An ERP Investigation on Subphonetic & Tonal Processes in Silent Chinese Reading

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Introduction

- The connnection between spoken words and semantic meaning is believed to be the primary association formed in the process of language acqusition. In contrast, it has been argued that the orthographic system development is appended onto the already existing speech process.
- Given that phonology plays a crucial role in speech comprehension, the orthographic devlopment claim implies that there is phonological mediation in reading.
- Robust evidence [3,6] on automatic, early phonological activation in reading seems to corroborate this proposition. However, a word of caution is required because the existence of phonological activation does not logically bear upon the issue of phonological constraints on semantic comprehension in reading.
- Chinese is a pictographic (Fig 2) and tonal language. In contrast with English words in which graphemic properties are confounded with phonetic attributes, there is an arbitrary relation between orthographic and phonological codes of a Chinese character [7] (i.e., homophones: Âŧma2'-linen; Âlma2'-ant).
- Three major issues were addressed in this study: is there any phonological representation in Chinese reading? If the answer to the above question is positive, then is the phonological activation bypassed or indispensable in access to meaning; and, is the phonological activation an impoverished process or detailed dynamic subphonological processing? In addition, do tonal attributes give any contribution to Chinese reading?
- Event-related brain potentials (ERPs) provide a continuous account of brain activity associated with sensory and cognitive functions. Among ERP potentials, there is a negative component (N400) that putatively reflects lexical semantic analysis [1,8].

Hypotheses

- The N400 will respond to subphonetic and tonal contextual cues.
- Based on recent neuroimaging studies, ERPs over frontal as well as temporal sites may present a clear picture of the nature of phonological encoding in reading.
- If there is phonological mediation in access to meaning, ERP features covarying with subphonetic violations will precede the semantic N400.

Methodology

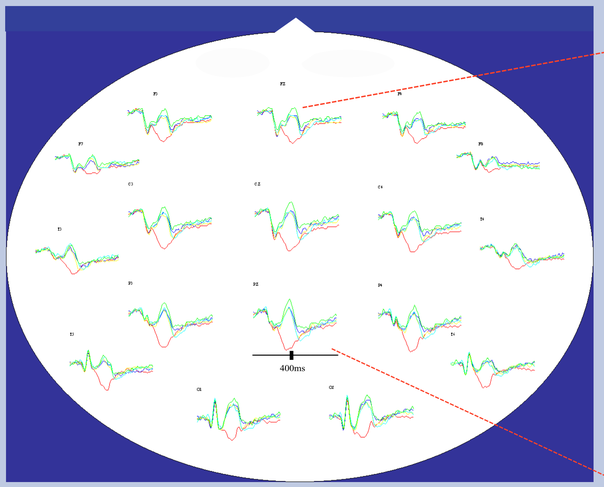
- Participants:
  - 15 native speakers of Chinese Mandarin (7M/8F)
  - Mean age = 22 yrs. (age range = 18-26 yrs.)
- Procedure:
  - Four-character Chinese idioms (proverbs) were presented one character at a time on a computer monitor
  - The phonetic assembly of a Chinese character generally consists of initial consonant, final vowel affiliated with a tone *(monosyllable)*
  - Five experimental conditions used proverbs in which the ending character varied according to initial consonant and/or final vowel and/or tone appropriateness. Four conditions involved semantic violations. (fig 1)
- Electrophysiological recordings
  - Analogue EEG activity (0.01-100 Hz; 500 Hz sampling rate) was recorded from 17 sites (fig 3) according to international 10-20 system.
  - ERPs were sampled 100 ms before target character onset and 1000ms after target onset.
  - Data analysis: the factors were the Condition factor (5), a Time factor(6 levels: 250-300ms, 300-350ms, 350-400ms, 400-450ms, 450-500ms, 500-550ms), and a Site factor (17). In addition, N400 peak amplitude and latency were scored within a latency range of 300 to 500 msec.

All statistical analyses were conducted using repeated measure ANOVA with conservative degrees of freedom and Tukey HSD post hoc analysis when necessary. All analyses required an alpha level of $p<0.05$ for statistical significance.

Figure 1 illustrates stimuli in five experimental conditions .

Accurate Condition: consonant match-vowel match -tone match-semantic match
(xian4) thread " Let sleeping dogs *lie* "
Consonant Change Condition: consonant mis.- vowel match- tone match- semantic mis.
(guo3) "» huo3)" fruit "fire" " Let sleeping dogs *tie* "
Vowel Change Condition: consonant match- vowel mis.- tone match- semantic mis.
(mi3) ¡Á(ma3)" rice "horse" " Let sleeping dogs *law* "
Tonal Change Condition: consonant match- vowel match- tone mis.-semantic mis.
(ming2) ¡Á(ming4)¡±brightness "life" (no equivalent examples in English)
Incongruous Condition: consonant mis.- vowel mis.- tone mis.- semantic mis.
(qiu1) ¡Ê(shui3)¡±autumn "water" " Let sleeping dogs *draw* "

Fig 2 exemplifies Chinese characters' evolution (from ancient Chinese inscriptions on bones of Shang Dynasty (c. 16th-11th century B.C) to simplified but more abstract modern Chinese writing).



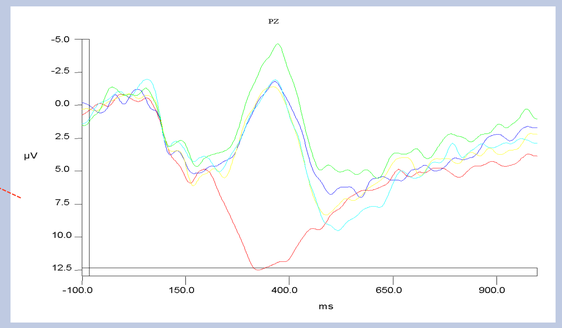


Fig 3: Grand average ERPs at 17 recording sites for idiom-ending characters in five Conditions from a sample of native Chinese speakers (N=15) while asked to think of the meaning of the ending character as accurately and clearly as possible. The N400 was seen in the last four conditions with the largest being in the fifth. There is a clear differentiation of ERP waveforms over frontal sites between suphonetic and tonal change conditions.Following the N400, there is a positivity most apparent in the tonal change condition.

