

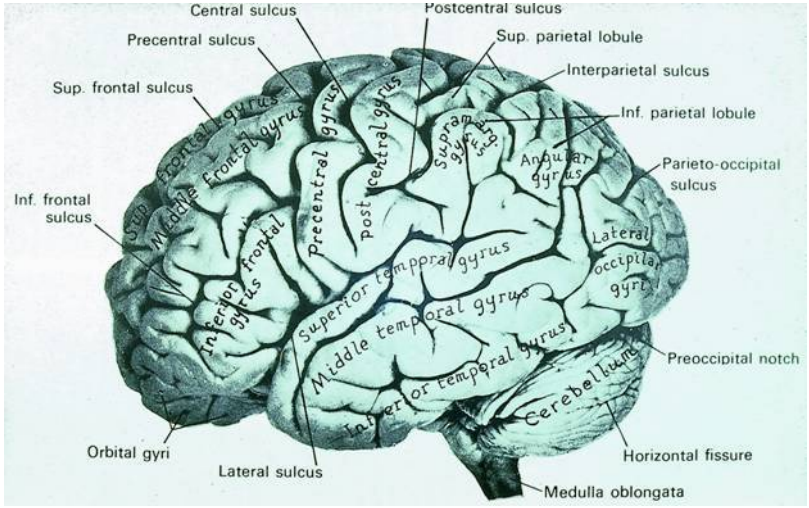

Joint Research Centre for Language and Human Complexity

The Impact of Language Diversity on the Brain

April 10, 2014

WHORF HYPOTHESIS

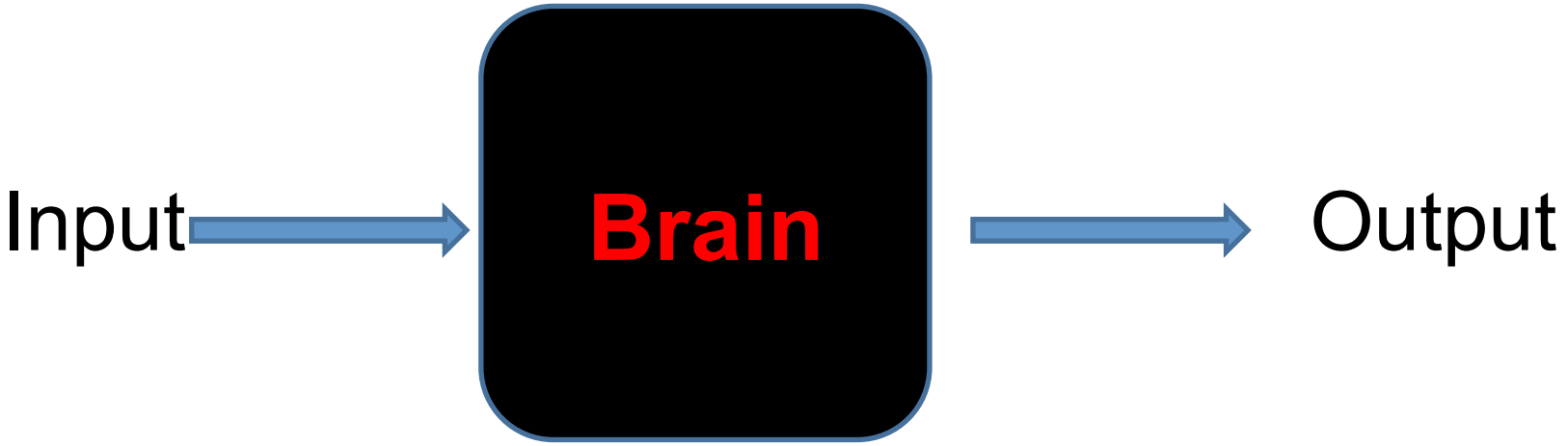
LANGUAGE → **BRAIN** → **BEHAVIOR**



Different LANGUAGES shape different BRAINS;
different brains produce different perceptions;
different perceptions produce different BEHAVIORS.

