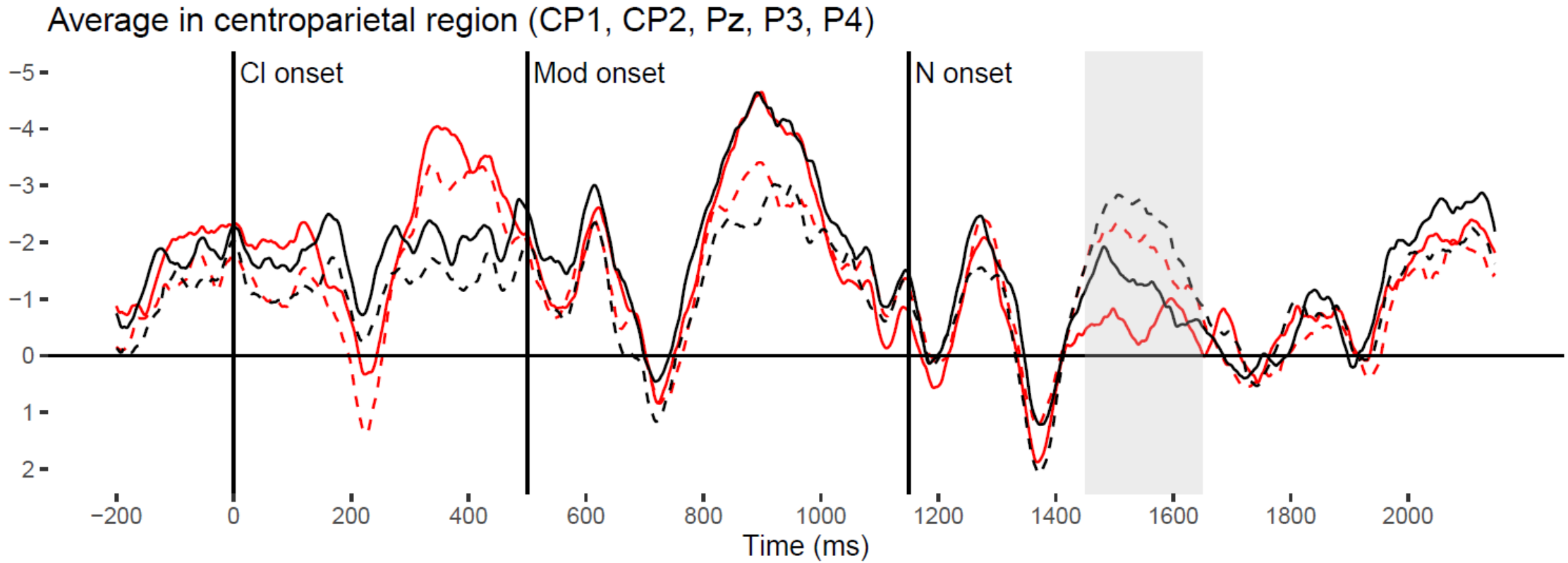
ERP at the modifier



Main effect of classifier
Main effect of modifier

Specific Cl, Informative Mod: one CL_{zhang} chess-playing table …
Specific Cl, Uninformative Mod: one CL_{zhang} good-looking table …
General Cl, Informative Mod: one CL_{xie} chess-playing table …
General Cl, Uninformative Mod: one CL_{xie} good-looking table …

ERP long epoch (no baseline correction)



