Electrophysiological evidence for how readers make use of the contextual information during language comprehension

Chia Ying Lee
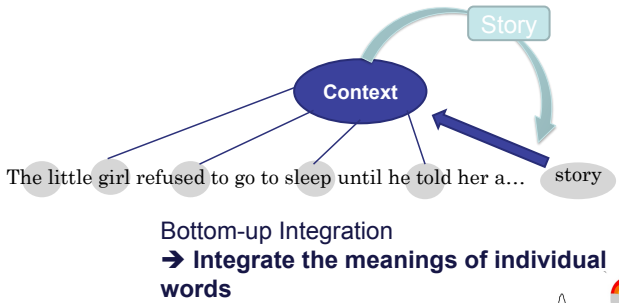
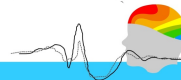Brain and Language Laboratory
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How do you read for comprehension

Top-down prediction
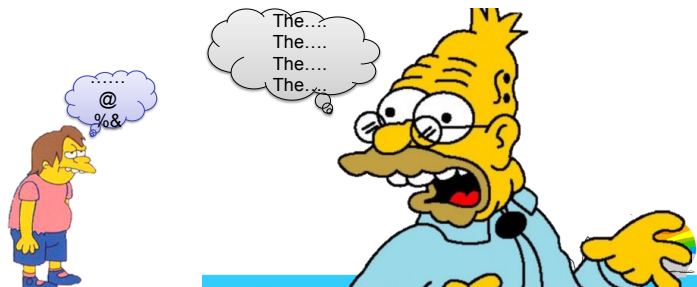➔ Use the context to predict the upcoming words

Story

Context

The little girl refused to go to sleep until he told her a…   story

Bottom-up Integration
➔ **Integrate the meanings of individual words**
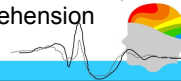
Aging and Language comprehension

- Aging has been associated with various cognitive declines, including attention, memory and executive function.
- How aging may cause qualitative and quantitative changes in language comprehension?

The….
The….
The….
The….

@%&

Outline

- N400, an ERPs component for semantic retrieval and integration
- ERPs studies for contextual influences
  - Cloze probability (predictability) effect in sentences comprehension
  - Chinese Classifier-noun agreement
    - Semantic constraint effect of classifier
    - Cloze probability effect of noun
- ERPs Data from
  - Young adults (college students),
  - Healthy elders
  - Aphasics with different severity of comprehension impairment

EEG: Electroencephalography
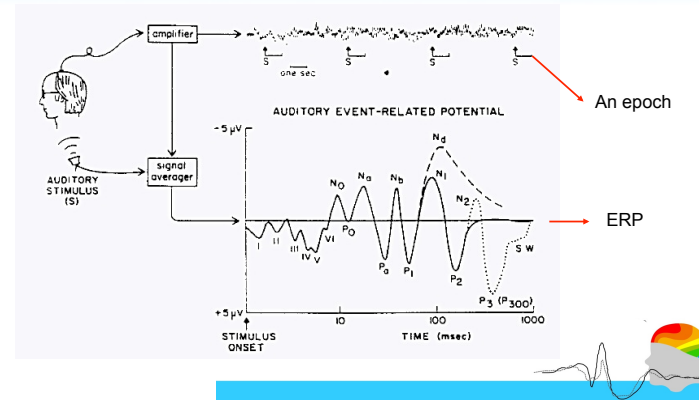## ERPs: Event-related potentials

- **E**lectro**E**ncephalo**G**raphy: a recording (graphy) of electrical signal (electro) from the brain (Encephalo).

Electroencephalography Recording System

Pen

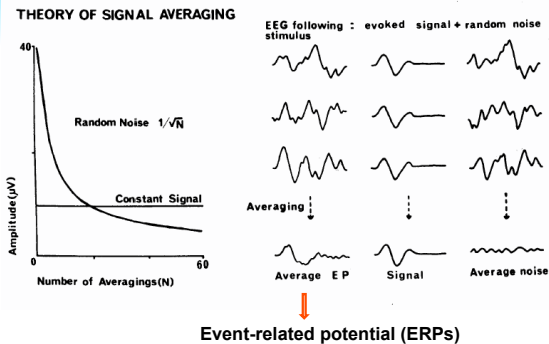Voltage

Time

AMPLIFIER

Scalp electrodes
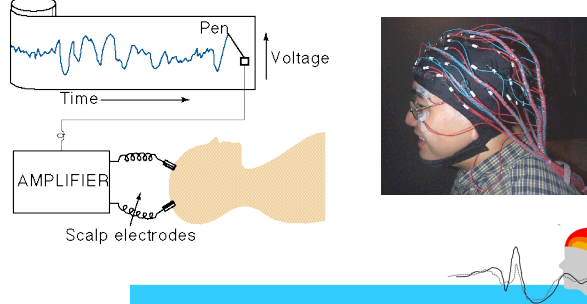
Event-Related Potentials: ERPs