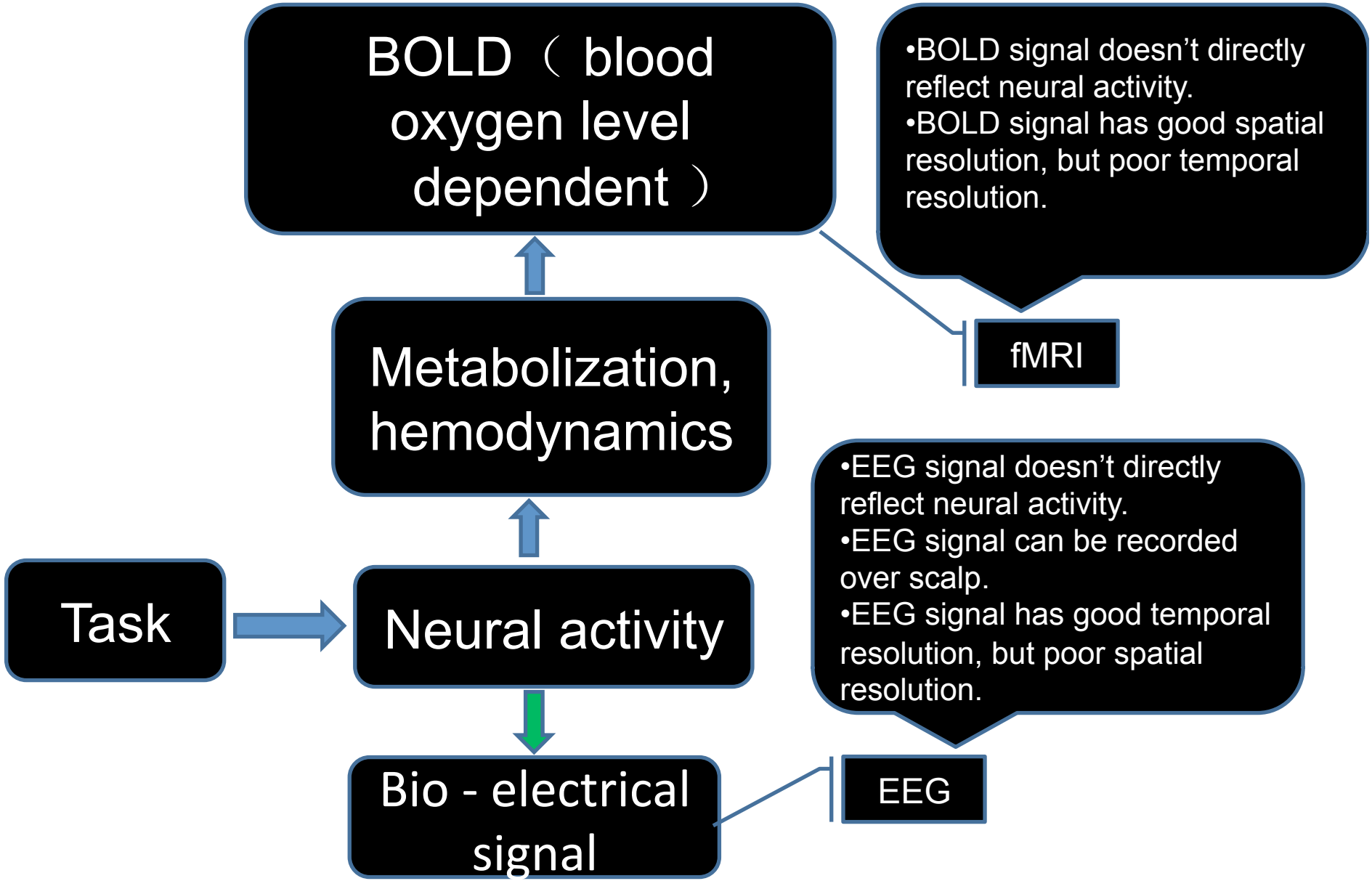
Methodology

- Behavioral tests



- Brain imaging tests：Electroencephalography (EEG), functional Magnetic Resonance Imaging (fMRI), Magnetoencephalography (MEG), etc.

