THE HONG KONG POLYTECHNIC UNIVERSITY
香港理工大學

Human vs. LLM Chinese Homonym Disambiguation:
Contextual, Syntactic, and Developmental Influences Across the Lifespan

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Outline

- Factors impacting homonym processing
  - Contextual influence
  - Syntactic influence: Part of speech (POS)
  - Developmental influence: Age of acquisition (AoA)

- Ongoing work on age-related changes
  - AoA effects
  - Word retrieval and forgetting mechanism
  - induced Pluripotent Stem Cell (iPSC)-based approaches to mitigate age-related deficits in memory and language functions

Context effect

- The Two-stage Exhaustive Access Hypothesis
  - all possible meanings of a homonym are initially accessed, with contextual information subsequently used to select the appropriate sense (Swinney, 1979).
- The Context-dependency Direct-access Hypothesis
  - context can directly influence which meaning is accessed, bypassing the exhaustive activation of all meanings (Simpson, 1981; Tabossi, 1988).
- The Reordered Access Hypothesis
  - context, frequency, and meaning dominance dynamically interact to reorder meaning accessibility during processing (Duffy, Morris, & Rayner, 1988; Twilley & Dixon, 2000).

duck: n. water bird
v. moving the head quickly downwards

He **ducked** his head to hide his admiration.

I **wound** my watch and **wound** my ankle while hiking the rocky trail.

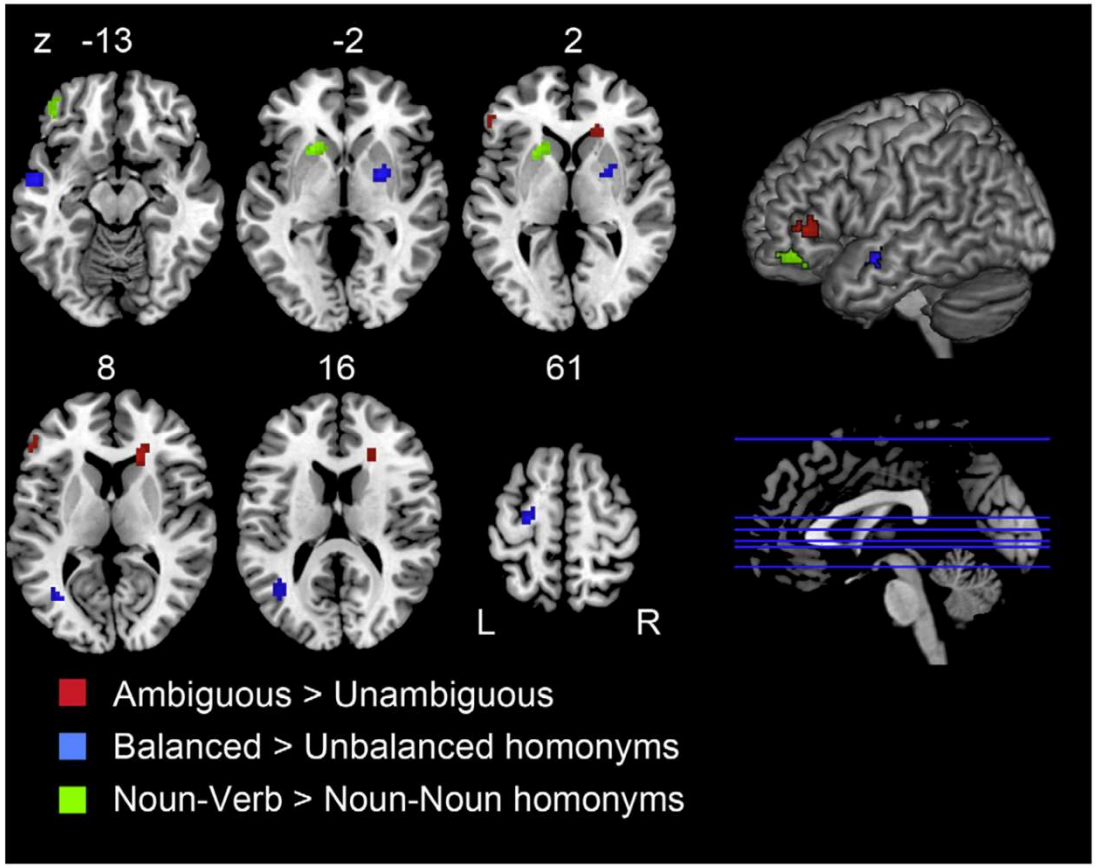
那个人把粉丝泡进了碗里，也把粉丝泡进了心里。

POS matters in meaning processing 1

noun–noun	balanced	match-fire, match-game
	unbalanced	toast-bread, toast-speech
noun–verb	balanced	rock-stone, rock-sway
	unbalanced	duck-bird, duck-avoid
noun		lake
verb		grow

Different-POS is more difficult than Same-POS

- *"Because two different frames are retrieved instead of one, noun–verb homonyms increase the demand on lexical-syntactic retrieval processes"*



Grindrod, C. M., et al. (2014). *Brain and Language.*

POS matters in meaning processing 2

- Semantic meaning * Syntactic category

(a) similar senses; same POS
- belt-clothing, belt-mechanical

(b) similar senses; different POS
- *hammer-tool*, *hammer-hit*

(c) unrelated meanings; same POS
- **deck-cards**, **deck-boat**

(d) unrelated meanings; different POS
- ***bark-tree***, ***bark-dog***

Mirman, D., et al. (2010). *Cognitive Science*.