The time-locked brain potential elicited by a specific event.

amplifier

one sec

AUDITORY EVENT-RELATED POTENTIAL

An epoch

ERP

AUDITORY STIMULUS (S)

signal averager

$-5\ \mu V$

N_d

N_O N_a N_b N_1

P_O N_2

I II III V_I

IV V

P_a P_1

P_2

S W

P_3 (P_{300})

$+5\ \mu V$

STIMULUS ONSET

TIME (msec)

10   100   1000

Theory of Signal Averaging

THEORY OF SIGNAL AVERAGING

EEG following : evoked signal + random noise stimulus

Random Noise $1/\sqrt{N}$

Constant Signal

Amplitude (μV)

40

0

Number of Averagings(N)   60

Averaging

Average E P   Signal   Average noise

Event-related potential (ERPs)
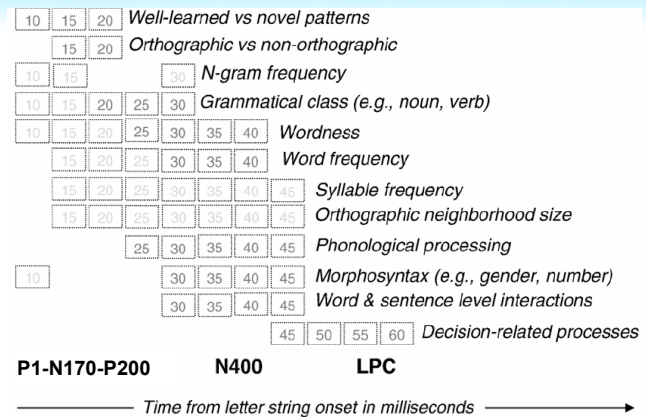
Electrical activities associated with specific cognitive processes are embedded in EEG and may be extracted by enhancing the signal/noise ratio.

Time courses of ERP sensitivities during visual word recognition
  – adapted from Barber and Kutas (2007)

10	15	20								Well-learned vs novel patterns
	15	20								Orthographic vs non-orthographic
10	15		30							N-gram frequency
10	15	20	25	30						Grammatical class (e.g., noun, verb)
10	15	20	25	30	35	40				Wordness
	15	20	25	30	35	40				Word frequency
	15	20	25	30	35	40	45			Syllable frequency
	15	20	25	30	35	40	45			Orthographic neighborhood size
			25	30	35	40	45			Phonological processing
10				30	35	40	45			Morphosyntax (e.g., gender, number)
				30	35	40	45			Word & sentence level interactions
						45	50	55	60	Decision-related processes

P1-N170-P200   N400   LPC

—— Time from letter string onset in milliseconds ——>

Slide 1

N400: semantic congruency

I like my coffee with cream and…

Sugar semantic congruent
Socks semantic incongruent

−5 μV

N400

1,000 ms

Socks

+

Sugar

Kutas & Hillyard (1980)

Slide 2

Aging and N400
N400 responses have been found to decrease in amplitude and increase in latency with age.

latency

Group composition: gender, age, handedness, years of education

Decade	No. men	No. women	Mean age	Handedness	Education
20s	7	5	24 (2.9)	10 R, 2 L	15.5 (2.1)
30s	5	7	34 (3.7)	12 R	17.6 (2.3)
40s	5	7	45 (3.6)	12 R	17.0 (2.3)
50s	6	6	54 (3.3)	12 R	14.7 (3.0)
60s	6	6	66 (2.8)	10 R, 2 A	16.3 (2.5)
70s	6	6	74 (3.1)	11 R, 1 A	16.3 (2.8)

20's   30's   40's   50's   60's   70's

L. PARIETAL

R. PARIETAL

0 400 800   0 400 800   0 400 800   0 400 800   0 400 800   0 400   ms

Antonyms ——— Categories ···········

20's
30's
40's
50's
60's
70's

0   400   msec

Kutas & Iragui (1998)