Basic principles



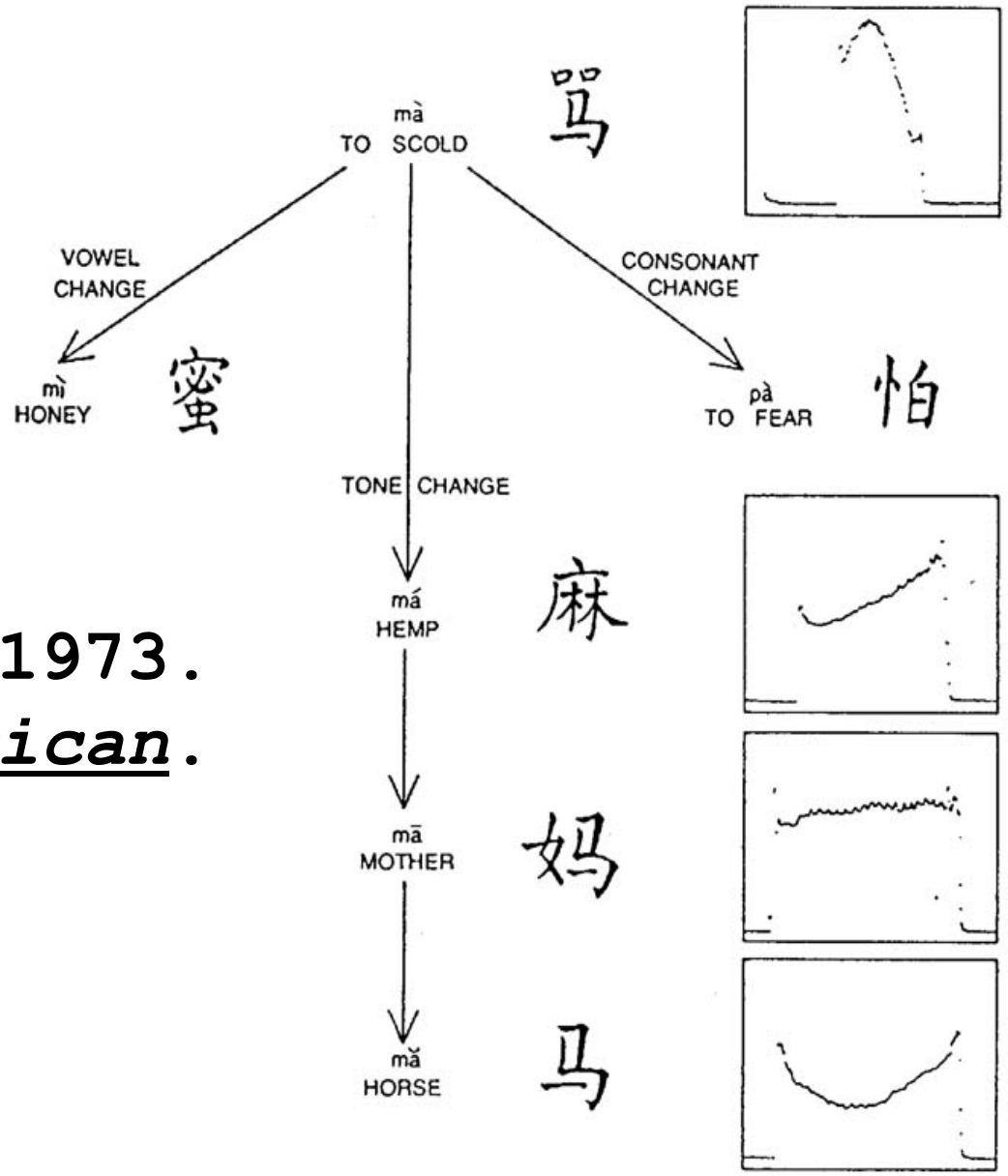
MRI

EEG

[http://www.scientificamerican.com/article.cfm?id=jacking-into-the-brain]

Tone perception

Chinese tones

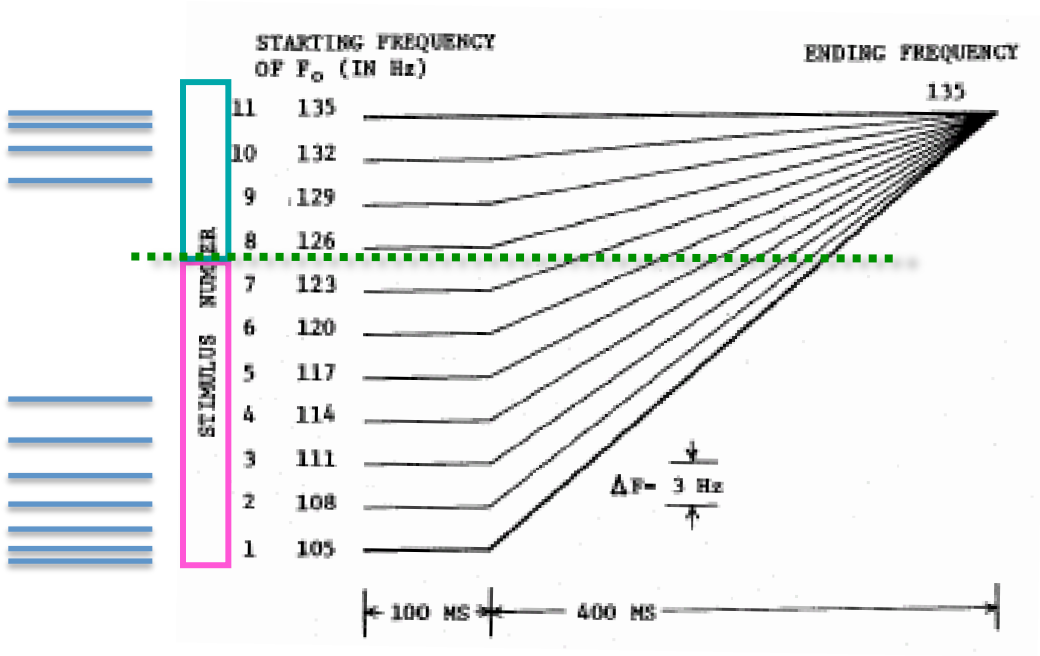


W.S-Y.Wang.Feb.1973.
***Scientific American*.**

Categorical perception (CP)

- Sounds are physically continuous but linguistic phonemes are discrete and limited.

- Categorical perception happens in the perceptual domain to facilitate the transformation procedure.