Different-POS is easier than Same-POS

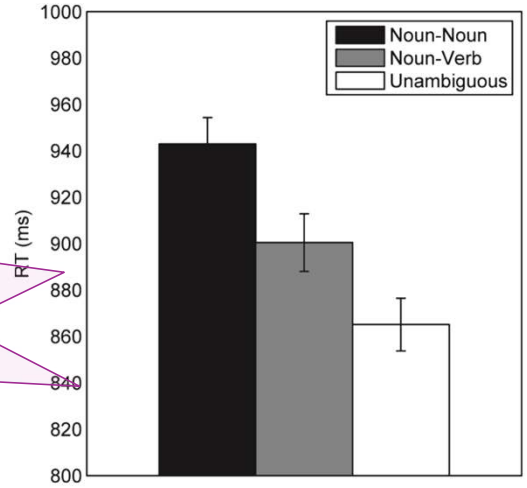
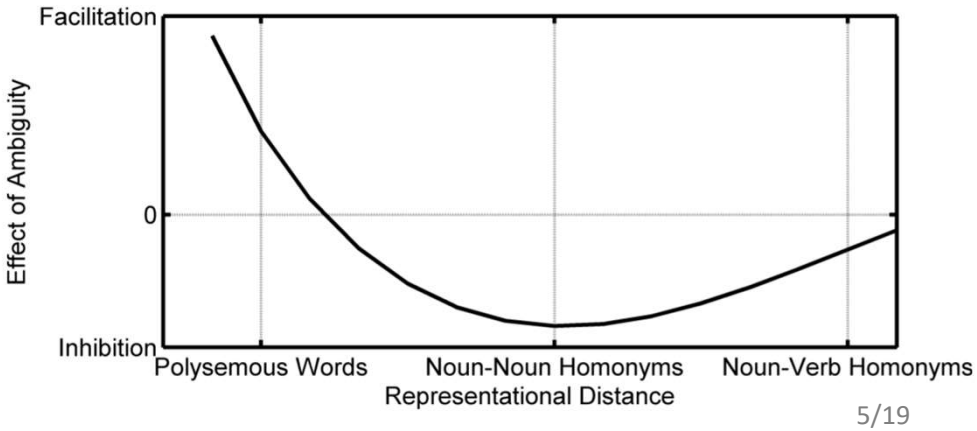


Fig. 1. Experiment 1 response time results. Error bars indicate ± SE.

lexical decision may be performed without linguistic access, merely on the basis of perceptual familiarity (e.g., matching a stimulus to stored graphic representations), For a discussion see Rogers, T. T., et al. (2004). *Cognitive Neuropsychology*.



Psycholinguistic property matters

-Human

- Early learned words are recognized and produced faster than later learned words.

Ellis, A. W., & Lambon Ralph, M. A. (2000). Journal of Experimental Psychology: Learning, Memory, and Cognition

- Early acquired words is more resistant to the effect of aging than late acquired words.

Hodgson, C., & Ellis, A. W. (1998). Brain and Language

- Retrogenesis Hypothesis

Xie, C., et al. (2023).Frontiers in Psychology

-Model

- Catastrophic interference : Knowledge of the first set, which is no longer being trained, is gradually lost as the second set is learned.

McCloskey, M., & Cohen, N. J. (1989). *Psychology of Learning and Motivation.*

- Curriculum learning helps build robust initial representations by starting with simpler, foundational patterns. These stable representations are less likely to be overwritten during subsequent learning, reducing interference when new tasks are introduced.

Bengio, Y., et al. (2009). Proceedings of the 26th Annual International Conference on Machine Learning.

Our two experiments

Homonymous senses discrimination between human and language models

Context & POS effects

AoA

Homonymous senses discrimination between younger and older adults

Aging effects

Cellular and molecular explanation

Stimuli design

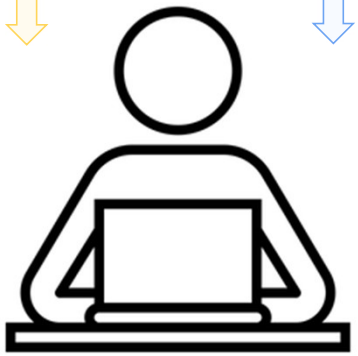
- 512 sentence-pair & 64 homonyms (32 same POS + 32 different POSs)

