Using EEG to Measure L2 Word Learning

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Jeffrey Green, Ellen Knell, and Rachel Yu Liu

Main question

How can brain-based measures help us understand second-language acquisition?

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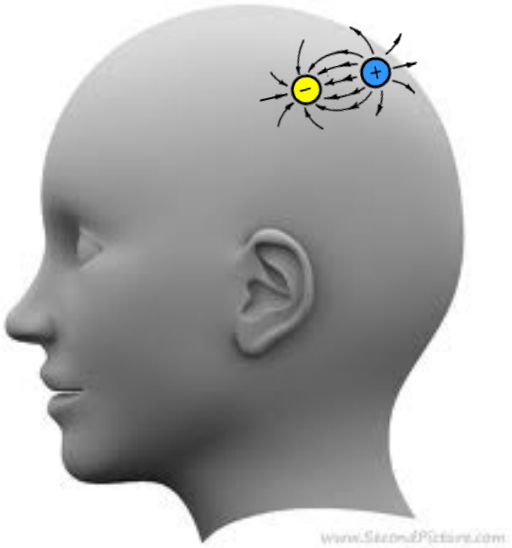
Electroencephalography (EEG)

- Recording of subject's brainwaves as they perform a task
- Highly sensitive
- Excellent temporal resolution

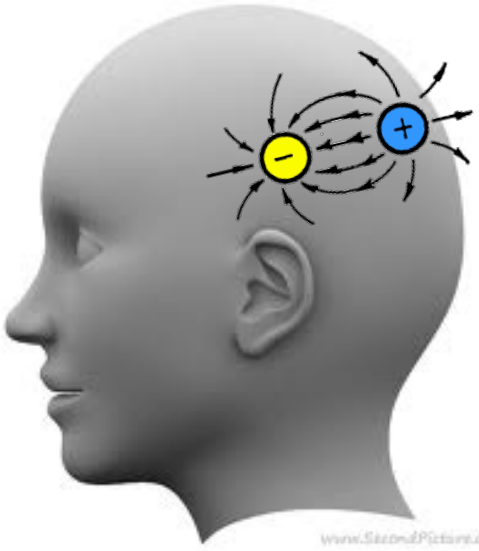
EEG & Event Related Potentials (ERPs)

- Changing neural activity will change electrical fields outside the head
  - These changing fields give rise to the EEG
- ERP: An EEG response time-locked to the presentation of a stimulus

DOG



Time 0: baseline activity



Time 200ms: 'language' activity

EEG and L2 research

EEG has been used to demonstrate:

- Stages of learning that L2 learners go through
- That L2 learners can have similar processing strategies as L1 speakers
- That the brain begins to show evidence of learning before it shows up in behavior

The current study: What insights does EEG provide into the early stages of L2 Chinese character learning?

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Neural correlates of second-language word learning: minimal instruction produces rapid change

Judith McLaughlin, Lee Osterhout & Albert Kim

Adult second-language (L2) learning is often claimed to be slow and laborious compared to native language (L1) acquisition, but little is known about the rate of L2 word learning. Here we report that adult second-language learners' brain activity, as measured by event-related potentials (ERPs), discriminated between L2 words and L2 'pseudowords' (word-like letter strings) after just 14 h of classroom instruction. This occurred even while the learners performed at chance levels when making overt L2 word-nonword judgments, indicating that the early acquisition of some aspects of a new language may be overlooked by current behavioral assessments.

ERPs, measured from the scalp, provide a nearly continuous sampling of the brain's electrical activity[1]. We focused on learning-related changes to the N400 component, a negative wave that peaks at 400 ms after the visual presentation of a word[2]. The N400 is sensitive to lexical status (that is, whether or not a letter string is a word)[3] and word meaning[2,4]. For native speakers of a given language, the N400 amplitude is largest for pronounceable, orthographically legal nonwords (hereafter, 'pseudowords'); it is intermediate for words preceded by a semantically unrelated context; and it is smallest for words preceded by a semantically related context[5]. Our goal was to determine how much L2 exposure is needed before a learner's brain activity reflects the lexical status and meaning of L2 words.

Our participants included a group of university students who were enrolled in an introductory French course but had not had formal instruction in or significant exposure to French before the study ('learners'), and a control group who had never received any French instruction or significant exposure to French ('nonlearners'). All participants reported at least 1 year of instruction in another foreign language. We longitudinally obtained ERPs and behavioral responses from both groups in three separate sessions (for the learners at ses-

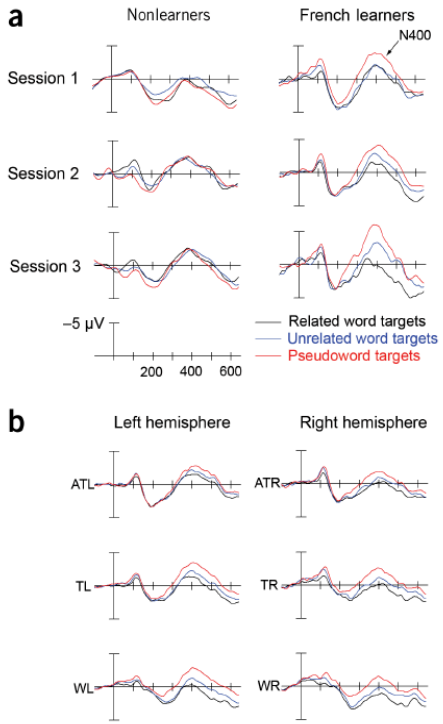

Figure 1 Event-related potentials to target stimuli. (**a**) ERPs to word and pseudoword targets during the three testing sessions, for the nonlearners (n = 8; mean age: 27.6 years) and French learners (n = 18, 16 and 13 for sessions 1, 2 and 3, respectively; mean age, 21.3 years). Informed consent was obtained from all participants. Data acquired over the central midline site (Cz) are shown. The vertical calibration bar indicates target onset. Each tick mark represents 100 ms. (**b**) Learners' ERPs to targets, averaged over sessions. ATL/R, anterior temporal left/right; TL/R, temporal left/right; WL/R, Wernicke's area left/right. Trial sequence: fixation cross (500 ms); blank screen (500 ms); prime (400 ms); blank screen (400 ms); target (400 ms); blank screen (400 ms); response prompt. Electroencephalographic activity was sampled at 200 Hz from 13 scalp sites (three midline, five lateral pairs; 0.01–100 Hz bandpass; 3 dB cut-off; left mastoid reference). Trials contaminated by artifacts (17%) were excluded. N400 amplitude was quantified as mean voltage within a 300–500 ms window, relative to a baseline of mean voltage from 100 ms before to 50 ms after stimulus onset. We used a repeated-measures ANOVA with the Greenhouse-Geisser correction.