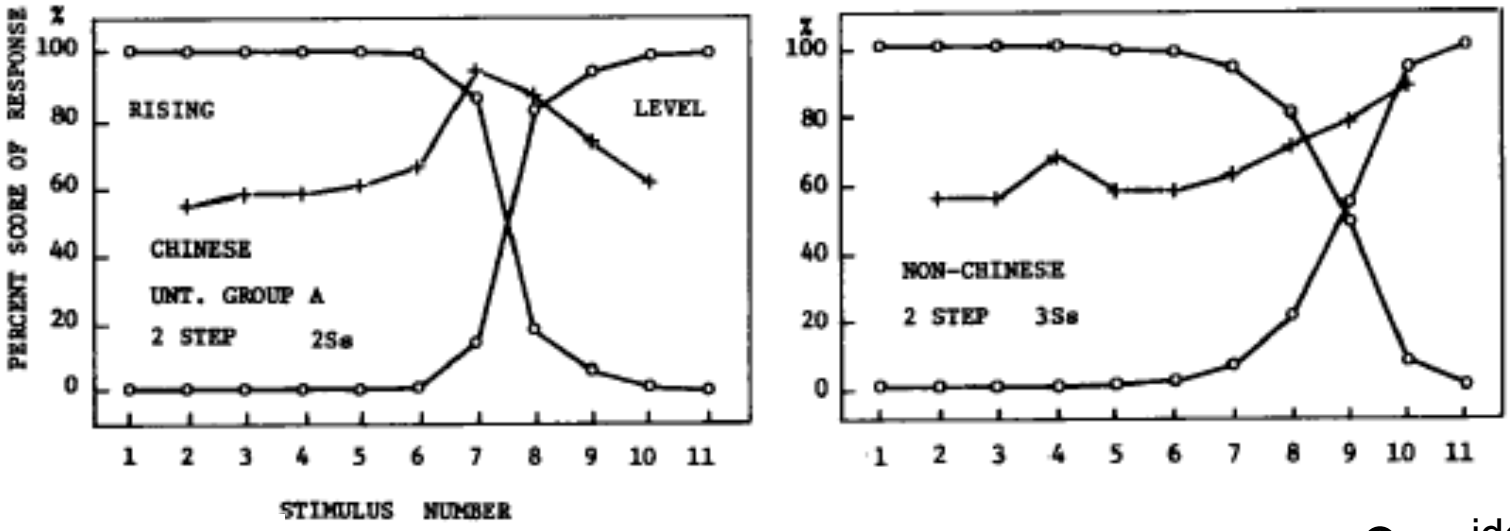
Perceptual domain <-> Physical domain

Wang, W.S-Y. 1976. Language change. *Annals of N.Y. Academy of Science* 280.61-72.

Tone CP

- CP is characterized by sharper transition across category boundary in the identification curve.

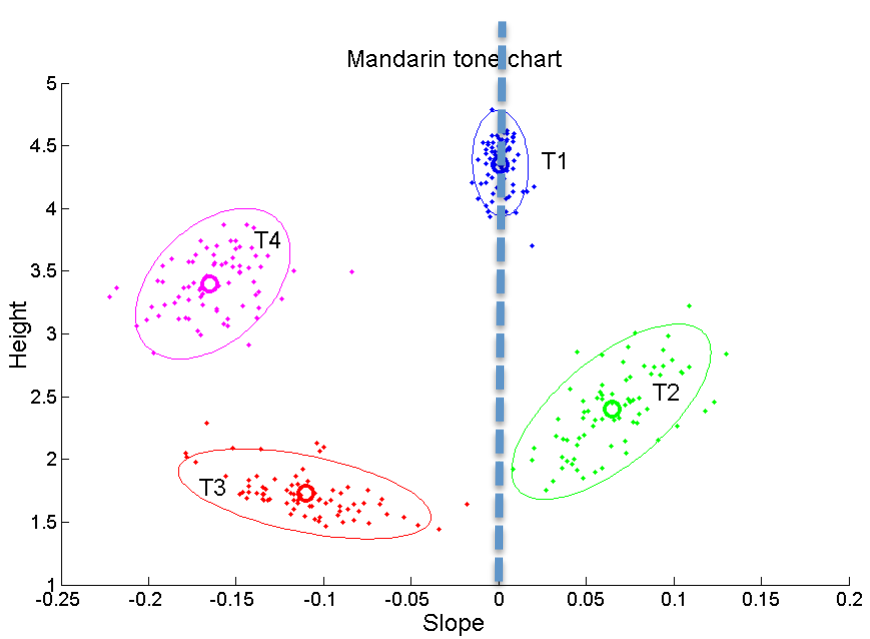
- CP is also characterized by the peak on category boundary in the discrimination curve, or better discrimination for across-category pair than for within-category pair.

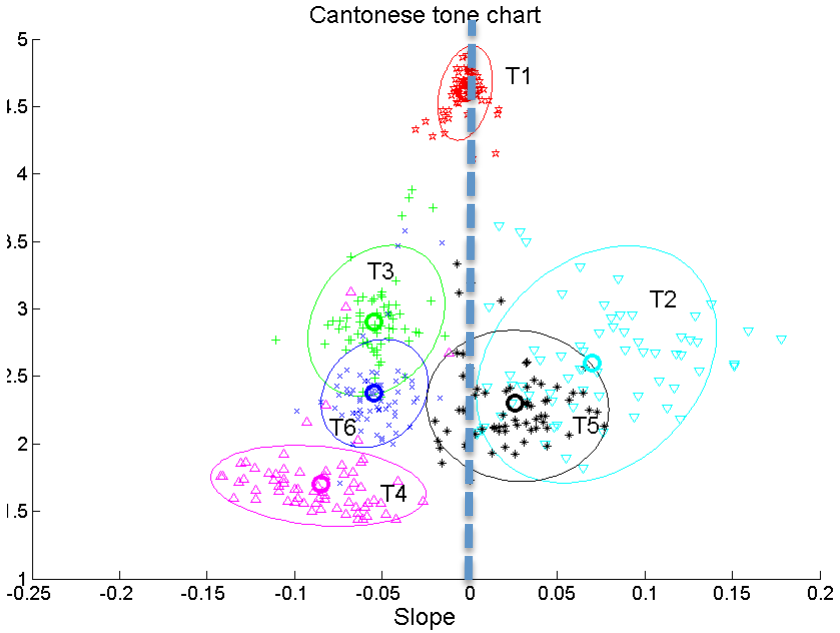


*i*² (姨, aunt) *i*¹ (衣, clothes)

