Contextual Influence on Chinese Homonym Disambiguation in Large Language Models: Evidence from Angular Distance Analysis

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Lexical Ambiguity & Context

homonym(s):

bank
- a financial institution 
- the land alongside a body of water 

粉丝
- someone's fan 
- stringy food made from starch such as green beans 

Lexical ambiguity: a single word form is associated with two or more distinct meanings (challenge for efficient communication)

Languages exploit ambiguity to balance speaker effort and listener resolution (Piantadosi et al., 2012);

Contextual information: rapidly narrows down the possible interpretations of an ambiguous word

stronger contextual content around a homonymous character significantly improves the selection of its intended meaning (Wang, 2011)

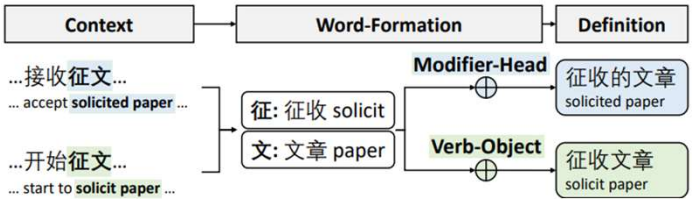
What is the inner world in Large Language Models?

Prior Work & Research Gap

The extent of congruent contextual affects the word embeddings of **English homonyms** (Trott & Bergen, 2021)

Chinese word senses → Transformer's self-attention mechanism (Li et al., 2024)
- **83.71%**
- **PKU Paraphrase Bank dataset**

FormBERT → Incorporates Chinese word-formation knowledge into LMs (Zheng et al., 2021)



However !

Rely more on annotated sense inventories, glosses, or auxiliary knowledge bases and focus on improving classification metrics

Less studies: integrating LLMs with internal architecture for ***Chinese ambiguity resolution***

(Zhang & Jia, 2025)

A clear gap: understanding context-driven sense representations in LLMs within the typologically distinct Chinese language

Research Question:

Main Question:

How does **context** influence the **disambiguation** of Chinese homonyms in large language models (LLMs)?

- To what extent does the **degree of contextual similarity** affect the semantic separation of homonyms in LLMs?
- How does the impact of context compare to other linguistic factors such as **sense** difference and **part-of-speech (POS)** categories?
- At which **layers** within LLMs does contextual information most strongly modulate **word representations**?

Dataset Construction:

a sentence-pair dataset comprising 64 Chinese homonyms while systematically controlling for sense, context similarity, and POS categories

人流：/ rén liú：

Same Context + Same Sense:

她因为刚做完人流而十分焦虑 / She is very anxious because she just had an abortion

她因为刚选择人流而十分焦虑 / She is very anxious because she just chose an abortion;

Different Context + Different Sense :

这个新建的旅游景点昨日人流巨大 / This newly built tourist attraction had a huge flow of people yesterday

去私立医院做人流往往收费较高 / Going to a private hospital for an abortion often comes with higher fees

Half of the target words were associated with two senses sharing the same POS

8 sentences for each sense, 1024 sentences total

Experimental Design:

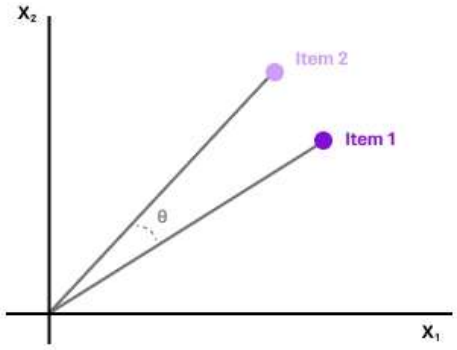
14 LLMs from two families: **Llama and Qwen**