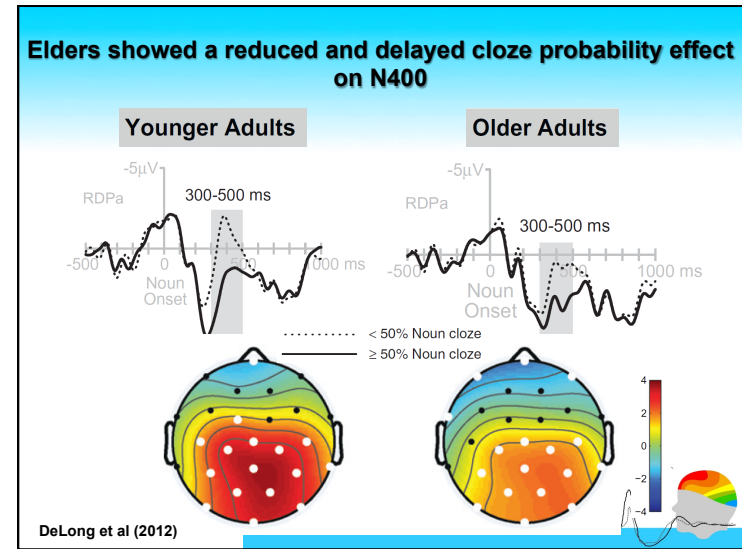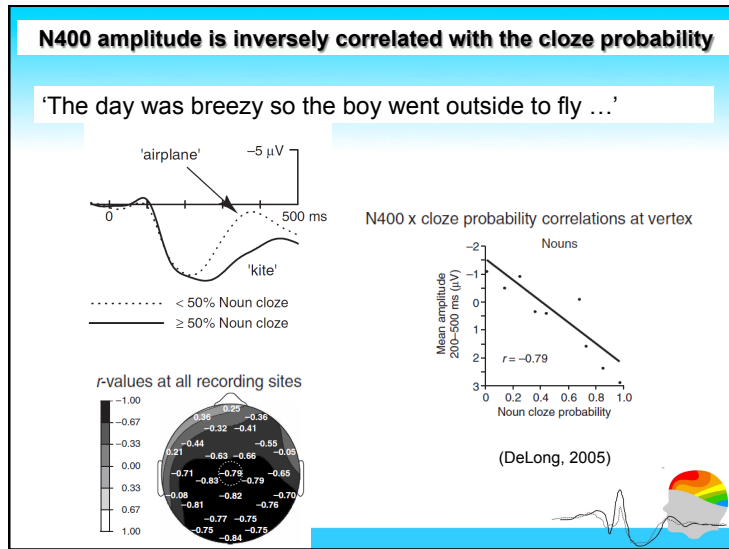## Slide 3

How to evaluate the contextual effect

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Slide 4

Cloze probability:
An index for language comprehension

Cloze probability of a word refers to the percentage of people who would complete a sentence frame with that particular word, determined empirically (Taylor, 1953).

He bought her a pearl necklace for her…   *Birthday*   **cloze=90%**

collections   **cloze=3%**

Slide 1

N400 amplitude is inversely correlated with the cloze probability

'The day was breezy so the boy went outside to fly …'

'airplane'

−5 µV

0   500 ms

'kite'

······ < 50% Noun cloze

——— ≥ 50% Noun cloze

r-values at all recording sites

N400 x cloze probability correlations at vertex

Nouns

Mean amplitude 200–500 ms (µV)

r = −0.79

Noun cloze probability

(DeLong, 2005)

Slide 2

Elders showed a reduced and delayed cloze probability effect on N400

| Younger Adults | Older Adults |

-5µV

RDPa

300-500 ms

-500   0   Noun Onset   1000 ms

-5µV

RDPa

300-500 ms

-500   0   Noun Onset   1000 ms

······ < 50% Noun cloze

——— ≥ 50% Noun cloze

DeLong et al (2012)

Slide 3

How contextual information influences the visual word recognition

2 by 2 design (Frequency X Predictability)
- High frequency/High predictability (HFHP)
  - 小明平常不注意口腔衛生，現在牙痛發炎，痛得他無法進食
- High frequency/Low predictability (HFLP)
  - 爺爺實在很固執，即使已經牙痛到站不起來，還是不看牙醫
- Low frequency/High predictability (LFHP)
  - 葉片上的水分傳輸，是藉由葉脈以主動或被動的方式傳送
- Low frequency/Low predictability (LFLP)
  - 自然課中藉著帶領小朋友觀察葉脈可以加深他們的學習印象