Nature Neuroscience, 7(7)

McLaughlin, Osterhout, & Kim (2004)

Research Question

- Adult L2 learning can be slow and laborious
- Little is known about the rate of learning

How quickly does the brain show evidence for learning (lexical status and meaning) of L2 words?

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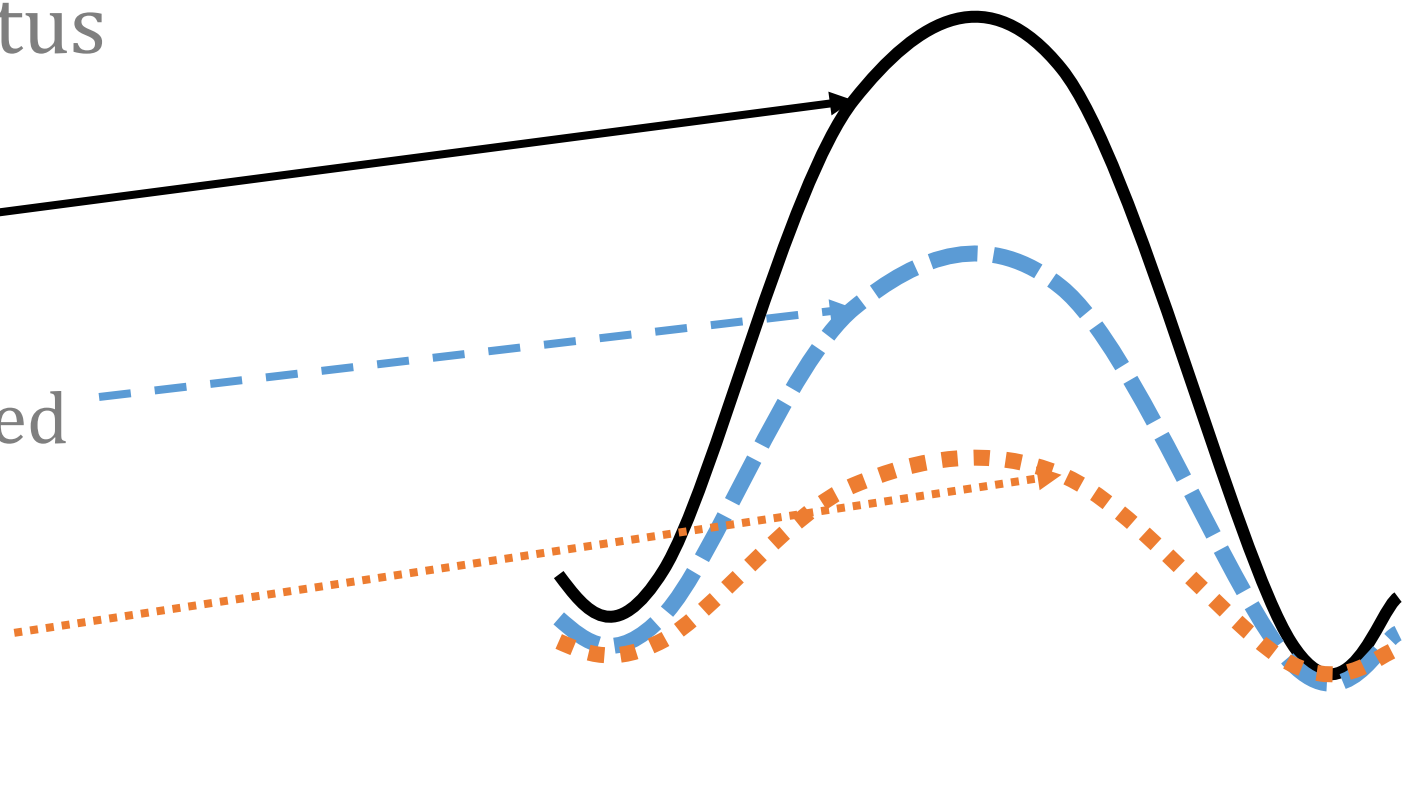
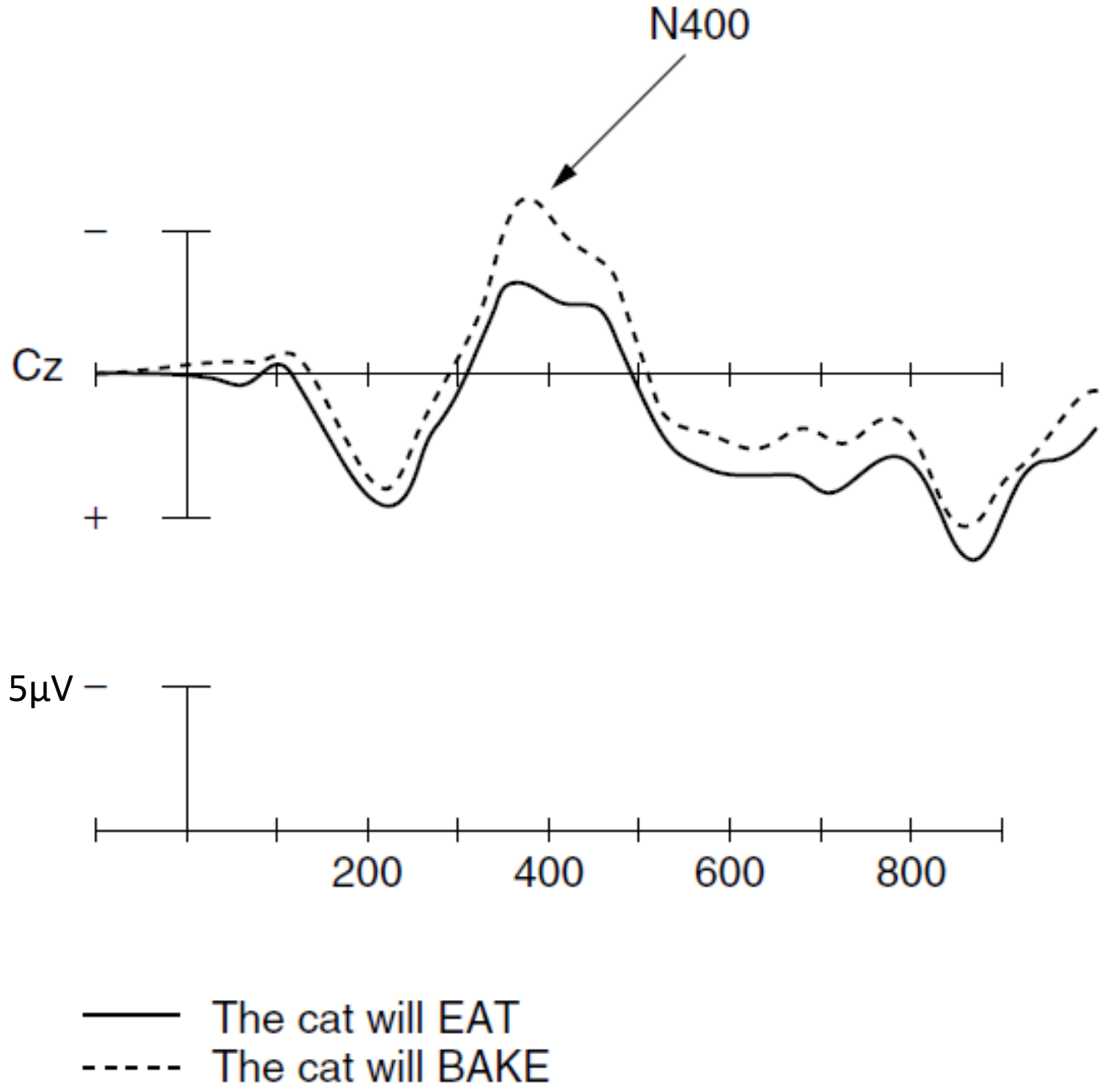
The N400