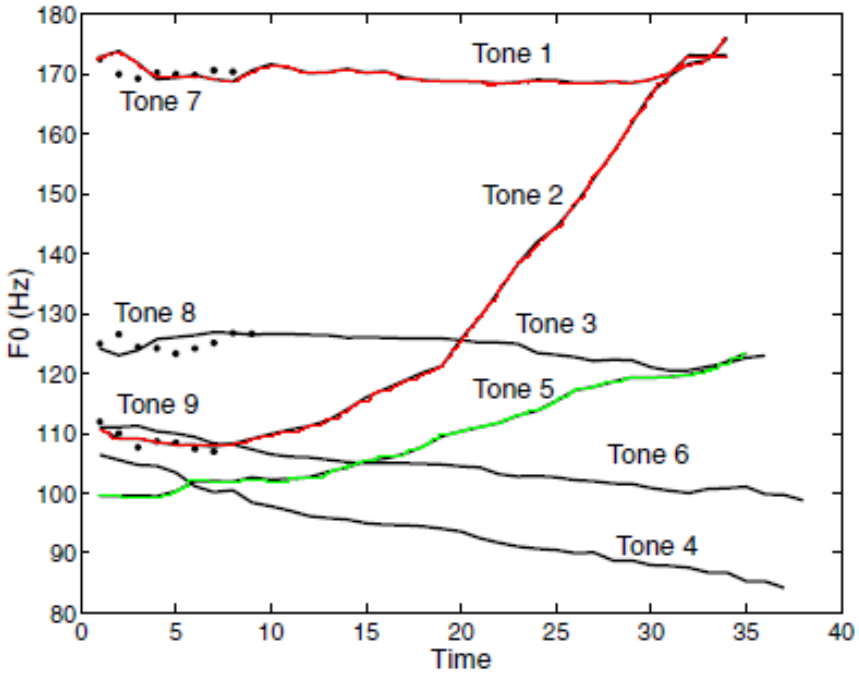
identification
discrimination

Peng, G.(2006) "Temporal and tonal aspects of Chinese syllables: A corpus-based comparative study of Mandarin and Cantonese." *Journal of Chinese Linguistics* 34.1:134-154.

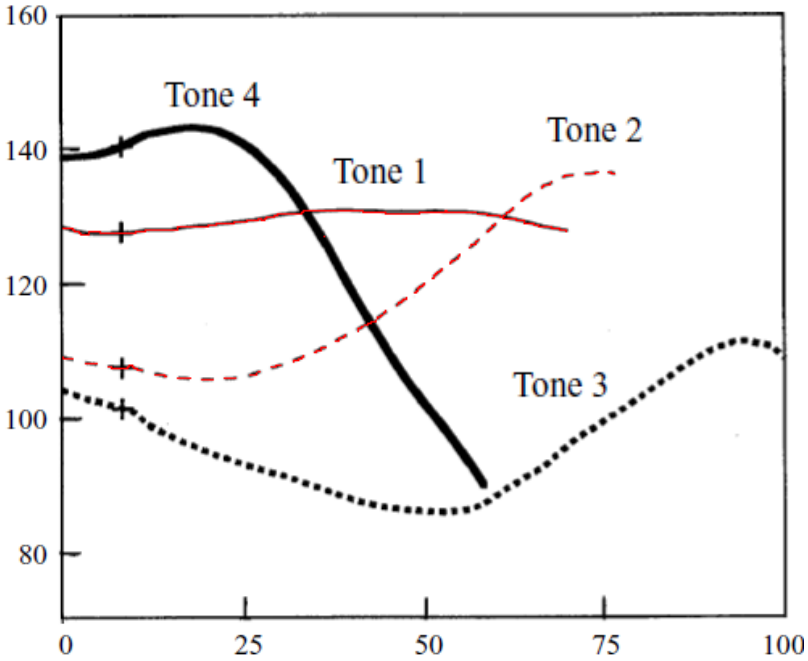




Mandarin tones are relatively compact and discretely distributed, which allows for more successful recognition. In contrast, Cantonese tones are tightly squeezed into the lower pitch range, suggesting on-going mergers.