Lee, Liu, & Tsai (2012)
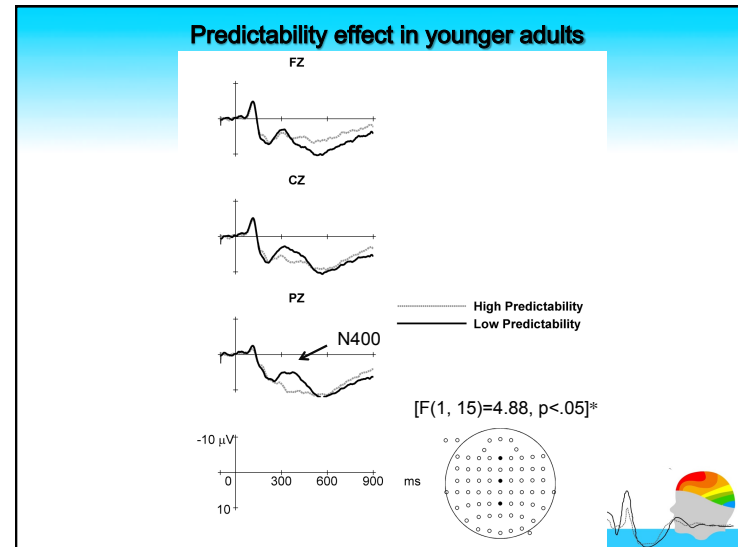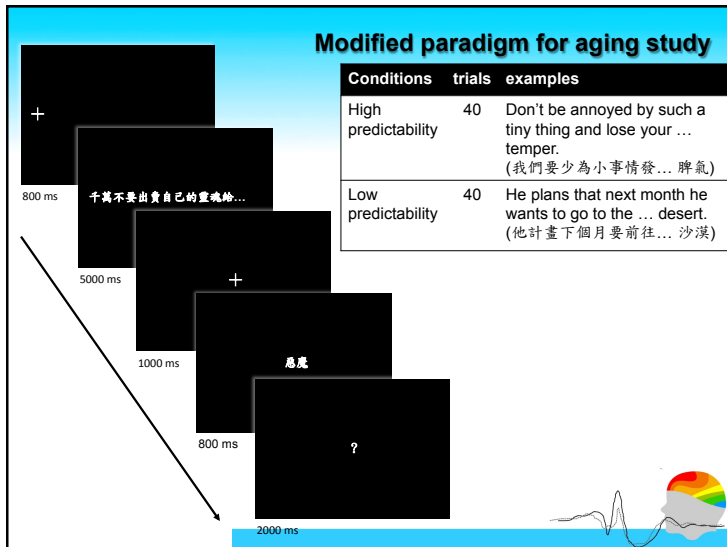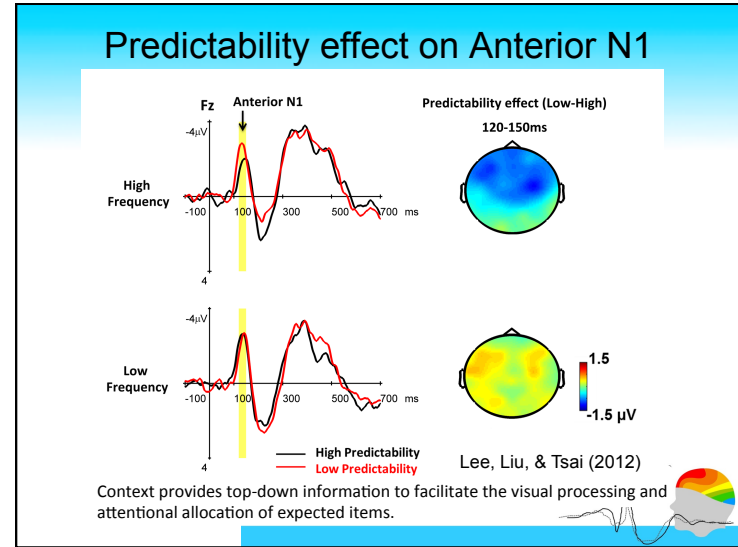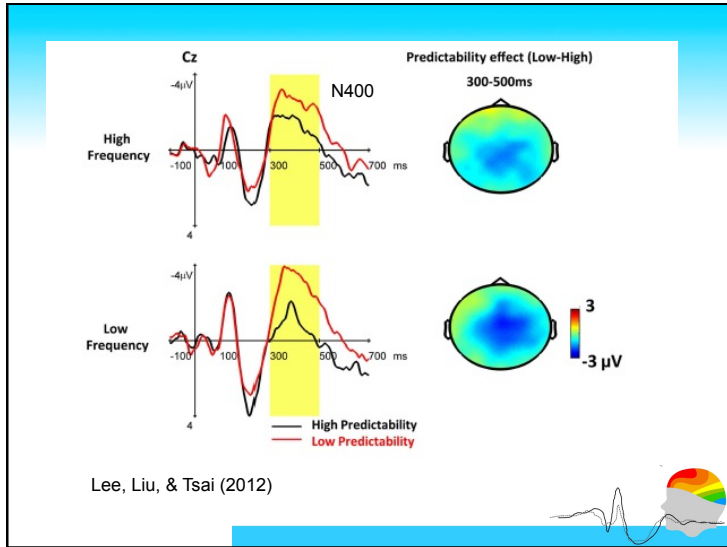
Slide 4

Material and Procedure

4 conditions, each condition composed of 25 target words (two characters) 200 experimental sentences.