Sensitive to lexical status

- For L1 speakers:
  - ‘pseudowords’
  - Words preceded by semantically unrelated context
  - Words preceded by semantically related context

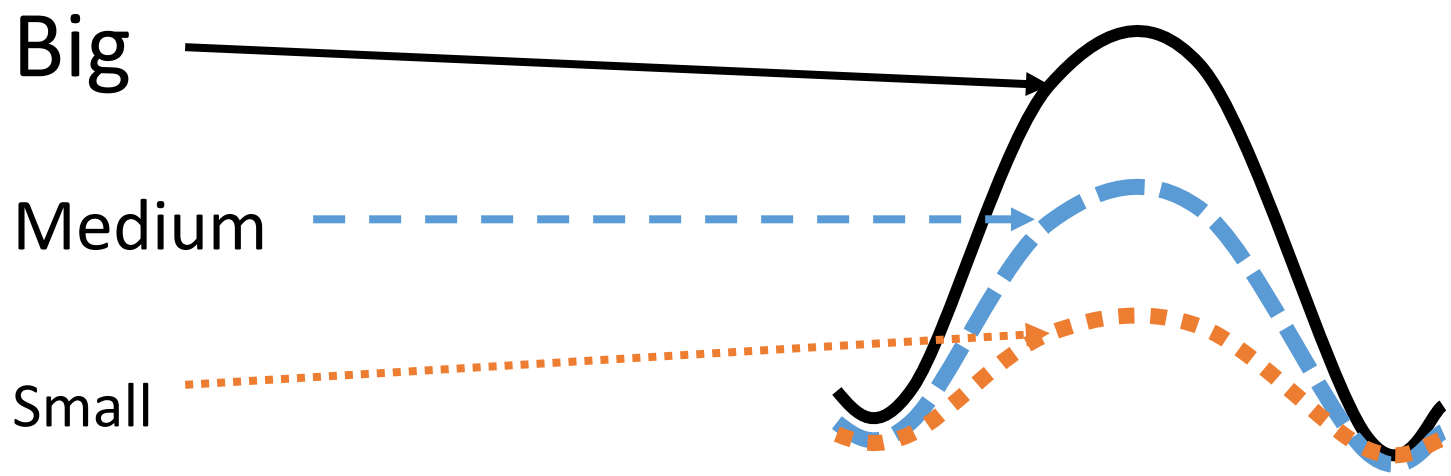


The N400



Stimuli

Prime-Target pair	Expected target N400 (native-like)
Word-pseudoword: *mot – nasier (word --)*	Big
Semantically unrelated: *maison-soif (home-thirst)*	Medium
Semantically related: *chien-chat (dog-cat)*	Small



Method

- Lexical decision for the second word in each prime-target pair
- Concurrent with EEG recording, behavioral score obtained
- Target words were selected from the class textbook
  - Pseudowords were derived by taking words from the text and replacing one or two of the letters

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Participants

- Beginning university French students
  - No previous exposure to French
  - (*n*=18)
- Non-learners
  - No previous exposure to French
  - (*n*=8)

- 13 scalp sites

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Sessions

Obtained ERP and behavioral responses from both groups in 3 separate sessions

- Session 1: mean 14 h of instruction for learners
- Session 2: mean 63 h
- Session 3: mean 138 h