Word	POS1	POS2	POSWord	Context	Sense	Sentence1	Sentence2
粉丝	Noun	Noun	same	same	same	这种透明的粉丝是用绿豆淀粉制成的。 *This transparent vermicelli is made from mung bean starch.*	这种细长的粉丝是用绿豆淀粉制成的。 *This thin vermicelli is made from mung bean starch.*
粉丝	Noun	Noun	same	same	same	她的忠实粉丝常常为她的作品刷屏支持。 *Her loyal fan often supports her works online.*	她的铁杆粉丝常常为她的作品刷屏支持。 *Her die-hard fan often supports her works online.*
粉丝	Noun	Noun	same	same	different	艺人们纷纷抱怨起那些难缠的粉丝。 *The artists all complained about those troublesome fans.*	艺人们纷纷抱怨那些失控的粉丝。 *The artists all complained about those out-of-control fans.*
粉丝	Noun	Noun	same	same	different	那些激动的粉丝让专家们感到非常吃惊。 *Those excited fans surprised the experts very much.*	那些过期的粉丝让专家们感到非常吃惊。 *Those expired vermicelli surprised the experts very much.*
粉丝	Noun	Noun	same	different	same	我妈妈做的粉丝汤味道真鲜美。 *The vermicelli soup my mom made is really delicious.*	粉丝是广东菜中常见的食材之一。 *Vermicelli is one of the common ingredients in Cantonese cuisine.*
粉丝	Noun	Noun	same	different	same	周杰伦的粉丝会唱他的每一首歌。 *Jay Chou's fans can sing every one of his songs.*	粉丝们在演唱会上的热情非常高涨。 *The fans were very enthusiastic at the concert.*
粉丝	Noun	Noun	same	different	different	饥肠辘辘的他只想来一碗热腾腾的酸辣粉丝。 *Starving, he just wanted a bowl of hot and sour vermicelli.*	前来接机的粉丝把整个机场大厅都挤满了。 *The fans who came to pick up at the airport filled the entire hall.*
粉丝	Noun	Noun	same	different	different	这场签售会吸引了上万的粉丝。 *This signing event attracted tens of thousands of fans.*	妈妈正在厨房里准备凉拌粉丝。 *Mom is preparing cold vermicelli salad in the kitchen.*
风化	Noun	Verb	different	same	same	他的举举对年轻人起到了良好的风化示范作用。 *His actions set a good example of moral influence for young people.*	他的举举对年轻人起到了良好的风化促进作用。 *His actions had a positive moralizing effect on young people.*
风化	Noun	Verb	different	same	same	某些矿物在潮湿环境中容易发生风化反应。 *Certain minerals are prone to weathering reactions in humid environments.*	某些矿物在潮湿环境中容易发生风化侵蚀。 *Certain minerals are prone to weathering erosion in humid environments.*
风化	Noun	Verb	different	same	different	一个地区的风化观念往往是在长年累月的结果。 *A region's concept of public morals is often the result of many years.*	一个地区的风化作用往往是在长年累月的结果。 *A region's weathering process is often the result of many years.*
风化	Noun	Verb	different	same	different	专家们正在调查社会风化对人民生活的影响。 *Experts are investigating the effects of social morality on people's lives.*	专家们正在调查岩石风化对人民生活的影响。 *Experts are investigating the effects of rock weathering on people's lives.*
风化	Noun	Verb	different	different	same	发达国家的风化水平往往在体现了其文明程度。 *The level of morality in developed countries often reflects their level of civilization.*	风化习俗的传承有助于增强民族的凝聚力。 *The inheritance of moral customs helps strengthen national cohesion.*
风化	Noun	Verb	different	different	same	风化后的岩石表面会出现许多微小的裂缝。 *The rock surface after weathering will have many tiny cracks.*	地貌的形成与频繁的风化密切相关。 *The formation of landforms is closely related to frequent weathering.*
风化	Noun	Verb	different	different	different	村里新修建的祠堂成了传播风化理念的中心。 *The newly built shrine in the village became a center for promoting morality ideas.*	石碑上的文字因受风化影响而变得模糊不清了。 *The text on the stele became blurred due to the influence of weathering.*
风化	Noun	Verb	different	different	different	那块花岗岩的表面出现了明显的风化裂纹。 *Obvious weathering cracks appeared on the surface of that granite.*	这次文化活动的目的是为了促进地方风化建设。 *The purpose of this cultural activity is to promote the local morality construction.*