	Word Freq	Predictability
High	>500	>70%
Low	<2	<1%

0.04 0.05   0.68 0.77

LP   HP

■LF ■HF

Rapid serial visual presentation (RSVP) word-by-word presentation

Target words were located at the middle of sentence.

父母親

經常

450 ms

250 ms

450 ms

250 ms

+

500 ms

Randomly follow a **comprehension task** at the end of sentences. (20% of trials)

Lee, Liu, & Tsai (2012)

Predictability effect on Anterior N1

Lee, Liu, & Tsai (2012)

Context provides top-down information to facilitate the visual processing and attentional allocation of expected items.

Modified paradigm for aging study

Conditions	trials	examples
High predictability	40	Don't be annoyed by such a tiny thing and lose your … temper. (我們要少為小事情發… 脾氣)
Low predictability	40	He plans that next month he wants to go to the … desert. (他計畫下個月要前往… 沙漠)

Predictability effect in younger adults

$[F(1, 15)=4.88, p<.05]*$

Slide 1

Young adults   **Healthy elders**

FZ   FZ

CZ   CZ

PZ   PZ

N400

Reduced and delayed N400

-10 μV

········ High Predictability
——— Low Predictability

0   300   600   900   ms

10

Slide 2

Healthy elders   **High ability aphasics**   **Low ability aphasics**

FZ   FZ   FZ   N400

CZ   CZ   N400   CZ

PZ   N400   PZ   PZ

-10 μV

0   300   600   900   ms

10

········ High Predictability
——— Low Predictability

Slide 3

The predictability effect on N400 is sensitive to the severity of comprehension impairment

- Young adults
  - typical central-posterior distributed predictability effect on N400
- Elder controls
  - reduced and delayed N400 with central posterior distribution
- Aphasics with high ability
  - reduced and delayed N400 with central distribution
- Aphasics with low ability
  - reduced and prolonged N400 with frontal distribution
  - Multiple cues/resources were used to compensate for their comprehension deficit, so they showed a frontal distributed N400

Slide 4

To separate two types of contextual effects: Contextual Constraint versus Cloze probability

Top-down prediction

Story

Context

The little girl refused to go to sleep until he told her a…   story

Bottom-up Integration
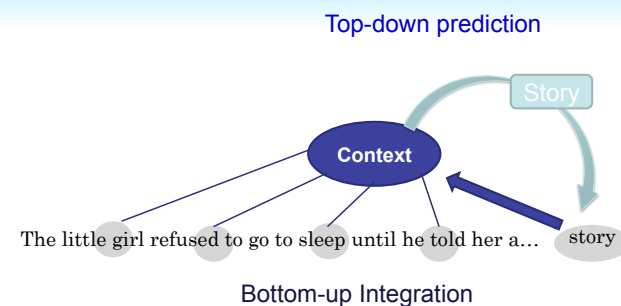
The cloze probability effect may be reasoned as:
1. It is easier to integrate the meaning of the high cloze word into the context
2. it is easier to predict the high cloze word based on the context

Cloze probability

Cloze probability of a word refers to the percentage of people who would complete a sentence frame with that particular word, determined empirically (Taylor, 1953).

He bought her a pearl necklace for her… *Birthday* **cloze=90%**

He looked worried because he might broken his… *Arm*
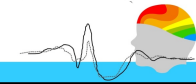
cloze=36%
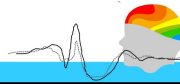
Contextual Constraint

The number of words that can be used to complete the sentences. Sentence constraint influences the range of completions.

Strongly constrained:
He bought her a pearl necklace for her… *Birthday*
collection

Weakly constrained:
He looked worried because he might broken his… *Arm*
leg, cup, treasure, mirror…collection

A possible confound
between cloze probability and contextual constraint

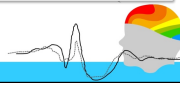Edward W. Wlotko , Kara D. Federmeier (2007)

Strongly constrained

He bought her a pearl necklace

for her _____ | Birthday | expect | 90.3%
Collection | unexpected | 3.1%

Weakly constrained

He looked worried because he might have

broken his _____ | Arm | expect | 36.2%
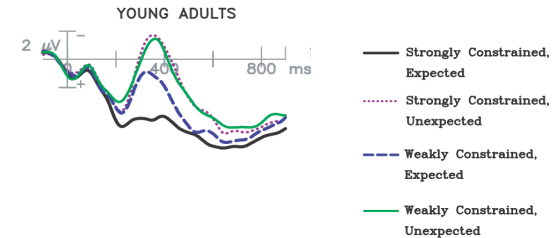Collection | unexpected | 3.1%

Not well matched!!
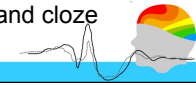
Contextual constraint and Cloze probability effects in sentence reading

Federmeier et. al (2007)

	Sentence frame	Expected	Unexpected
SC	He bought her a pearl necklace for her	birthday	collection
WC	He looked worried because he might have broken his	arm	collection

YOUNG ADULTS

2 μV

400   800 ms

— Strongly Constrained, Expected
···· Strongly Constrained, Unexpected
– – Weakly Constrained, Expected
— Weakly Constrained, Unexpected

● A significant interaction between constraint and cloze probability on N400.