Specific Cl, Informative Mod: one CL_{zhang} chess-playing table …

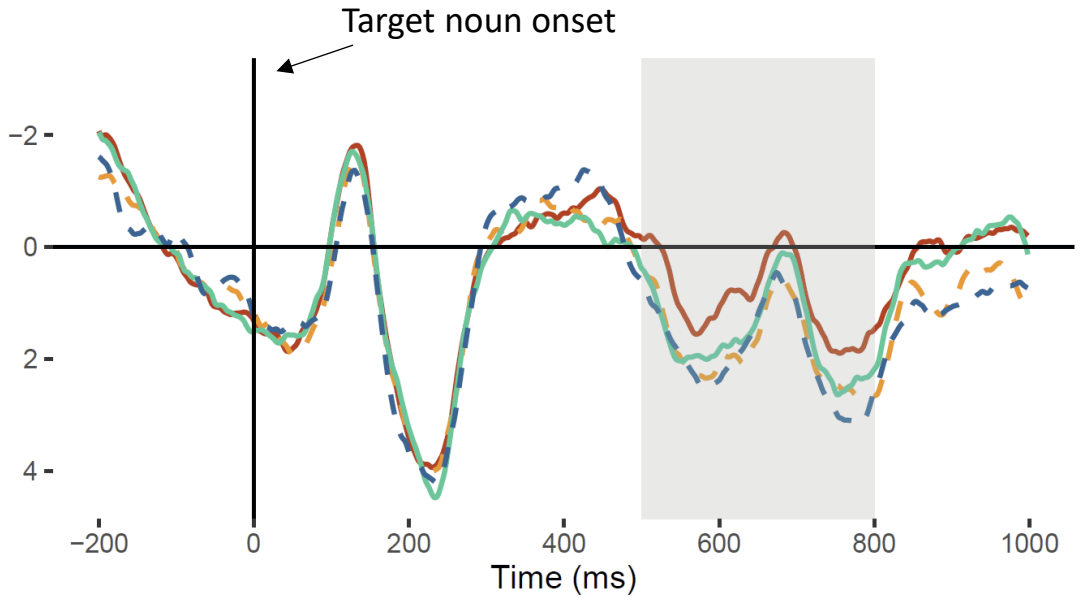
Specific Cl, Uninformative Mod: one CL_{zhang} good-looking table …

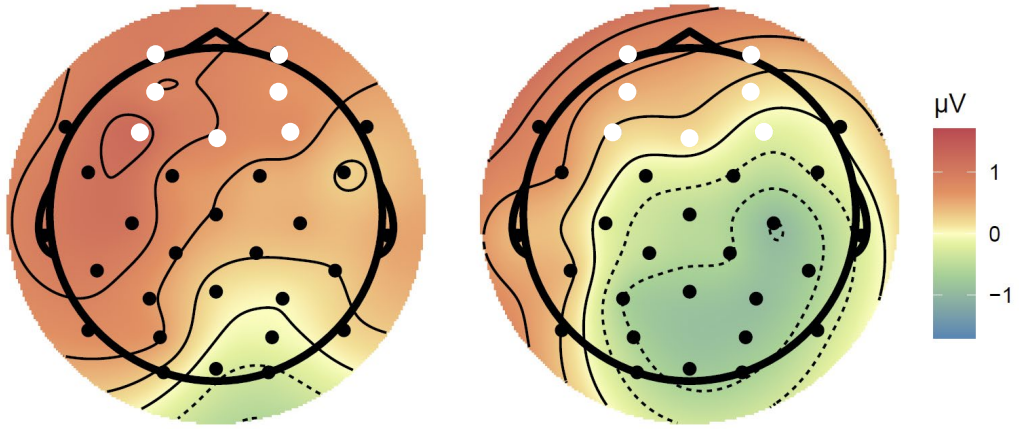
General Cl, Informative Mod: one CL_{xie} chess-playing table …