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Behavioral results

Table 1 Proportion of words and pseudowords identified as a word in the lexical decision task, and the *d′* measure of sensitivity

	Words			
	Related	Unrelated	Pseudowords	d′
Nonlearners				
Session 1	0.57	0.57	0.60	–0.1
Session 2	0.56	0.54	0.56	0.0
Session 3	0.56	0.55	0.54	0.0
French learners				
Session 1	0.61	0.62	0.63	0.0
Session 2	0.70	0.65	0.48	0.5
Session 3	0.74	0.71	0.44	0.8

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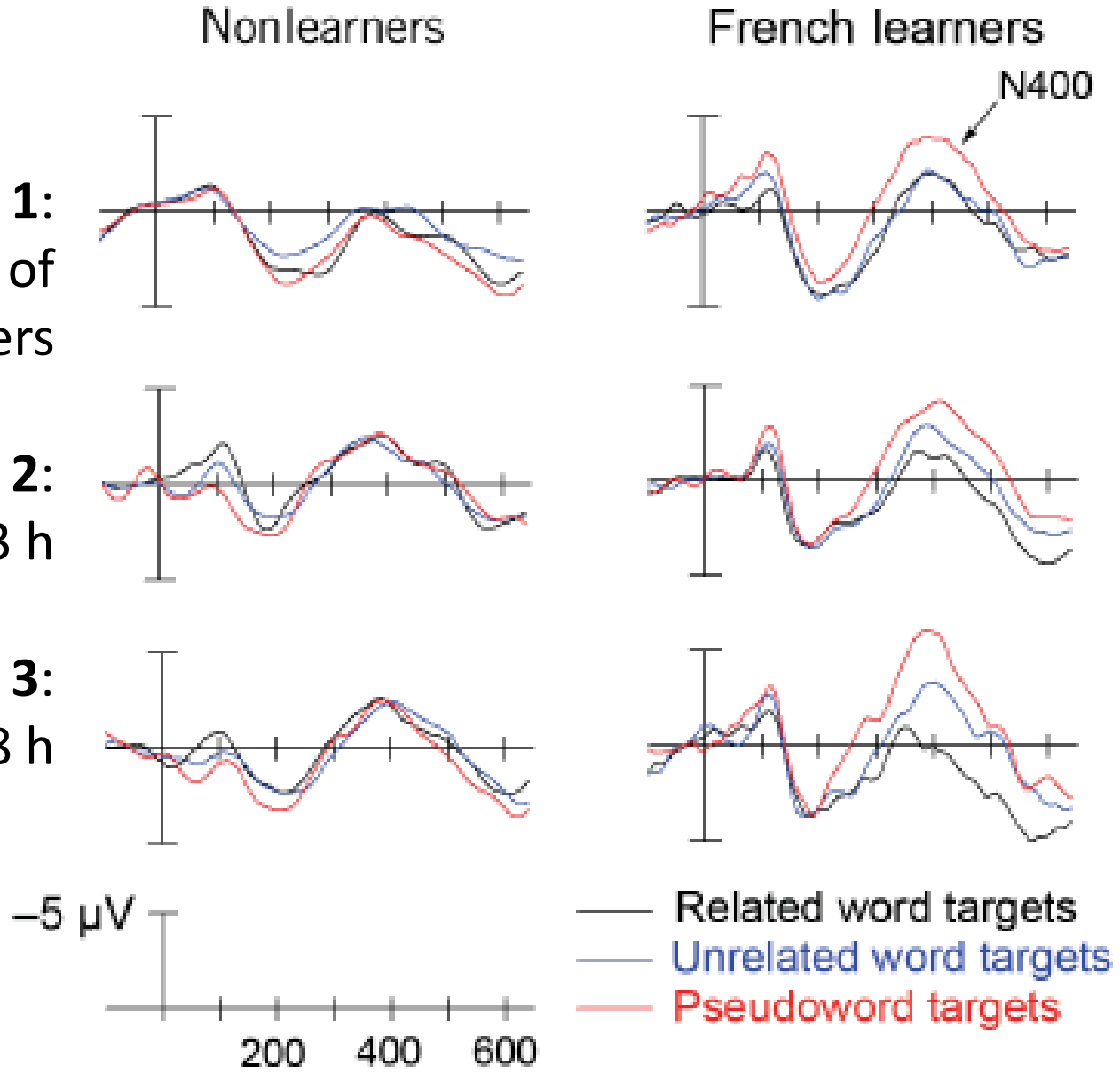
ERP results