Methods

艺人们纷纷抱怨起那些难吃的**粉丝**。

艺人们纷纷抱怨起那些失控的**粉丝**。



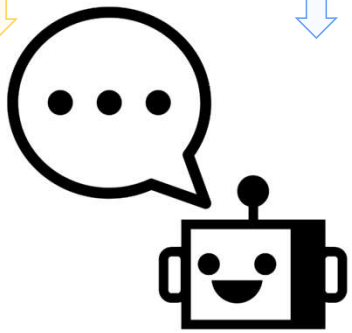
different 1 2 3 4 5 6 7 same

Judgement Score

Reaction time

发达国家的**风化**水平往往体现了其文明程度。

风化习俗的传承有助于增强民族的凝聚力。



different 1 2 3 4 5 6 7 same

Judgement Score

Next-token probability

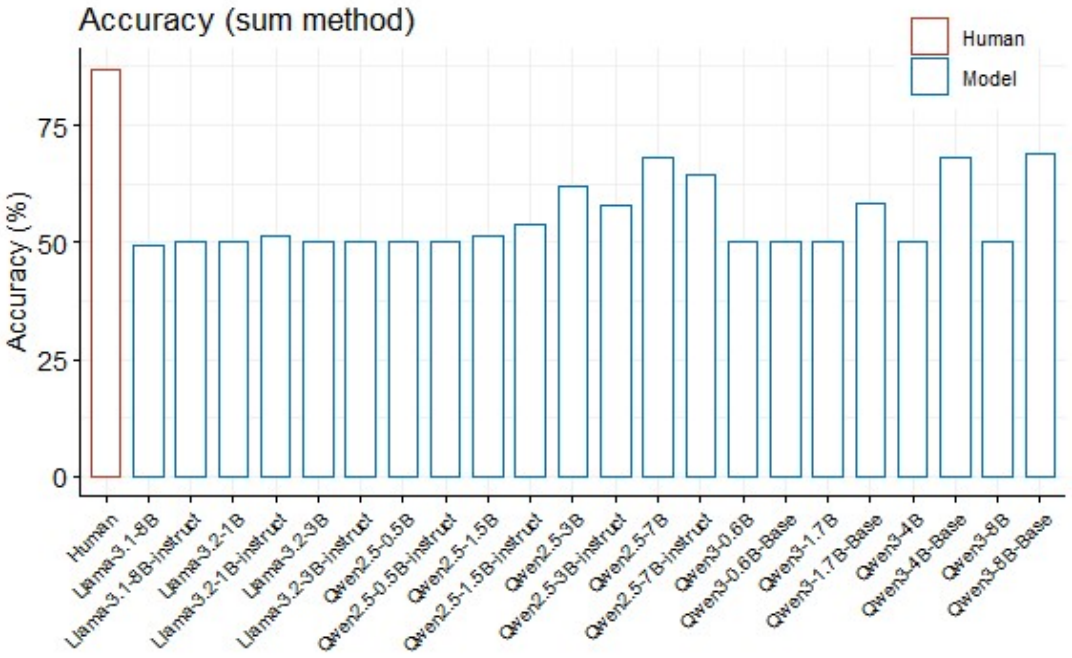
你是一名非语言学、心理学相关专业的高校学生，你的母语是汉语普通话，现在你参加一个语言实验。这个实验要求你根据自己的语感判断一个词语在两个句子中的意思是否相同，如果非常相同请选择7，如果完全不同请选择1，若介于中间则请选择2、3、4、5或者6。请判断（1）“发达国家的风化水平往往体现了其文明程度。”和（2）“**风化**习俗的传承有助于增强民族的凝聚力。”中“风化”的意思，请直接给出数字回答，你的选择是：

Judgements Scores

- Next-token probability of numerical responses = different {1, 2, 3, 4, 5, 6, 7} same
- **Sum method**: sum(correct) > sum(incorrect)