1. Input: **feed sentence pairs** containing homonyms into each model

2. Embedding Extraction: extract contextualized **token embeddings** at each transformer layer for the target homonym

3. Similarity Computation: compute **angular distance** between the **two embeddings**

$$\theta = \arccos\left(\frac{v_1 \cdot v_2}{\|v_1\|\|v_2\|}\right)$$

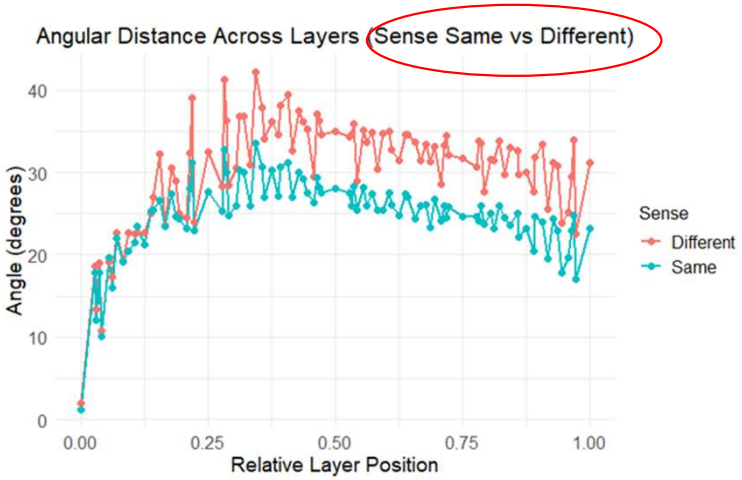


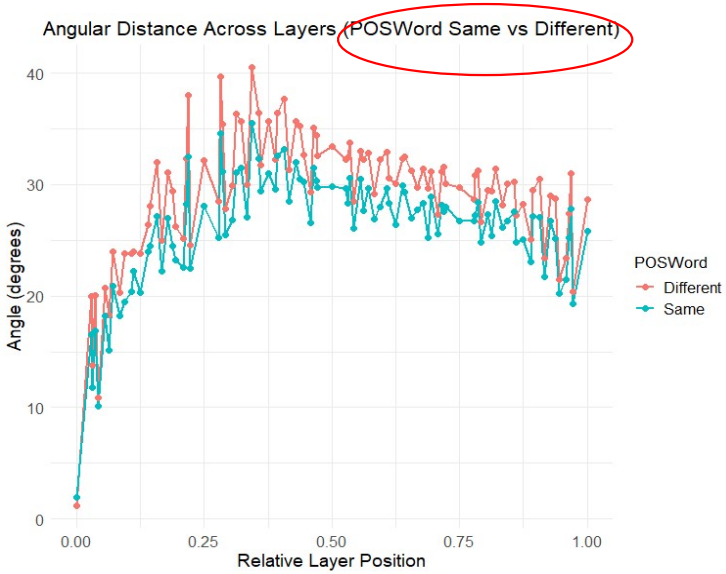
semantic separation between two embedding vectors