Slide 1

A possible confound between cloze probability and contextual constraint

YOUNG ADULTS

2 μV

400   800 ms

Wlotko et. al (2008)

- —— Strongly Constrained, Expected
- ······ Strongly Constrained, Unexpected
- – – – Weakly Constrained, Expected
- —— Weakly Constrained, Unexpected

	Overall cloze (%)	
SC-EE	90.3 (7.61)	**Not well matched!!**
WC-EE	36.2 (11.37)	
SC-UE	3.1 (3.78)	
WC-UE	3.1 (5.60)	

Slide 2
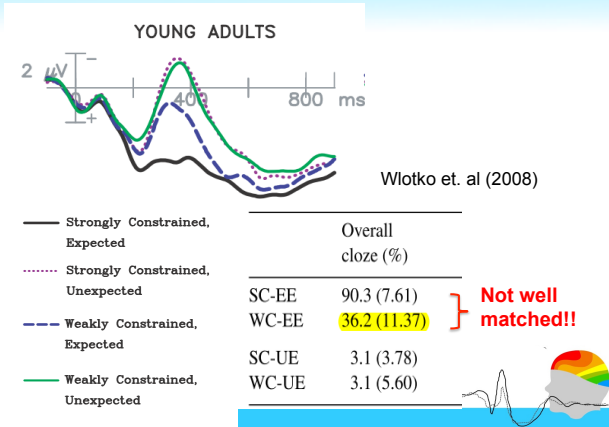
Chinese Classifier-noun agreement

NP

DP   Object-NP

Numeral   **Classifier**   Noun

一   條   繩子 (a rope)

Classifier		Noun (meaning, CP%)
Strongly Constrained (SC)	頂 /ding3/	帽子(hat, 96.55%) 假髮(wig, 24.14%) 王冠(crown, 10.34%) 斗笠(wide-brimmed rain hat, 3.45 %)
Weakly Constrained (WC)	瓶 /ping2/	飲料(drink, 72.41%) 水(water, 51.70%) 啤酒(beer, 20.60%) 果汁(juice, 20.70%) 牛奶(milk, 10.30%) 毒藥(poison, 6.90%) 膠水(glue, 3.45%)

Slide 3

A 2-by-3 factorial design
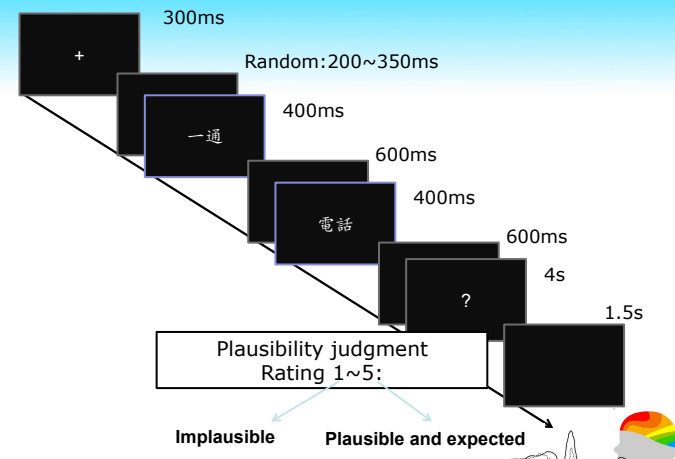
Strongly versus weakly constrained classifier:
Measured by the number of nouns that can be paired by a specific classifier.

Cloze probability (CP) of a following noun:
High cloze (CP>50%)
Low cloze (CP<6.9%),
Implausible noun (CP=0%)

Examples of the materials			
constraint (rating)	High cloze	Low cloze	Implausible
SC (3.1)	一通-電話(73.79%)	一架-飛機(4.25%)	一通-戰場/ 一架-國王
WC(4.4)	一瓶-飲料(75.63%)	一條-馬路(3.68%)	一瓶-晚餐/ 一條-首都

Slide 4

Procedure

300ms
+

Random:200~350ms

400ms
一通

600ms

400ms
電話

600ms
?