艺人们纷纷抱怨起那些难吃的粉丝。

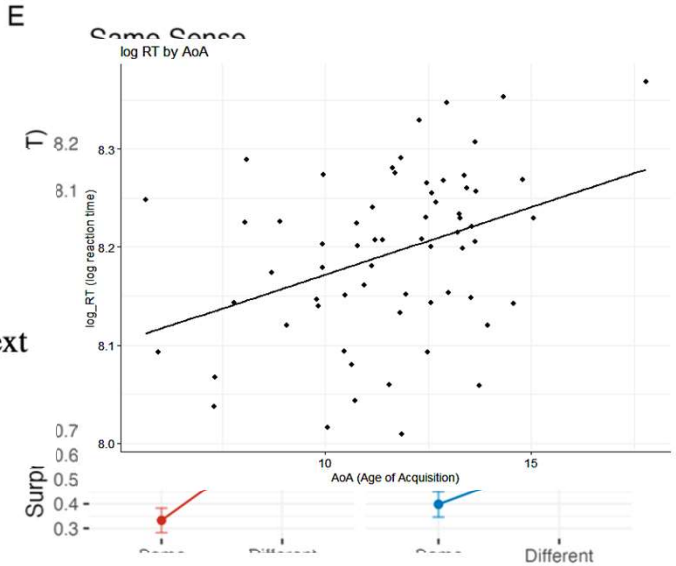
艺人们纷纷抱怨起那些失控的粉丝。

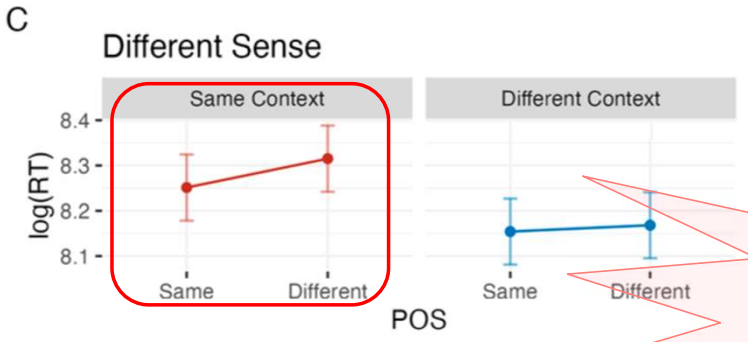


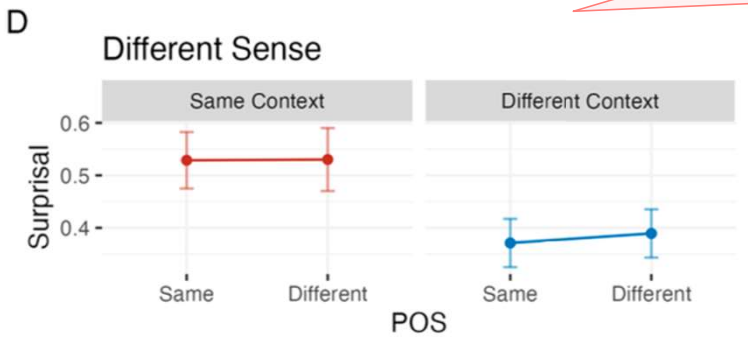
'你是一名非语言学、心理学相关专业的高校学生，你的母语是汉语普通话，现在你参加一个语言实验。这个实验要求你根据自己的语感判断一个词语在两个句子中的意思是否相同，如果非常相同请选择7，如果完全不同请选择1，若介于中间则请选择2、3、4、5或者6。请判断（1）“空头的白话往往让人难以信服。”和（2）“浮夸的白话往往让人难以信服。”中“白话”的意思，请直接给出数字回答，你的选择是： 两个语言'

Regressions

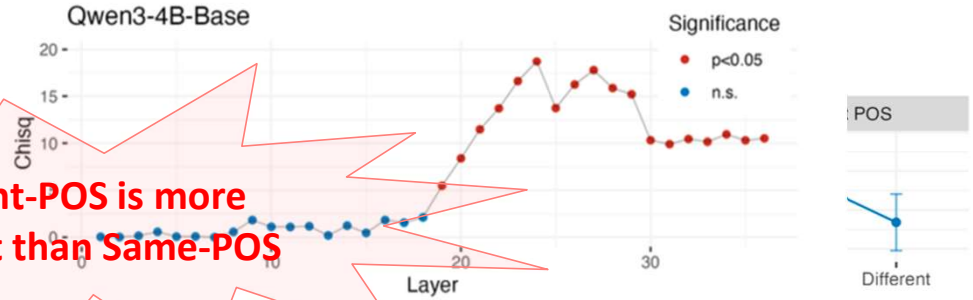
	Final model
Human	log(RT) ~ Sense + Context + POS + Trial + AoA + PSPMI + (1|Subject) + (1|Word) + Sense:Context + Sense:POS + Context:POS + Sense:Context:POS
Qwen3-4B-Base	$\text{Surprisal}_{\text{sum}}$ ~ Sense + Context + Word_logW_CD + PMI + PSPMI + Sense:Context
Qwen3-8B-Base	$\text{Surprisal}_{\text{sum}}$ ~ Sense + Context + POSWord + EntropyCharacterFrequencies + Sense:Context + Sense:POS + Context:POS + Sense:Context:POS

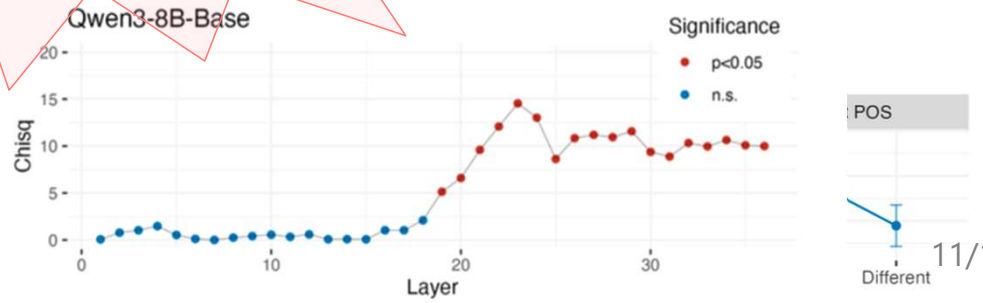






Different-POS is more difficult than Same-POS

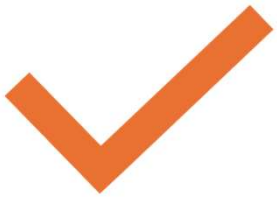




Interim summary

- Context similarity had similar effects on both humans and models.
- Only humans leveraged POS information during homonym disambiguation.
- Model-derived metrics (surprisal, entropy, and angular similarity) had significant predictive power while modeling human behavioural responses (reaction time).
- Psycholinguistic properties like AoA influenced human, but not model, response.

Our two experiments



Homonymous senses discrimination between human and language models

Context & POS effects

AoA

Homonymous senses discrimination between younger and older adults

Aging effects

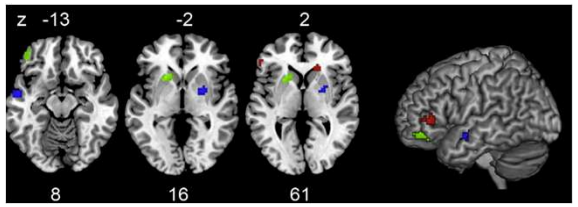
Cellular and molecular explanation

Age-related decline in POS and context effects

frontal lobe hypothesis

cognitive deficits in older adults are primarily due to the anatomical and functional deterioration of the frontal lobes

Cabeza, R., & Dennis, N. A. (2012). *Principles of frontal lobe function*.



Grindrod, C. M., et al. (2014).

A larger difference may be expected in (POS-difference minus POS-same).