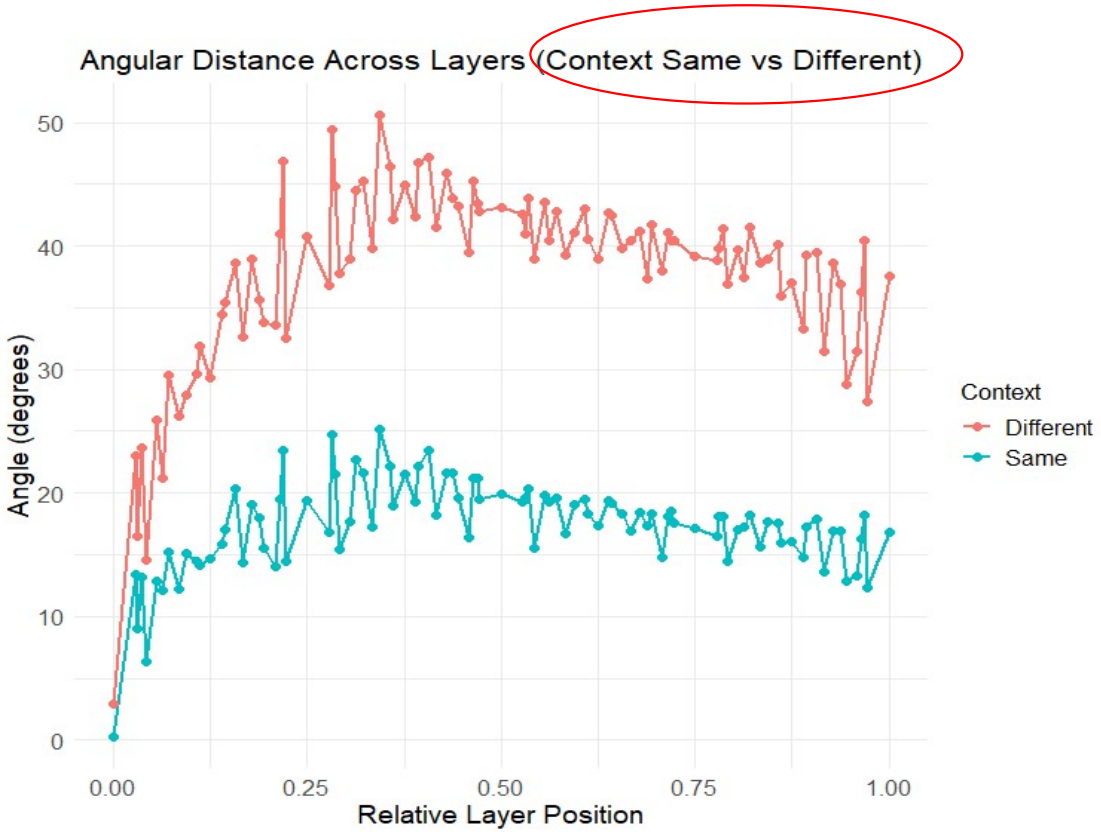
A smaller angular distance (closer to 0°) indicates that the two vectors are highly aligned