Session 1:
mean 14 h of
instruction for learners

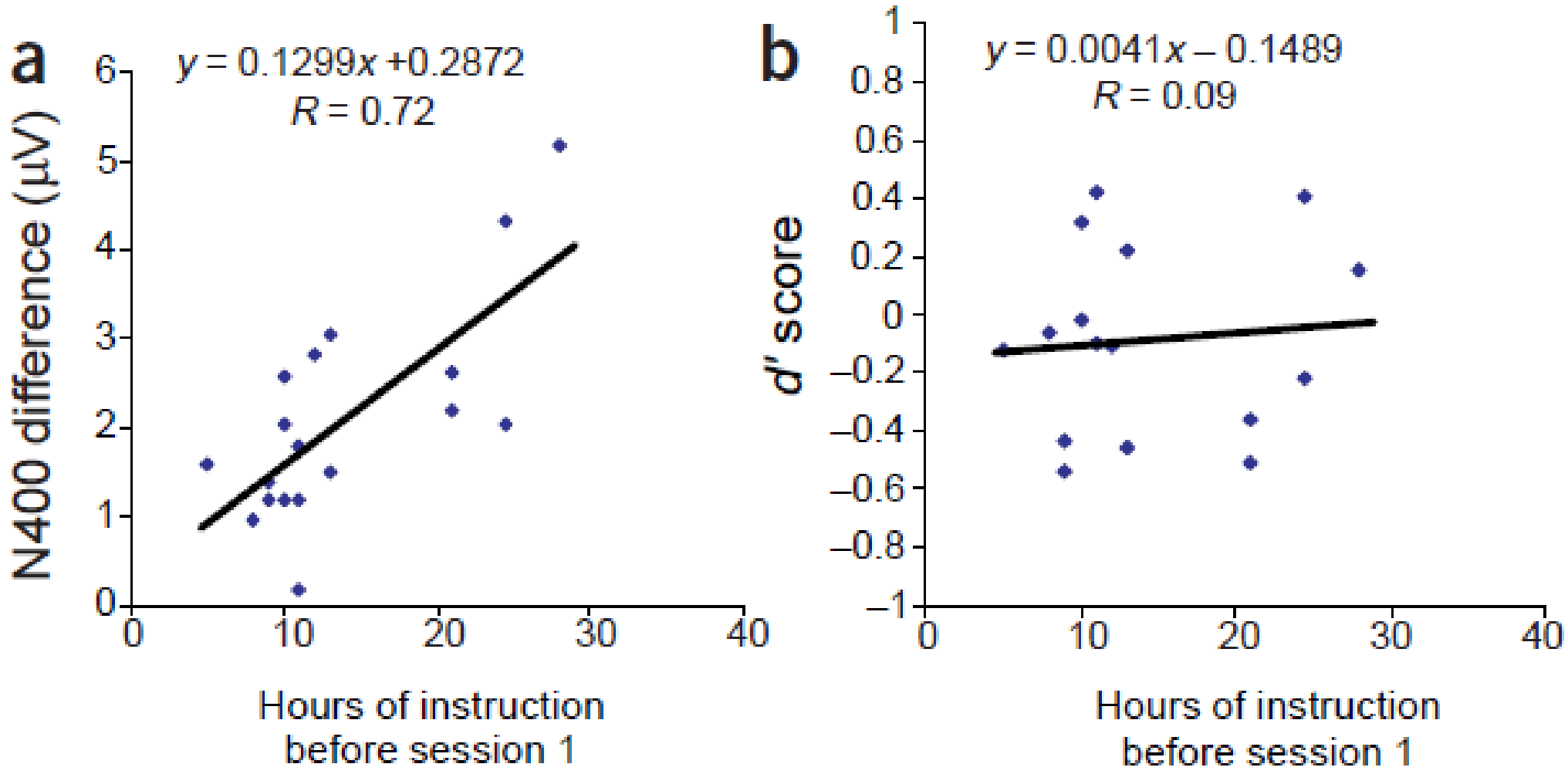
Session 2:
mean 63 h

Session 3:
mean 138 h



N400 correlated with exposure in session 1

Comparing words to pseudowords



Discussion

- Adult language learners rapidly accrue information about L2 words
  - First about word form
  - Then about word meaning
- Learner's brainwaves approximated native speakers' by end of one year of instruction

- Learning is happening before you can detect it behaviorally!

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Replication
Studies in Second Language Learning

- Beginning-level French students (Chinese students will be the control group)
- Beginning-level Chinese students (French students will be the control group)

    - Does a different word learning trajectory occur for the two languages
        - Chinese is a nonalphabetic writing system
        - Learning characters can be very challenging for L2 learners
        - Not phonologically accessible

- Improved equipment (cap has 30 electrodes instead of 13)
- Mixed-effects model will be used instead of an ANOVA

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THE CURRENT STUDY


Replication study

Studies in Second Language Learning

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Why Chinese?

- Should Chinese character instruction be delayed for beginners?
  - In favor: Overwhelming for learners; can focus on oral learning/Pinyin; learners are more motivated
  - Against: Characters are the basis of Chinese language; learning four skills together can support learning
    - **Packard (1990)** delayed group had better oral fluency than non-lag group but no differences in reading
    - **Knell & West (2017)** early instruction group performed significantly better than the delayed group on reading comprehension and writing but no difference in oral measures

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Stimuli

Prime-Target pair

Character - pseudo character:

月 *month* - 貝

Semantically unrelated:

月 *month - hundred* 百

Semantically related:

月 *month - day* 日

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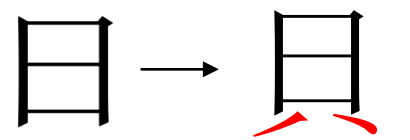
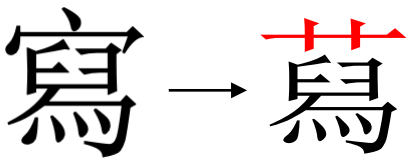
Stimuli

- Creating pseudo characters:
  - Increasing / reducing strokes
  - Replacing radicals / components





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Method

- Lexical decision task in both French and Chinese
- First-semester French or Chinese students

- One session recorded so far
  - French students: mean of 17 hours of instruction
  - Chinese students: mean of 24 hours of instruction

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Behavioral results

FRENCH

Students	Words: Related	Unrelated	Pseudowords	D-prime
French	0.82	0.79	0.59	1.08
Chinese	0.75	0.71	0.43	0.44

CHINESE

Students	Words: Related	Unrelated	Pseudowords	D-prime
French	0.64	0.57	0.46	0.27
Chinese	0.66	0.68	0.52	0.56