"younger adults, but not older adults, were able to use semantic context information to resolve an ambiguity."

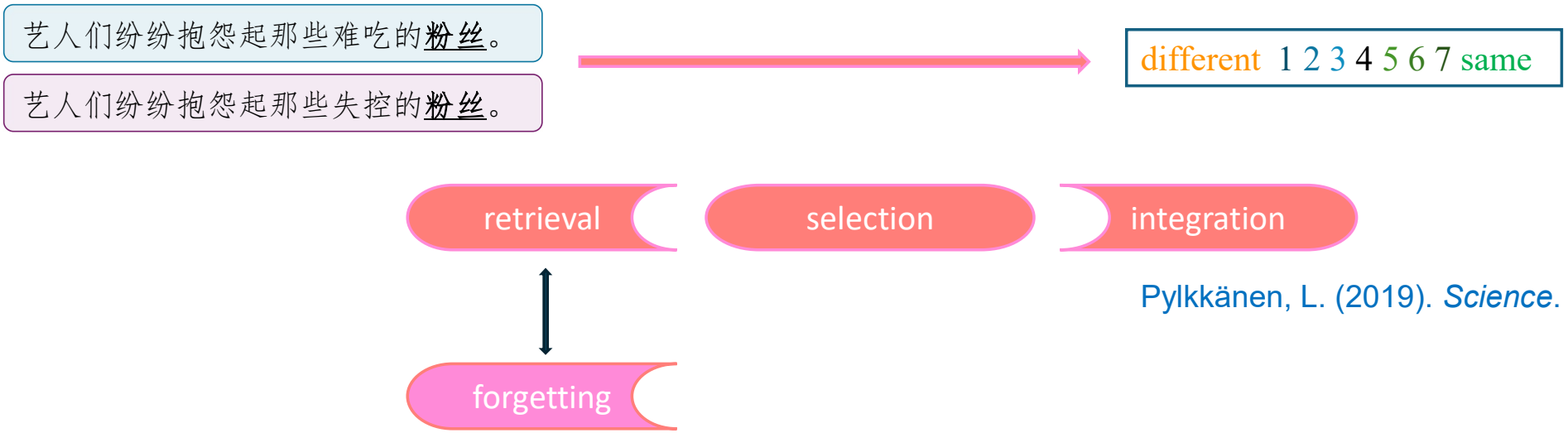
Dagerman, K. S., et al. (2006). *Cognitive Science*.

"age-related changes in context use during ambiguity resolution are restricted to older adults with reduced processing speed" which was indexed by verbal fluency

Grindrod, C. M., & Raizen, A. L. (2018). *Aging, Neuropsychology, and Cognition*.

A relatively poor performance in disambiguating homonyms for older adults with memory deficits

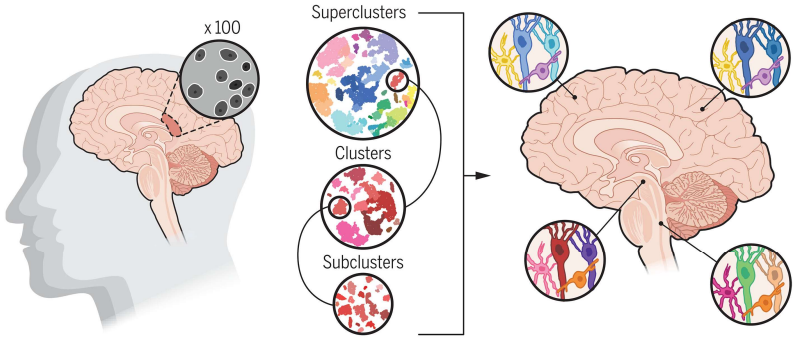
Retrieval deficits



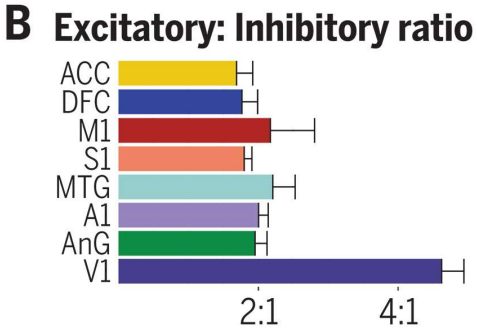
Pylkkänen, L. (2019). *Science*.

- *"a single **dopamine neuron** in Drosophila that mediates the memory suppression that results in transient forgetting."*
  Sabandal, J. M., et al. (2021). Dopamine-based mechanism for transient forgetting. *Nature*.
- *"retrieval-induced forgetting of competing memories in male rats requires prefrontal **dopamine** signaling through D1 receptors"*
  Gallo, F. T., et al. (2022). Dopamine Modulates Adaptive Forgetting in Medial Prefrontal Cortex. The Journal of Neuroscience.
- *"^{1}H magnetic resonance spectroscopy revealed that greater resting concentrations of hippocampal **GABA** predicted better mnemonic control."*
  Schmitz, T. W., et al. (2017). Hippocampal GABA enables inhibitory control over unwanted thoughts. Nature Communications.