4s

1.5s

Plausibility judgment
Rating 1~5:

Implausible   Plausible and expected

8

Slide 1:

- Constraint effect on **Classifiers**

  The constraint effect on P200 and N400
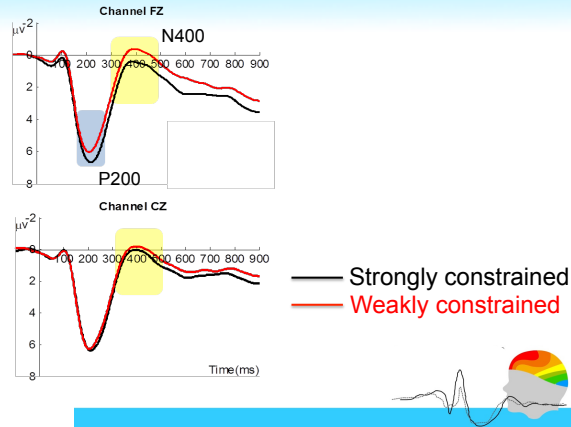
  Channel FZ
  N400
  P200

  Channel CZ

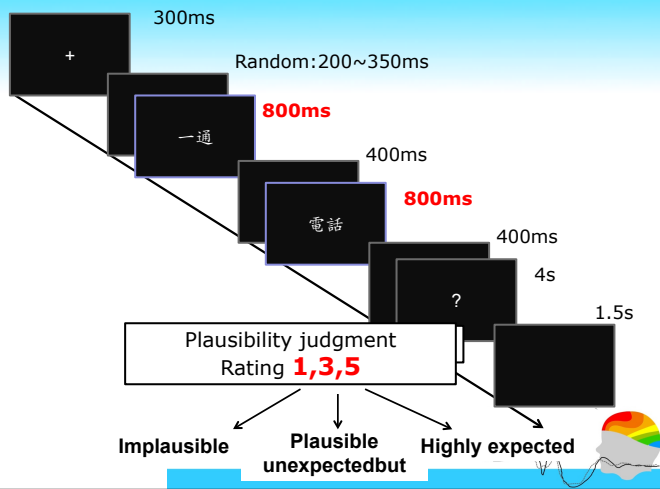 — Strongly constrained
  — Weakly constrained

Slide 2:

- For the pairing **Nouns**

  ● An interaction between constraint and cloze probability on N400

  Strongly   Weakly

  Channel CZ   Channel CZ
  N400

  High cloze
  Low cloze
  Implausible

  High<Low=Implausible   High<Low<Implausible

  電話
  一通
  電報、留言 戰場

  一瓶
  飲料、墨汁、牛奶、膠水…
  晚餐

Slide 3:
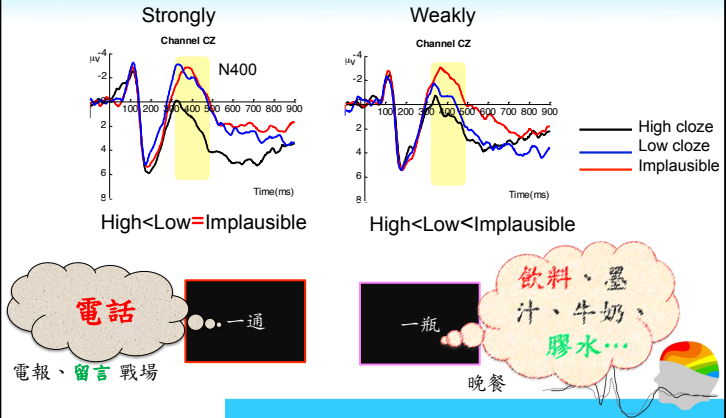
Modified paradigm for elders

300ms

Random：200~350ms

一通 **800ms**

400ms

電話 **800ms**

400ms

? 4s

1.5s

Plausibility judgment
Rating **1,3,5**

Implausible   Plausible
unexpectedbut   Highly expected

Slide 4:

- The constraint effect on **Classifiers**

  ● Only young adults showed a significant **Constraint** effect on N400

  Young adults   **Elders**

  Channel CPZ   Channel CPZ

  Constraint effect

  — Strongly constrained   一通
  — Weakly constrained   一瓶

ERPs elicited by the pairing Nouns

Younger Adults | **Older Adults**

Strongly Constrained / Weakly Constrained | Strongly Constrained / Weakly Constrained