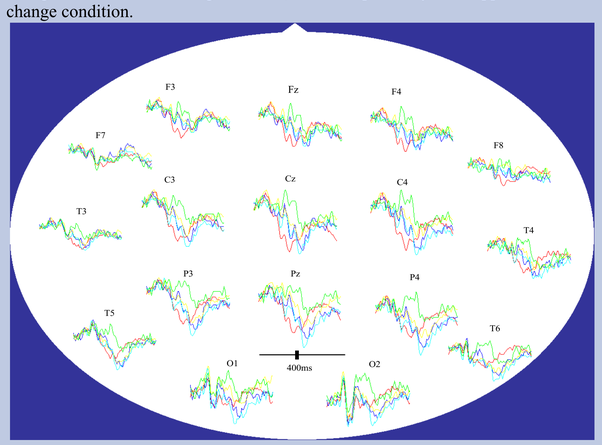


Fig 4: Individual ERPs for subject 09 while doing the silent Chinese reading task. This individual was believed to prefer 'o-p-s' route in Chinese character recognition.

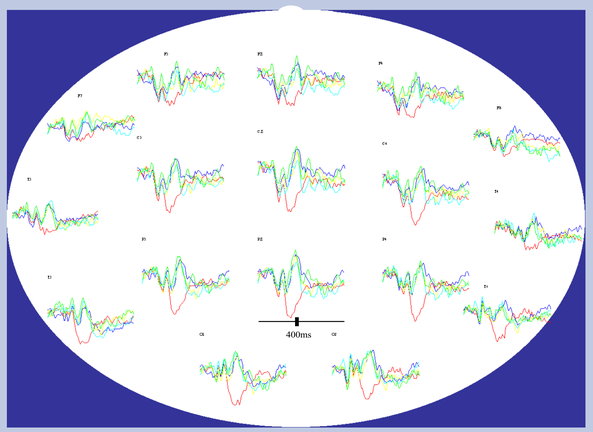


Fig 5: Individual ERPs for subject 01 while performing the Chinese reading task. The gross pattern of the ERP waveforms were observed in other 13 of 15 individuals tested.

Discussion and Conclusion

- Hypothesis 1 confirmed: There is a clear N400 response with left hemisphere dominance to tonal variations.

  The findings corroborate our claim [8] that tones in Chinese (i.e., word prosody) are represented in the mental lexicon. It is evident that tonal information has a critical role during reading and does not merely carry acoustic features and contribute only to speech comprehension.
- The findings that there are sub-phonological effects on the classical N400 indicate sub-phonological contextual primings in Chinese reading. It is noteworthy that phonological cues *do* play a role in silent Chinese reading in a ***top-down*** fashion.
- The ERP waveform pattern over frontal sites suggests that there are detailed sub-phonetic transformations rather than impoverished phonological encoding in Chinese reading. Most interestingly, subphonological transformation seems to start with vowel and tonal codes while consonantal encoding takes place at a relatively later stage. This finding seems compatible with the results from some behavioral English reading studies [2].

  In support of hypothsis 2, the sensitivity of frontal ERPs to subphonetic changes seems not inconsistent with the proposition addressed in some neuroimaging studies [3] that the activity in frontal and temporal areas subserves phonological transformation in reading.
- Our findings seem difficult to reconcile with the notion that semantic access is exclusively via the phonological mediation route [3]. Instead, these results are better understood within a parallel-distributed reading model [4].

  Taken together, it may be the case that the primary function of phonological activation in silent Chinese reading is to enable the character to be held in working memory while its context is processed further.
- Interestingly, among 15 individual ERP waveforms, there is one participant's ERPs (fig4) reflecting a clear orthography-phonology-semantic dynamic process pattern. The issue at stake here is the condition in which o-p-s processing takes priority over o-s processing.

References

1. Connolly J.F., Phillips N.A., and Forbes K.A.K (1995). The effects of phonological and semantic features of sentence-ending words on visual event-related brain potentials. Electroencephalography and clinical neurophysiology. 94: 276-287
2. Berstein S.E. and Treiman, R. (2001). Learning a novel grapheme:effects of positional and phonemic context on children's spelling. Journal of Experimental child psychology. 79(1): 56-77
3. Frost R. (1998) Toward a strong phonological theory of visual word recognition : true issues and false trials. Psychological bulletin 123(1): 71-99
4. Rumsey J.M., Horwitz B., Donohue B.C., et al (1997). Phonological and orthographic components of word recognition: a PET_rCBF study. Brain 120: 739-759
5. Seidenberg M. S. and McClelland J.L. (1989) A distributed, developmental model of word recognition and naming. Psychological Review 96: 523-568
6. Tan L.H., and Perfetti C.A. (1998). Phonological codes as early sources of constraint in Chinese word identification: A review of current discoveries and theoretical accounts. Reading and Writing: An Interdisciplinary Journal 10: 165-200
7. Zhou X., and Marslen-Wilson W. (1999). Phonology, Orthography, and Semantic Activation in Reading Chinese. Journal of memory and language. 41: 579-606
8. Wang J.T. and Connolly J.F (to be submitted). An ERP study on Tonal and segmental Processing in Spoken Chinese Mandarin.

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