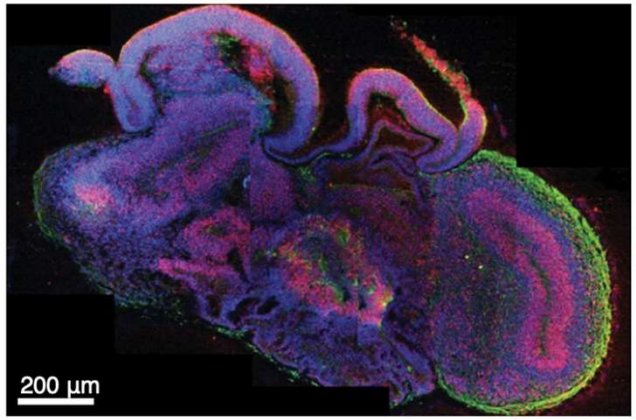
Brain cell atlas and induced Pluripotent Stem Cell (**iPSC**)



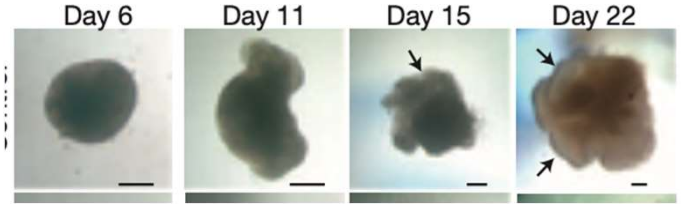
Cellular diversity across the entire human brain.
Siletti, K., et al. (2023). Transcriptomic diversity of cell types across the adult human brain. *Science*.



Jorstad, N. L., et al. (2023). Transcriptomic cytoarchitecture reveals principles of human neocortex organization. *Science*.



Bock, C., et al. (2021). The Organoid Cell Atlas. *Nature Biotechnology*.

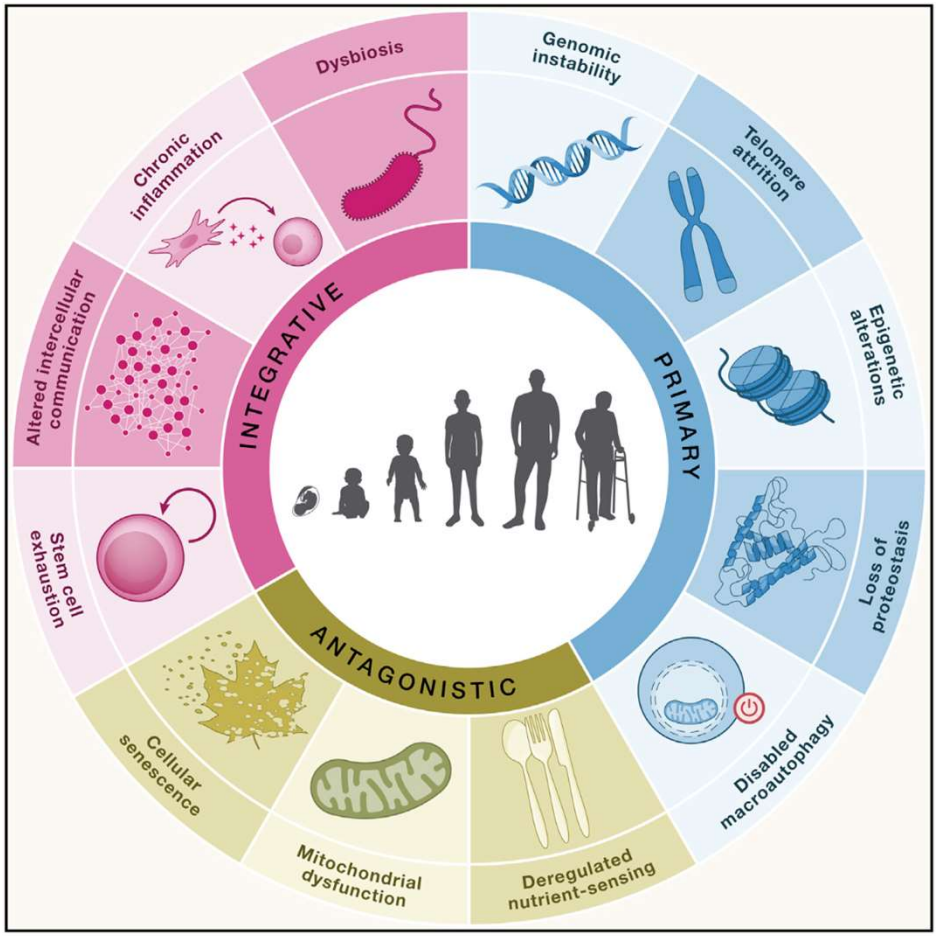


Lancaster, M. A., et al. (2013). *Nature*.