angular distance offers a more interpretable geometric measure

Result 1: Context Effect Strongest



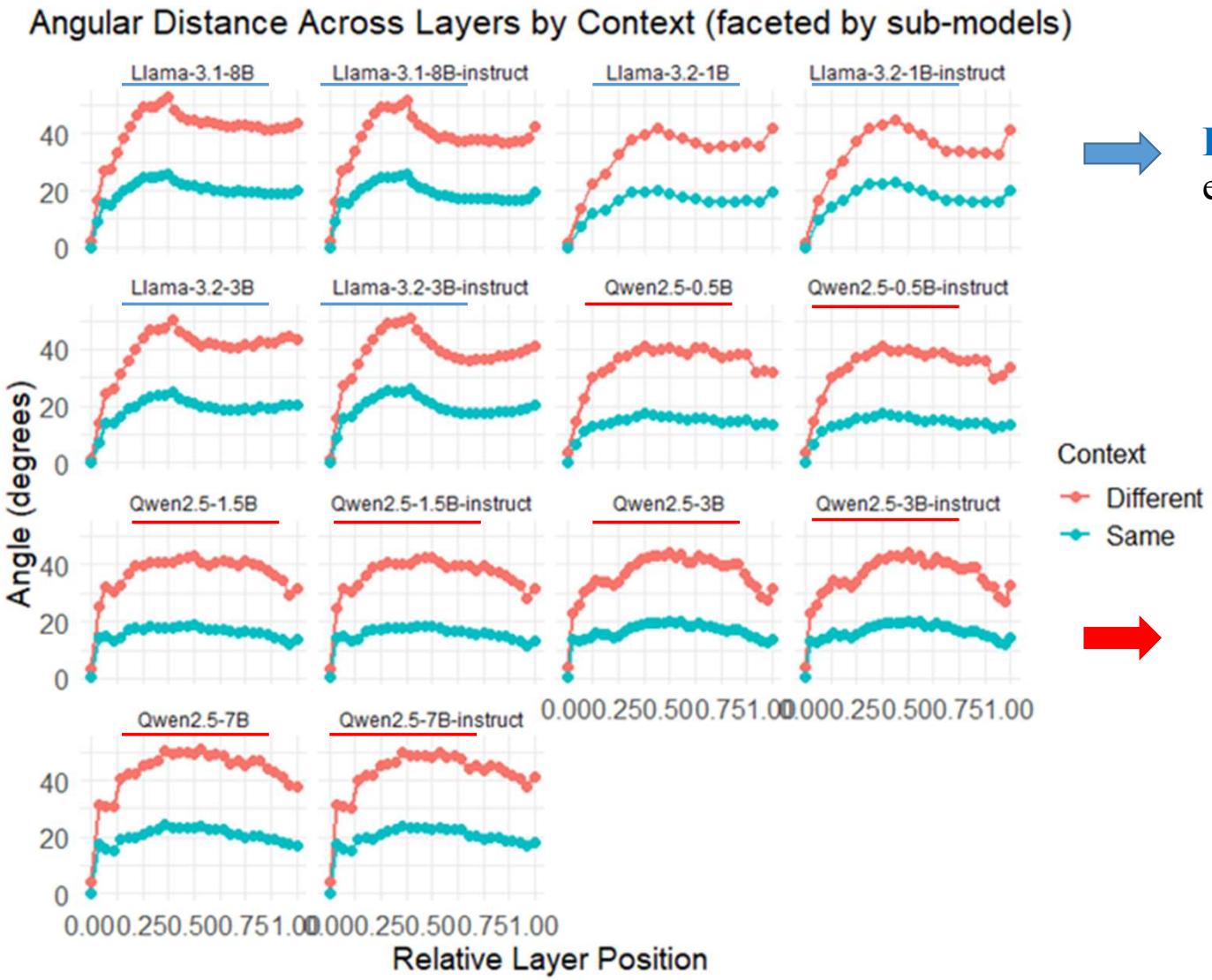




Context produced the largest angular separation in embedding space

LLMs are particularly sensitive to **contextual divergence** when processing ambiguous words

Result 1: Context Effect Strongest



Llama family: reach a peak separation earlier in their layer depths

Llama family show earlier and sharper context differentiation, whereas **Qwen family** distribute it more evenly across layers

Qwen family: reach a more gradual and relatively flatter angular separation profile