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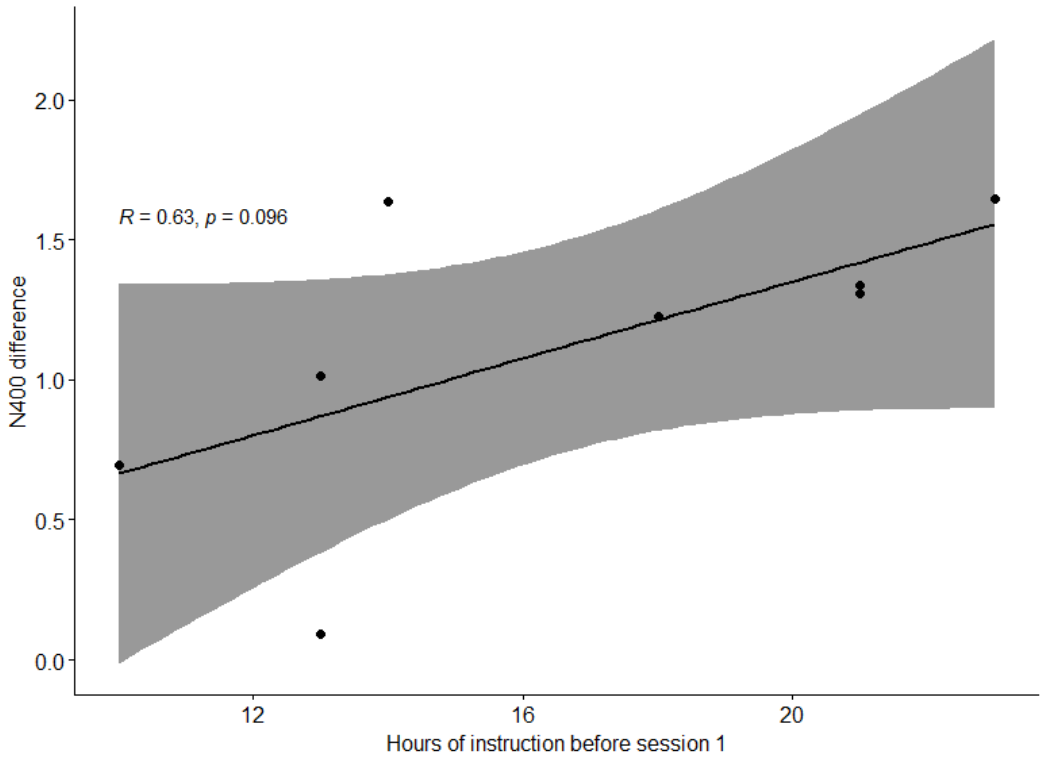
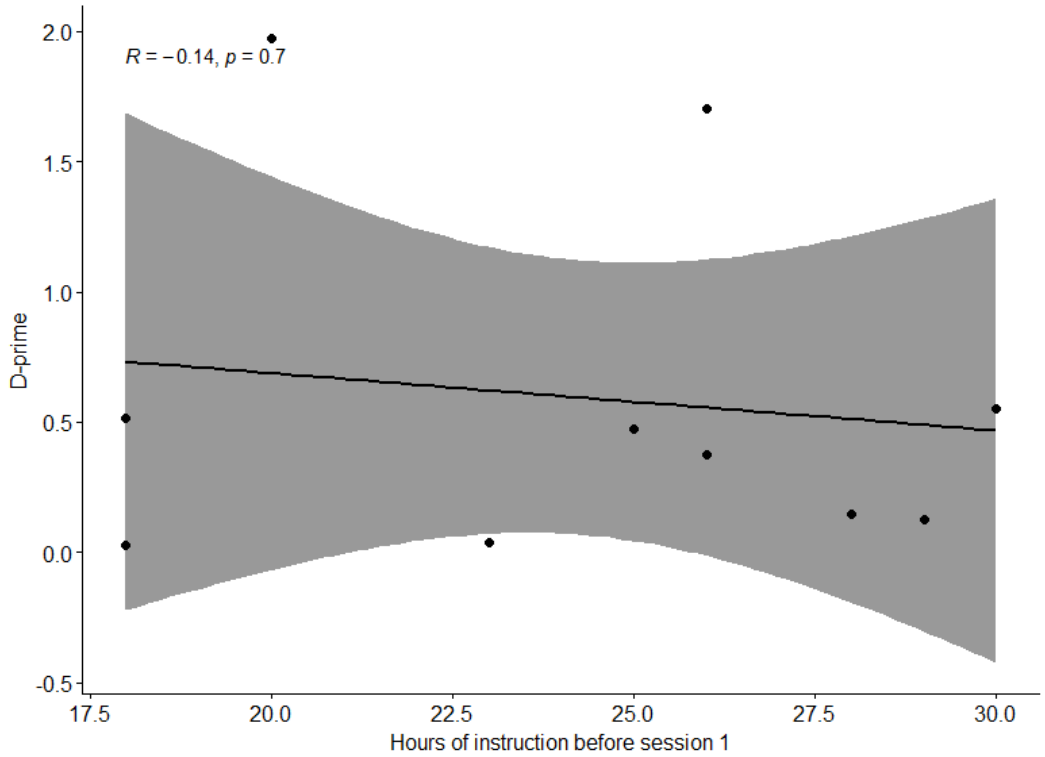
Correlation of D-prime and exposure

French students (n=8)



Chinese students (n=10)