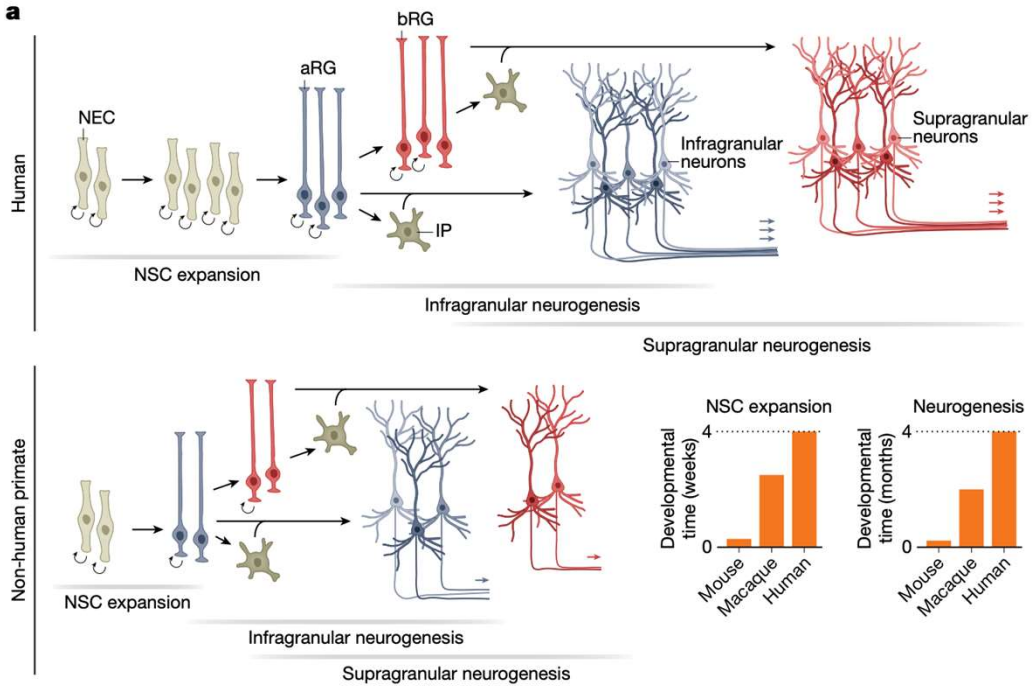
- *"allogeneic transplantation of iPS-cell-derived DA progenitors is a safe and effective regenerative therapy for patients with PD"*

Sawamoto, N., et al. (2025). *Nature*.

Stem cell significance



López-Otín, C., et al. (2023). Hallmarks of aging: An expanding universe. *Cell*.



- *"The evolution of the modern human brain was accompanied by distinct molecular and cellular specializations, which underpin our diverse cognitive abilities but also increase our susceptibility to neurological diseases."*

Lindhout, F. W., et al. (2024). A molecular and cellular perspective on human brain evolution and tempo. *Nature*.

Take-home message

- 1. LLMs deepen our understanding of the underlying psycholinguistic mechanisms of homonym processing
  - context similarity influenced both human and LLMs similarly
  - only humans utilized POS information
  - AoA affected only human responses

- 2. These psycholinguistic mechanisms are expected to drive the behavioral difference between younger and older adults
  - Age-related decline is expected to be observed in those with memory deficits
  - iPSC is a promising direction for aging research

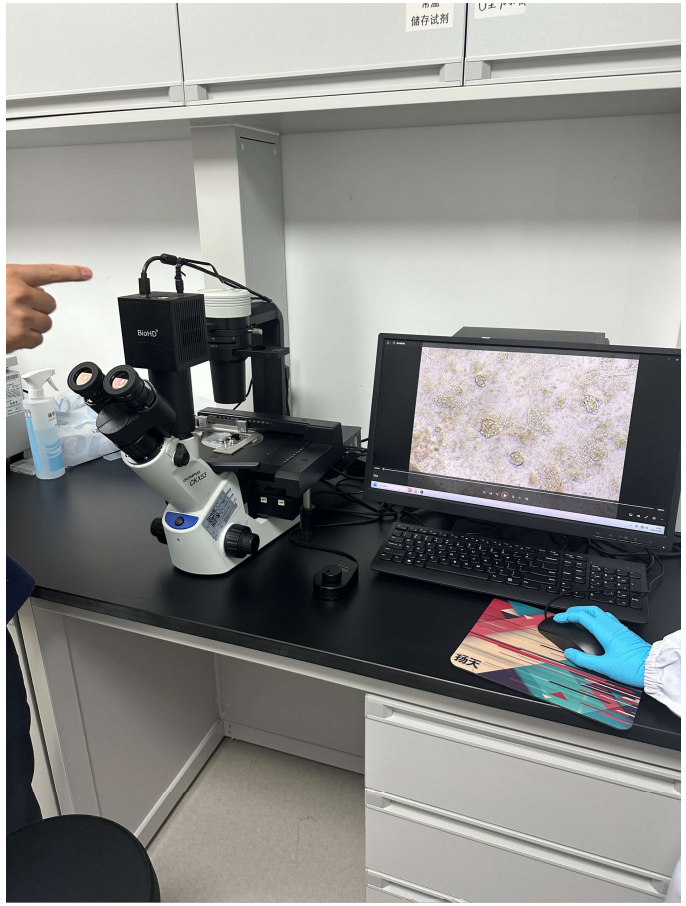


Photo shot @ Stem cell lab of Life Science centre @ PolyU Shenzhen Research Institute

- Team members:
  Dr. Manson FONG
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  Ms. Longyun HU
  Mr. Jingjing ZHOU
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THANKS FOR YOUR ATTENTION!