Cantonese tones in the monosyllable /i/ uttered in isolation. The solid lines are for long tones on unchecked syllables, while the dotted lines are for short tones on checked syllables. (Adapted from Peng & Wang, 2005)

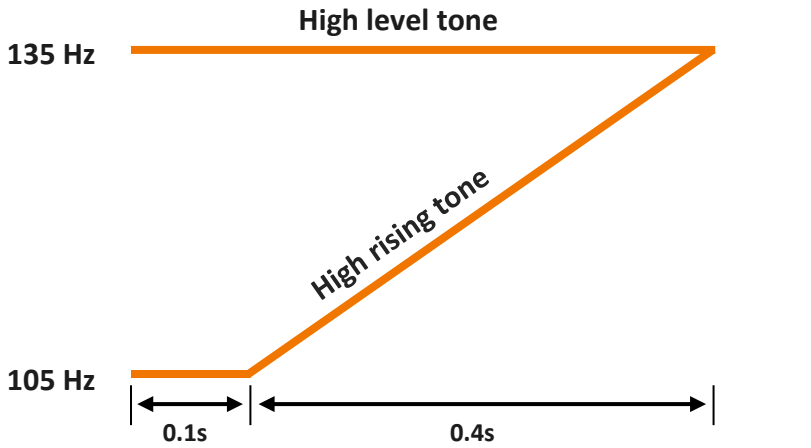


Mandarin tones in the monosyllable /ma/ uttered in isolation. The time is normalized , with all tones plotted with their average duration proportional to the average duration of Tone 3. (Adapted from Xu, 1997)

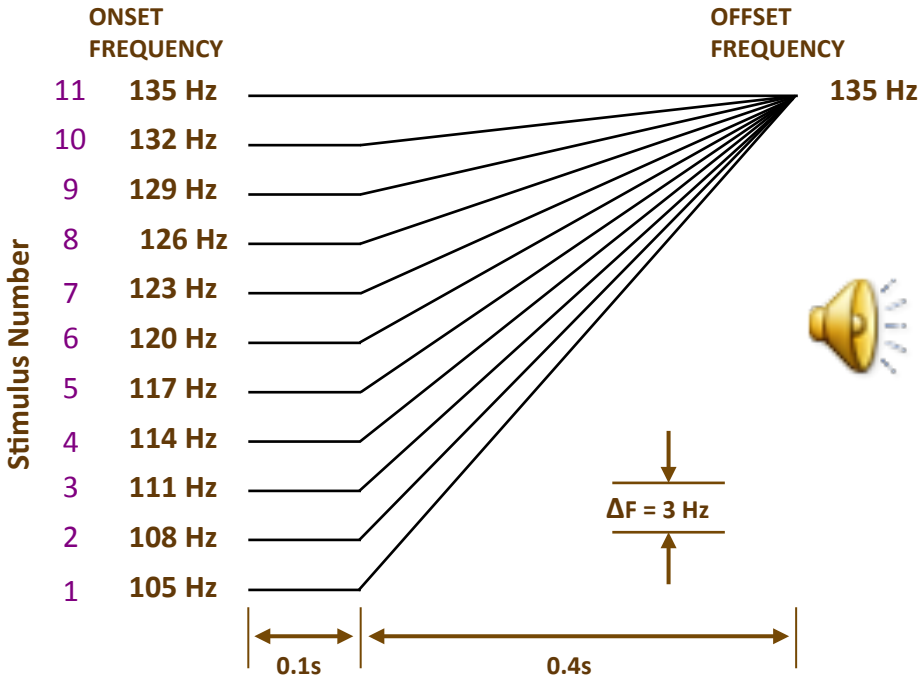
Peng, G., and Wang, W. S-Y. (2005). "Tone recognition of continuous Cantonese speech based on support vector machines". *Speech Communication* 45, 49-62.
Xu, Y., (1997). Contextual tonal variations in Mandarin. *Journal of Phonetics* 25, 61–83.

Materials

- Lexical tone is the use of (primarily) **pitch** to distinguish meaning.
- The tonal inventories of Mandarin and Hong Kong Cantonese **both** include lexical tones with:
  - a **high level** pitch contour
  - a **high rising** pitch contour