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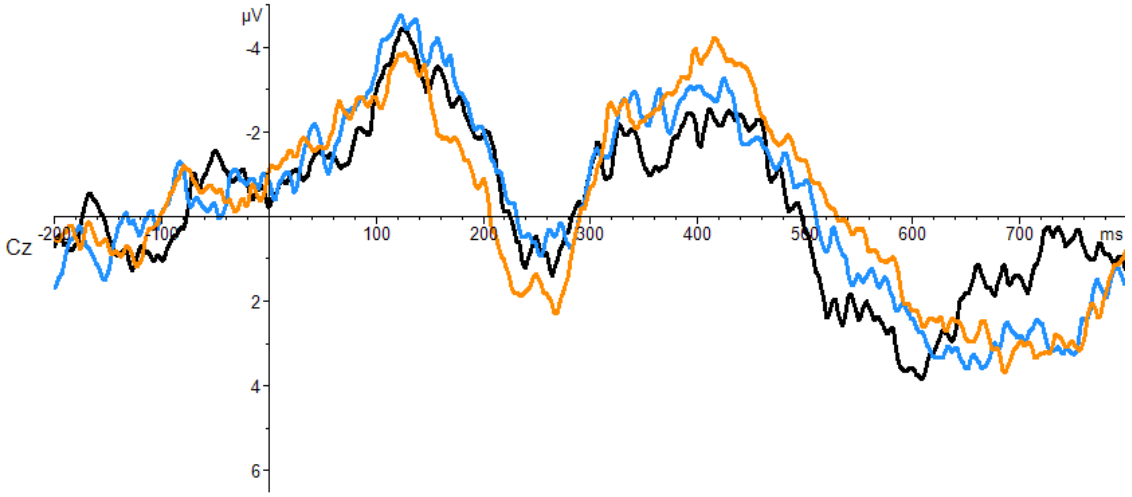
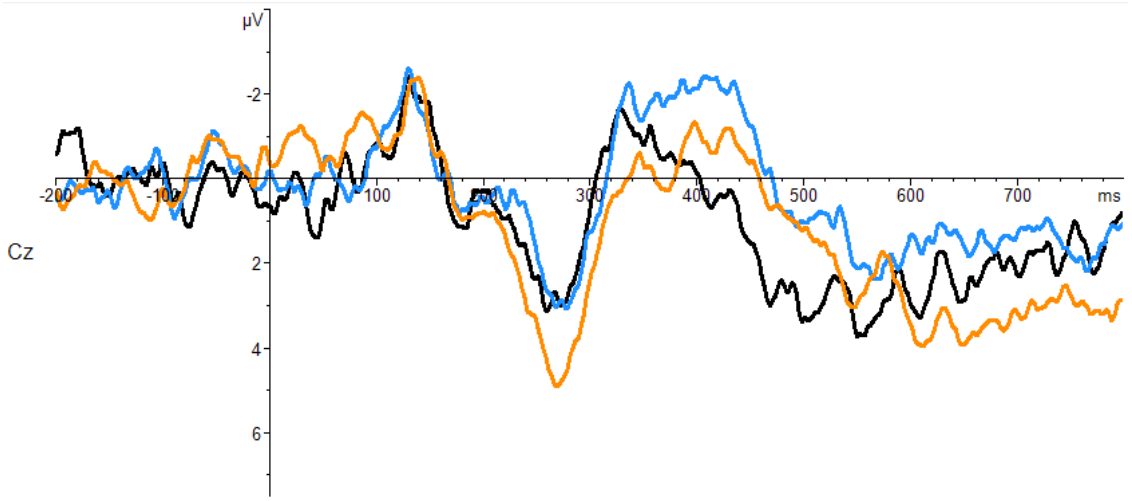
ERP results: French

French learners (n=8)



Non-learners (n=6)



Related
Unrelated
Pseudo

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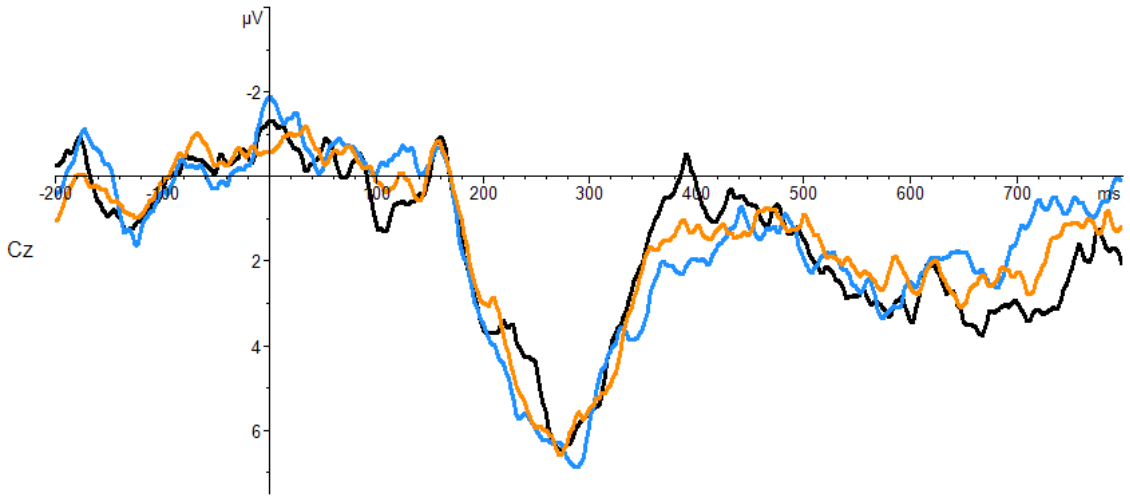
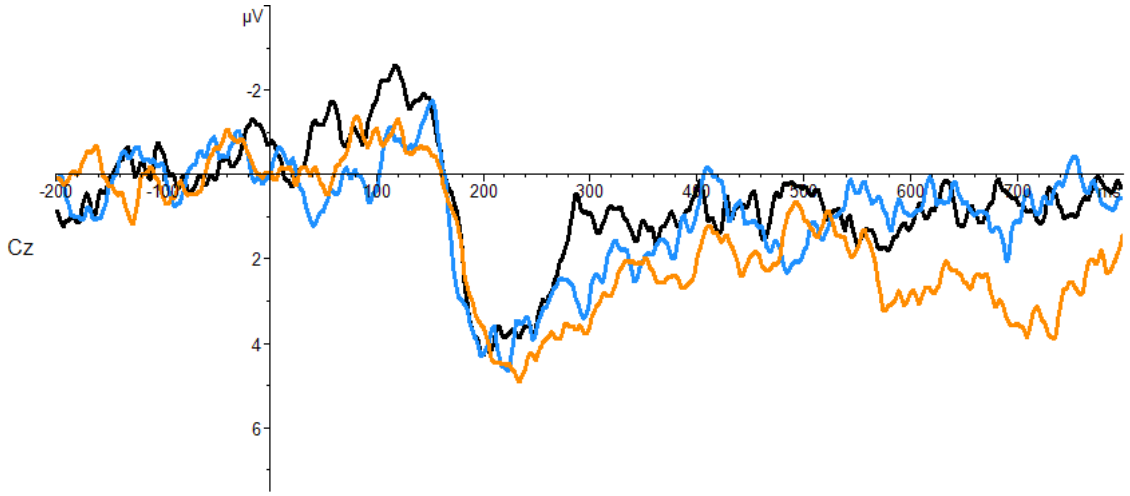
ERP results: Chinese