General Cl, Uninformative Mod: one CL_{xie} good-looking table …

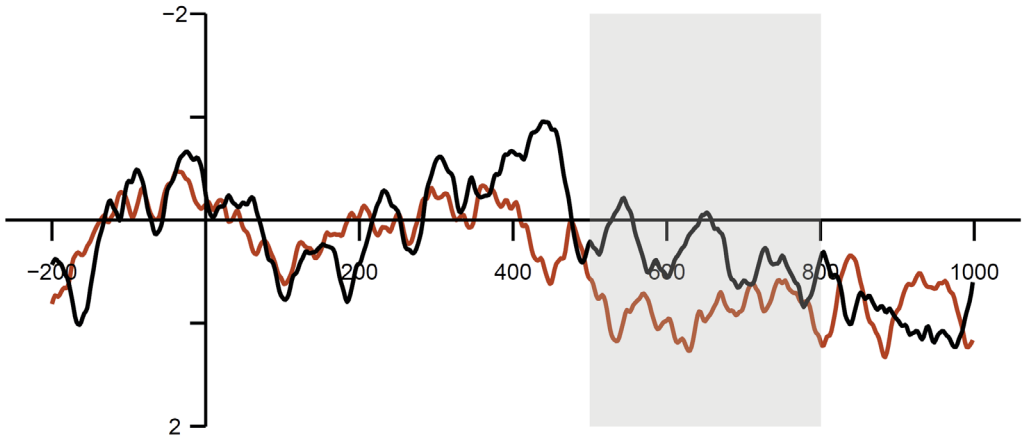
Frontal Cluster, 500-800 ms

Only a marginal effect of modifier





Specific Cl **General Cl**



The old house's courtyard is full of greenery, and in its centre, there is …

- Specific Cl, Informative Mod: one CL_{zhang} chess-playing table …
- Specific Cl, Uninformative Mod: one CL_{zhang} good-looking table …
- General Cl, Informative Mod: one CL_{xie} chess-playing table …
- General Cl, Uninformative Mod: one CL_{xie} good-looking table …

Specific Cl

General Cl

Difference wave: Uninformative – Informative

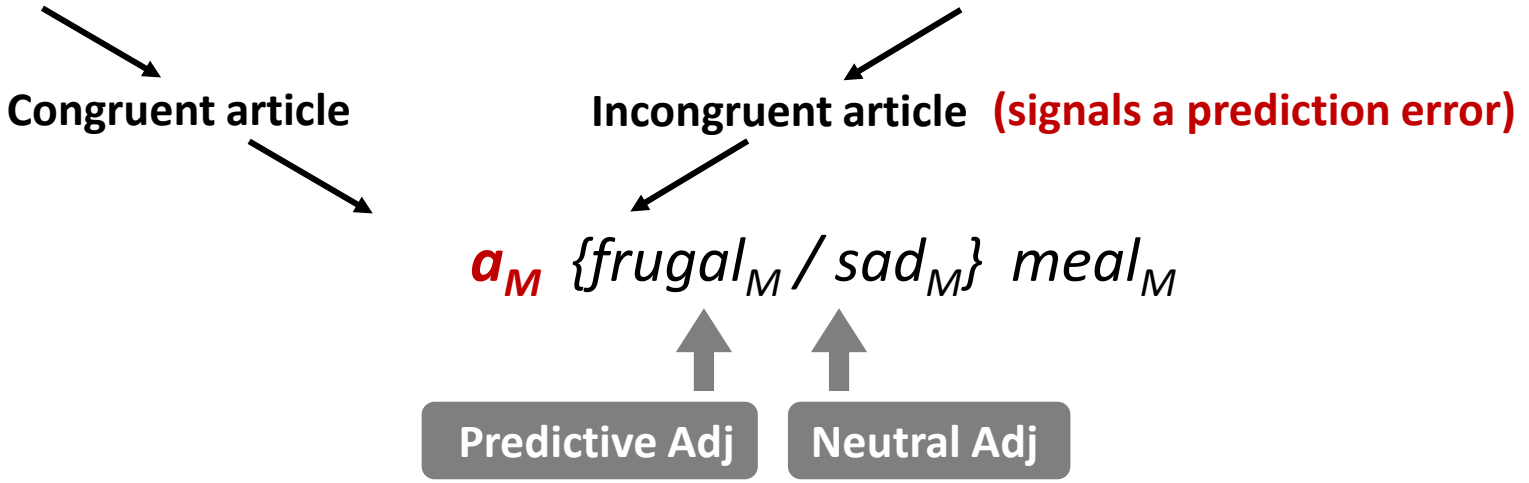
Prediction error can disrupt subsequent semantic processing?