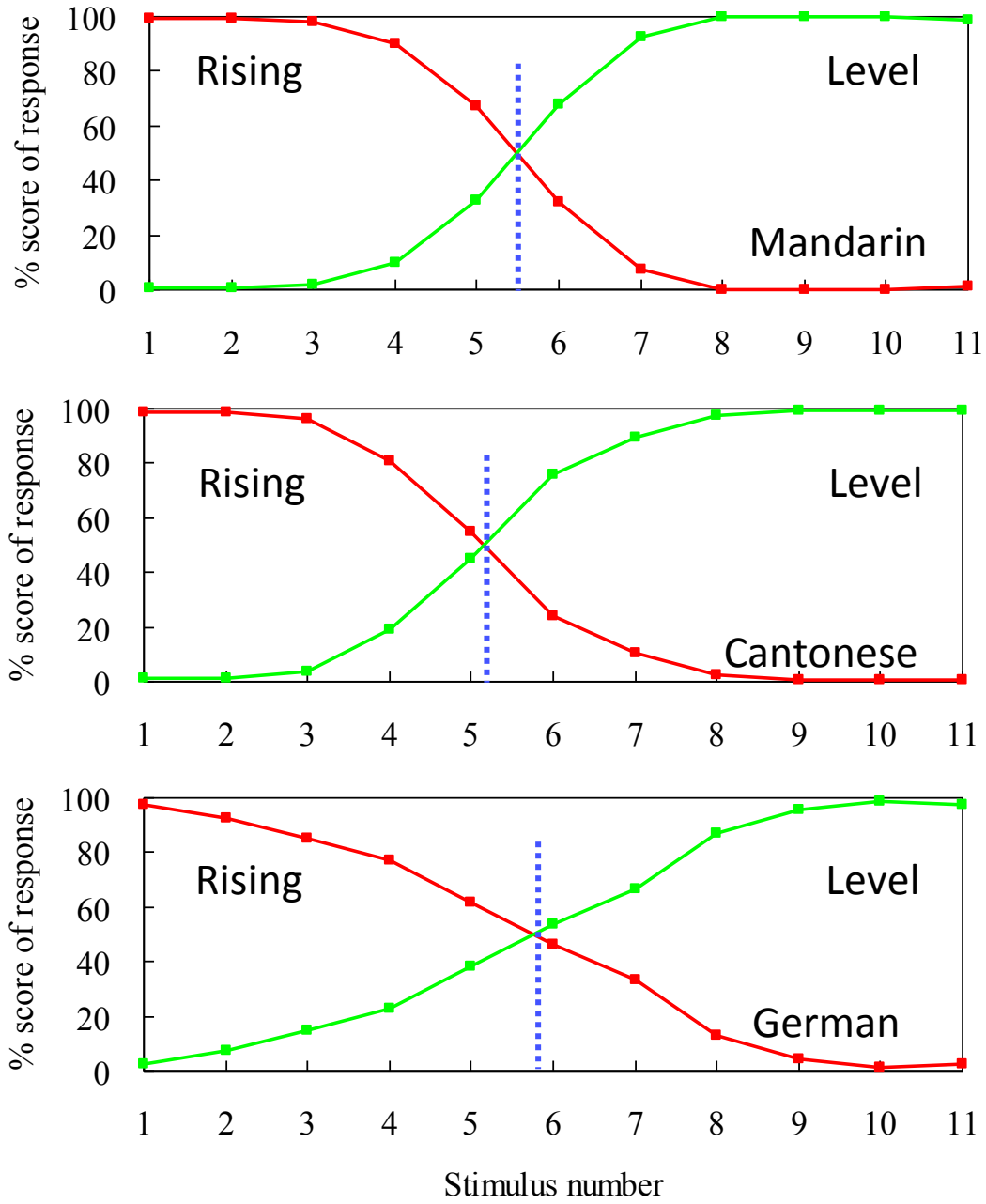


which may be approximated by piecewise linear pitch contours (Wang, 1976)



Wang, W.S-Y. 1976. Language change. *Annals of N.Y. Academy of Science* 280.61-72.