Result 2: Condition Combination Effect

```
Fixed effects:
                                Estimate  Std. Error          df  t value            Pr(>|t|)
(Intercept)                      41.8122      0.7048     13.3332   59.328 <0.0000000000000002 ***
SenseSame                        -9.4013      0.1195 219674.9978  -78.695 <0.0000000000000002 ***
ContextSame                     -17.6387      0.1195 219674.9978 -147.648 <0.0000000000000002 ***
POSwordSame                      -3.0308      0.1169 219674.9978  -25.916 <0.0000000000000002 ***
SenseSame:ContextSame             1.8207      0.1689 219674.9978   10.777 <0.0000000000000002 ***
SenseSame:POSwordSame             6.5898      0.1654 219674.9978   39.844 <0.0000000000000002 ***
ContextSame:POSwordSame          -5.6495      0.1654 219674.9978  -34.158 <0.0000000000000002 ***
SenseSame:ContextSame:POSwordSame -2.1732     0.2339 219674.9978   -9.291 <0.0000000000000002 ***
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Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
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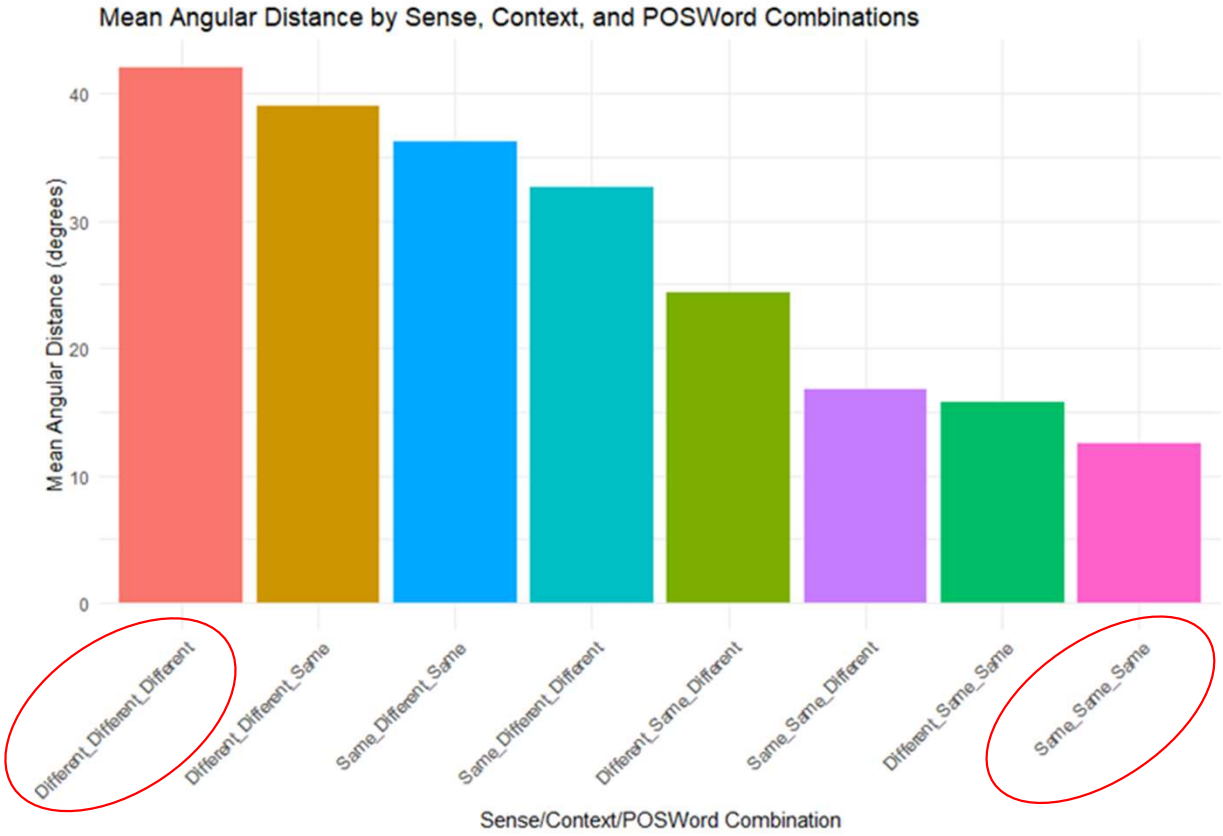