Frontal
Central
Parietal

-2μV
-100 100 300 500 700 900 ms

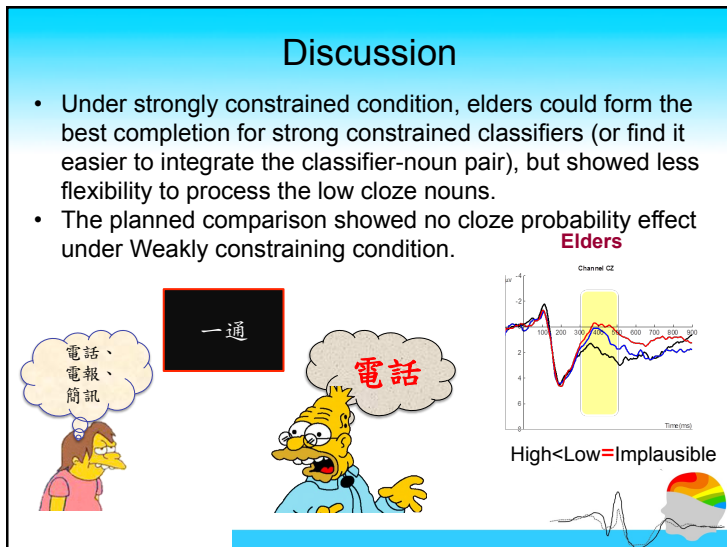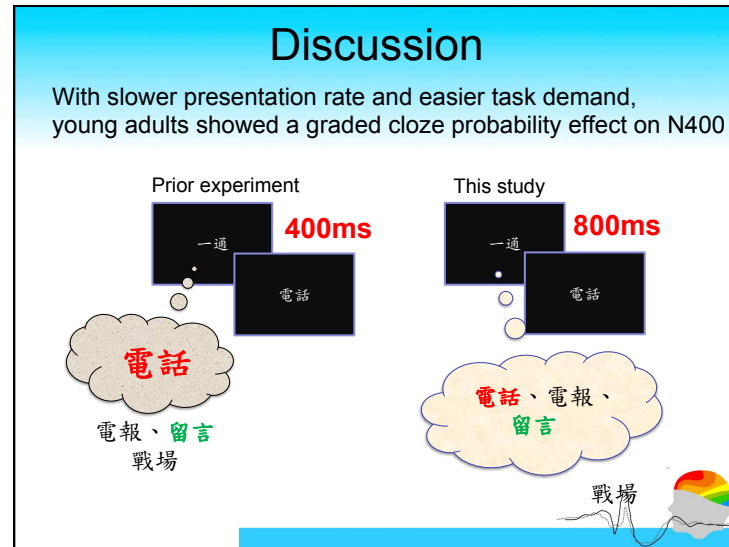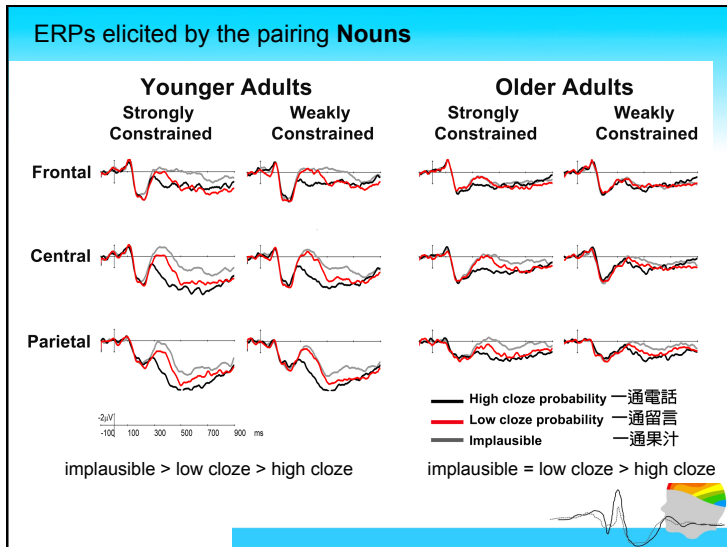High cloze probability 一通電話
Low cloze probability 一通留言
Implausible 一通果汁

implausible > low cloze > high cloze   implausible = low cloze > high cloze

---

Discussion

With slower presentation rate and easier task demand, young adults showed a graded cloze probability effect on N400

Prior experiment   This study
400ms   800ms
一通   一通
電話   電話

電話   電話、電報、留言
電報、留言
戰場   戰場

Discussion

- Under strongly constrained condition, elders could form the best completion for strong constrained classifiers (or find it easier to integrate the classifier-noun pair), but showed less flexibility to process the low cloze nouns.
- The planned comparison showed no cloze probability effect under Weakly constraining condition.

Elders

電話、電報、簡訊

一通

電話

Channel CZ

High<Low=Implausible

Conclusion

- Healthy elders showed
  - No constraining effect from the classifiers on P200 and N400.
  - Reduced and delayed cloze probability effect on N400.
- Our data supports that the ability to use the contextual information is compromised with age.

- The ERP components, such as P200 and N400 may serve as neural markers for evaluating the severity of comprehension impairment.

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Cloze Task
THANKS FOR YOUR _____!

ATTENTION (CLOZE P. =99%)

QUESTION (CLOZE P. =1%)