Husband and Bovolenta (2020) demonstrated that comprehenders couldn't take advantage of informative adjectives after they encountered a prediction error.

(originally in Italian)

Before the execution, the condemned person had ……
(**expected**: $meal_M$)

Many claim that the secretary stole some money, but he refused ……
(**expected**: $accusation_F$)



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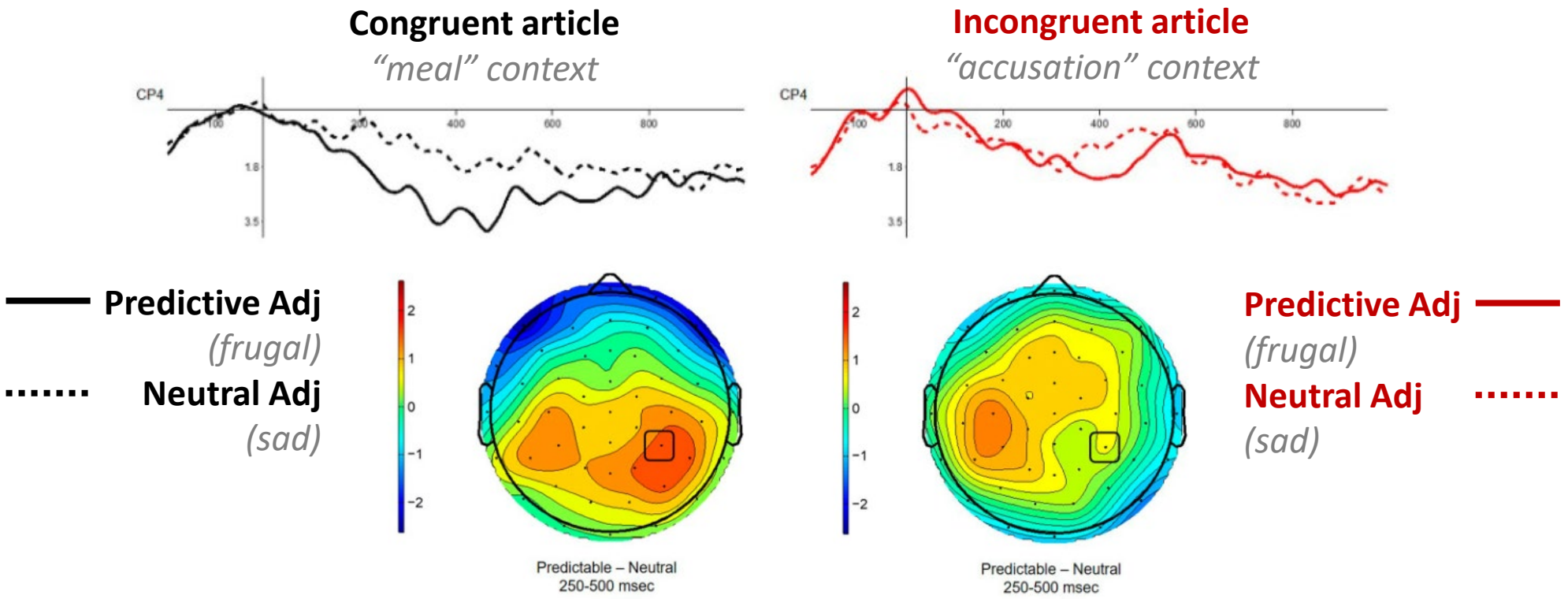

Prediction error can disrupt subsequent semantic processing?

However, Husband and Bovolenta (2020) defined predictive/neutral adjective by co-occurrence frequencies

- i.e., the conditional probability of the noun given the adjective in an Italian corpus.
- It is possible that the predictive adjectives were not truly predictive of the noun in the sentence context they used in the experiment.
- In fact, as the target noun was **implausible** following an incongruent article in most items, even the predictive adjective could not make the noun more likely in these sentence contexts.