```
lmer(angle ~ Sense * Context * POSword + (1 | model)
```

linear mixed-effects regression model:

Context had the strongest influence on angular distance

All main effects and interactions were highly significant ($p < 0.001$)

angular distance was largest when all three variables (sense, context, POS) differed

The greatest semantic representational separation under maximal divergence

Layer-wise Context Significance

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lmer(angle ~ Sense*Context*POSWord + (1|word)
```
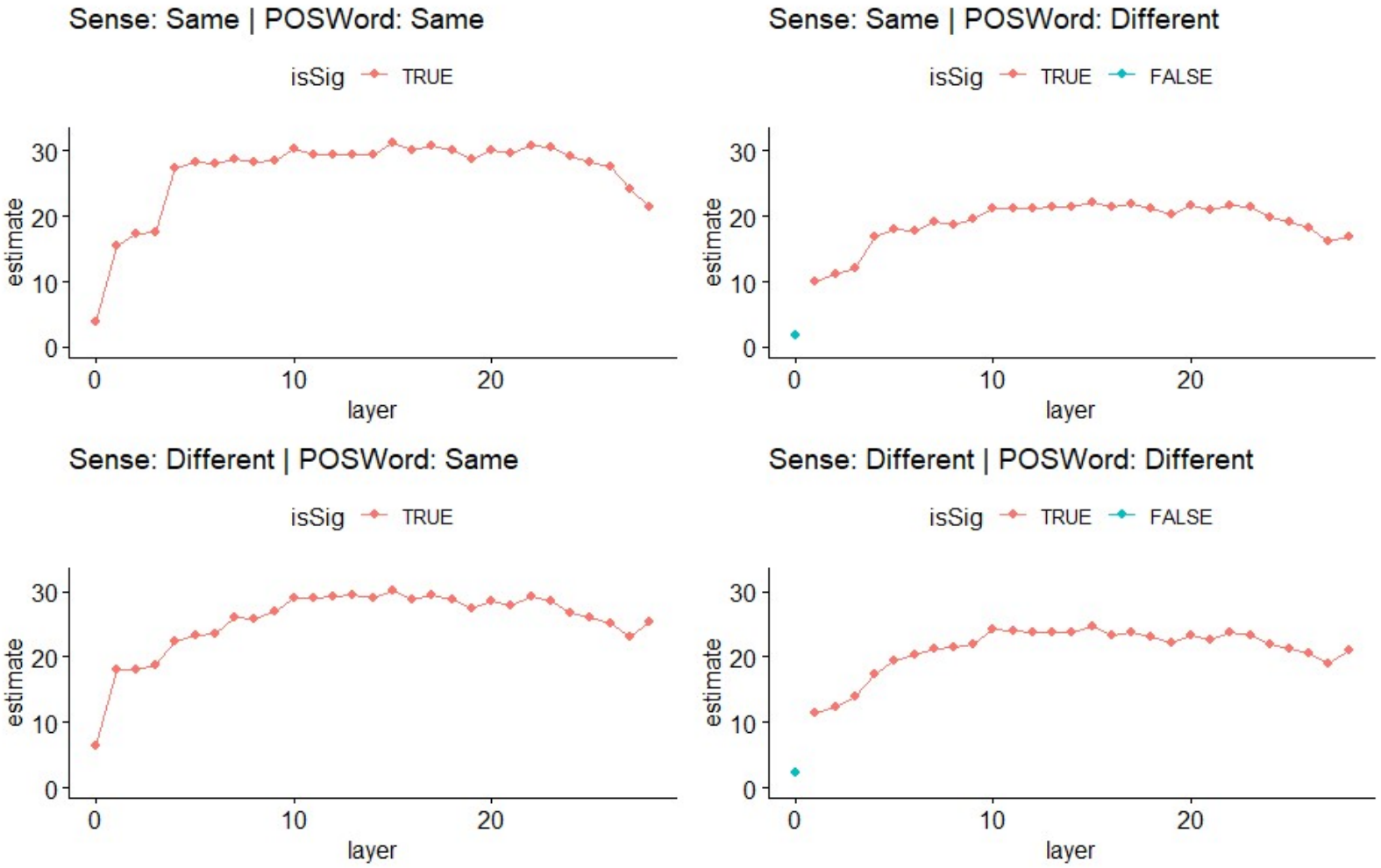

Qwen2.5-7B



contextual information exerts a growing and dominant role in shaping the internal semantic representations **as processing progresses through the model's layers**

Conclusion:

Investigated how context influences Chinese homonym disambiguation in LLMs by curating a controlled sentence-pair dataset

The context exerted the strongest effect compared to sense and POS factors

Contextual effects became stronger and more significant toward the middle and later layers

Models pre-trained on more Chinese data (e.g., Qwen) exhibited greater semantic separation for homonyms than models trained **predominantly on English data (e.g., Llama)** **?**

This study deepens our understanding of the inner representations by which LLMs process Chinese lexical ambiguity and informs the development of more trustworthy language models

Future Studies:

Incorporate human behavioral task (sentence-level semantic judgement task), and neurocognitive data (fMRI) to better align LLM internal processes with human semantic representations

Thanks for listening!

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