Chinese learners (n=10)



Non-learners (n=7)

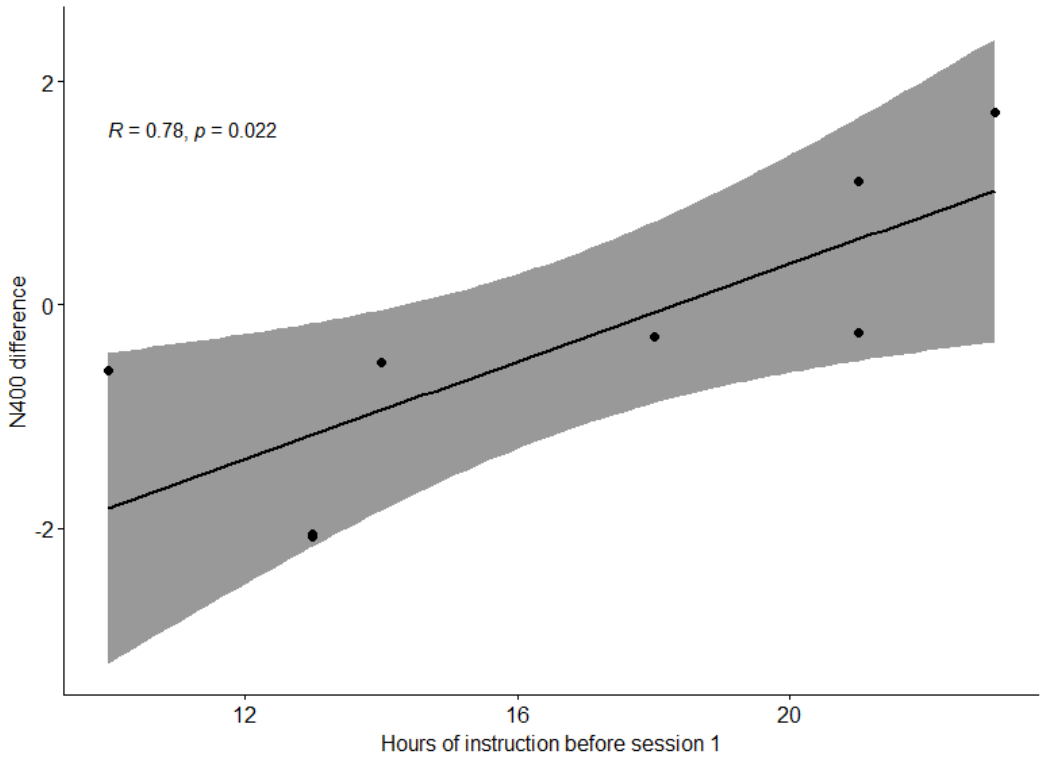


Related
Unrelated
Pseudo

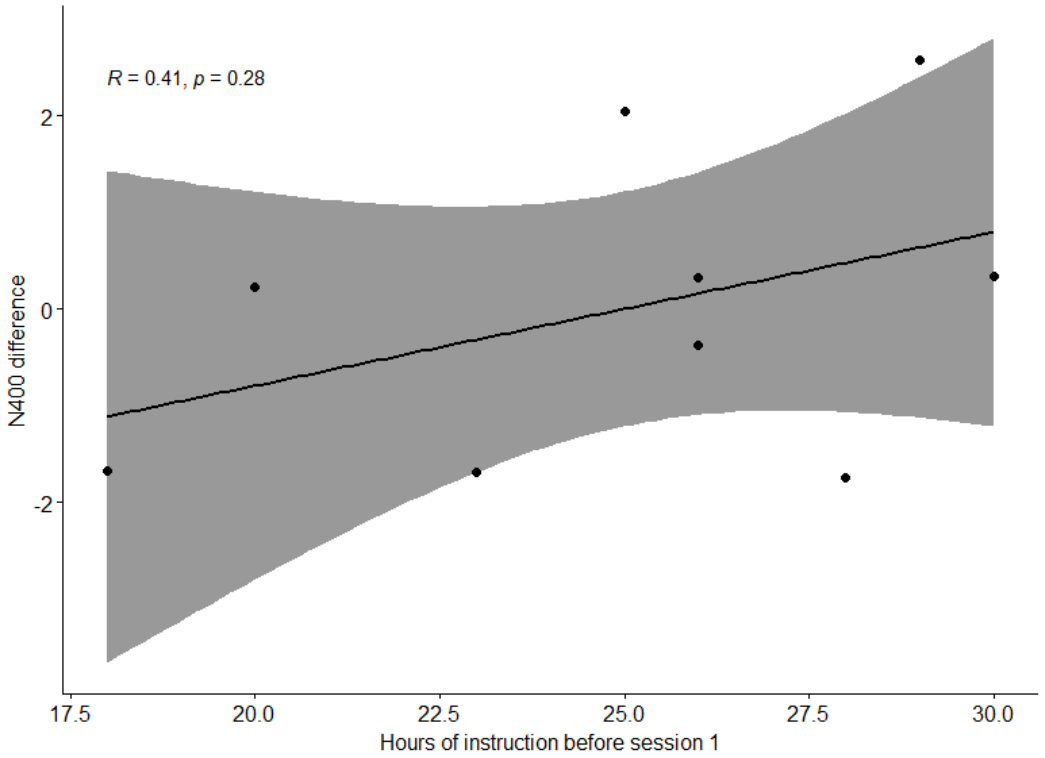
BYU

Correlation of N400 and exposure

French students (n=8)



Chinese students (n=10)



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Discussion

- French students may be showing more evidence for learning
- But the Chinese students also appear to treat the characters as meaningful, and show some evidence for learning over time

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Conclusion

Brain-based measures can provide insights into L2 learning beyond behavioral measures!

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Thanks

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