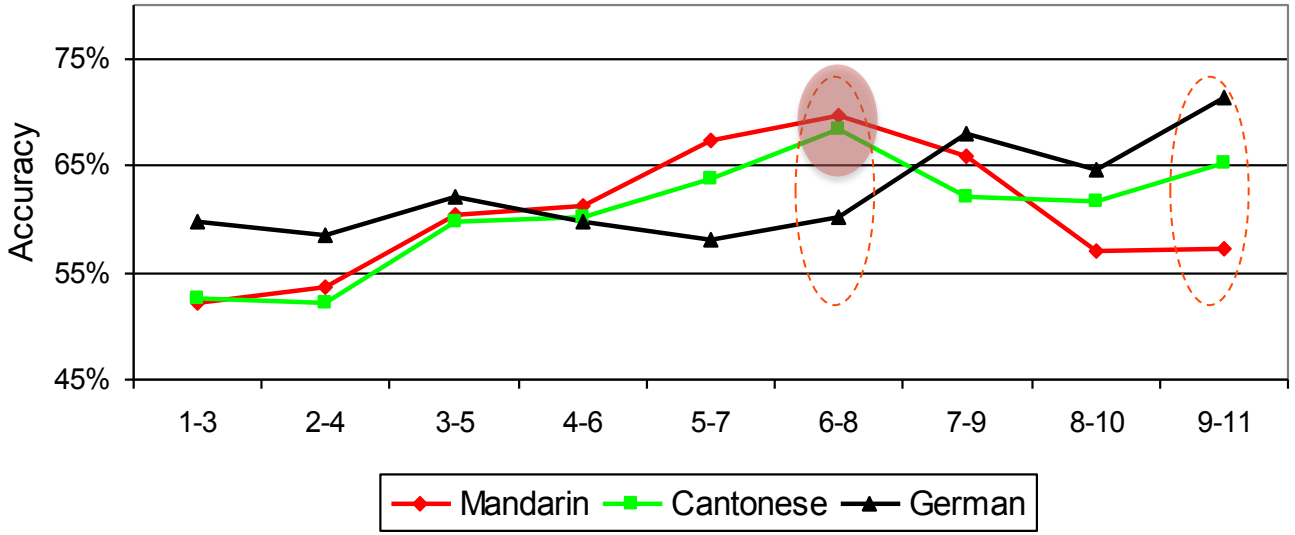
Results: Identification



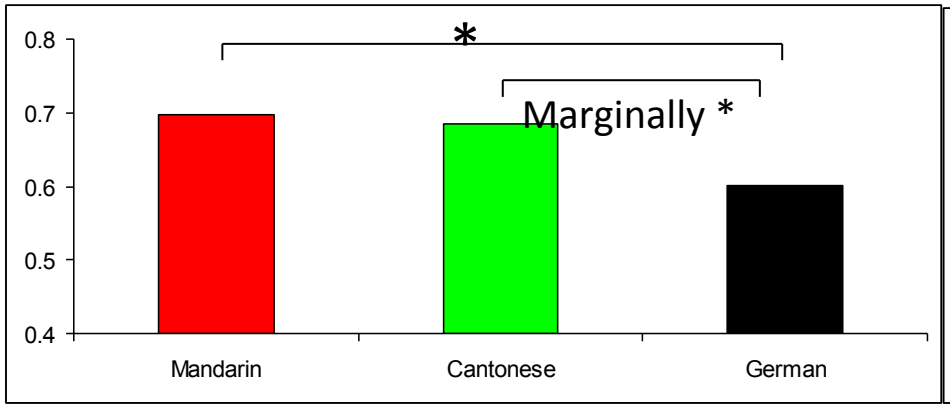
Boundary was significantly sharper for tone language (Mandarin and Cantonese) listeners than for non-tone language (German) listeners. This finding is highly consistent across several studies (Hallé, Chang, & Best, 2004; Wang, 1976; Xu, Gandour, & Francis, 2006).

Peng et al., 2010, Journal of Phonetics.

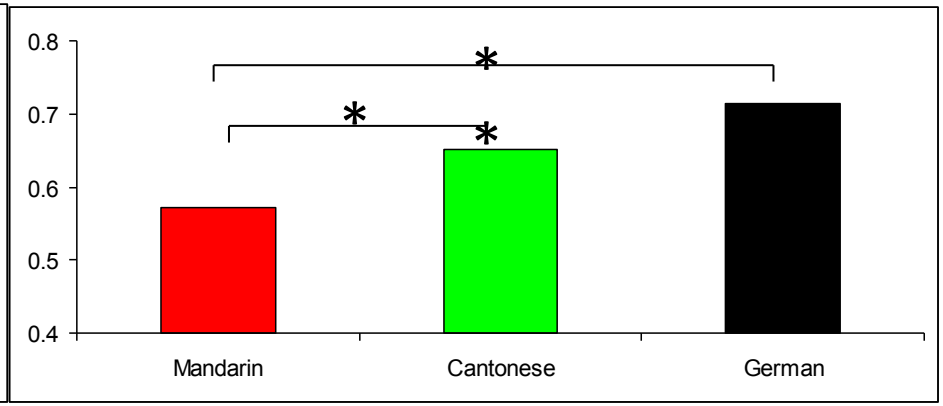
Results: Discrimination



Peng et al., 2010, Journal of Phonetics.



Pair 6-8

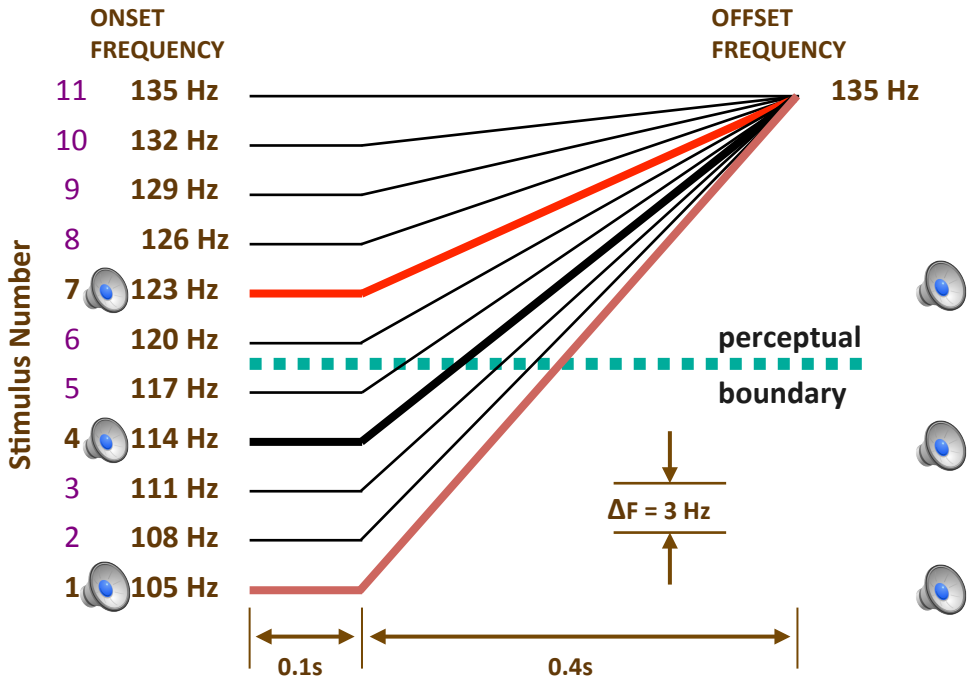


Pair 9-11

EEG: Materials

- Three sets of stimuli are synthesized on the continuum between the high level pitch contour and the high rising pitch contour:
  - standard [4]
  - **within-category** deviant [1]
  - **across-category** deviant [7]

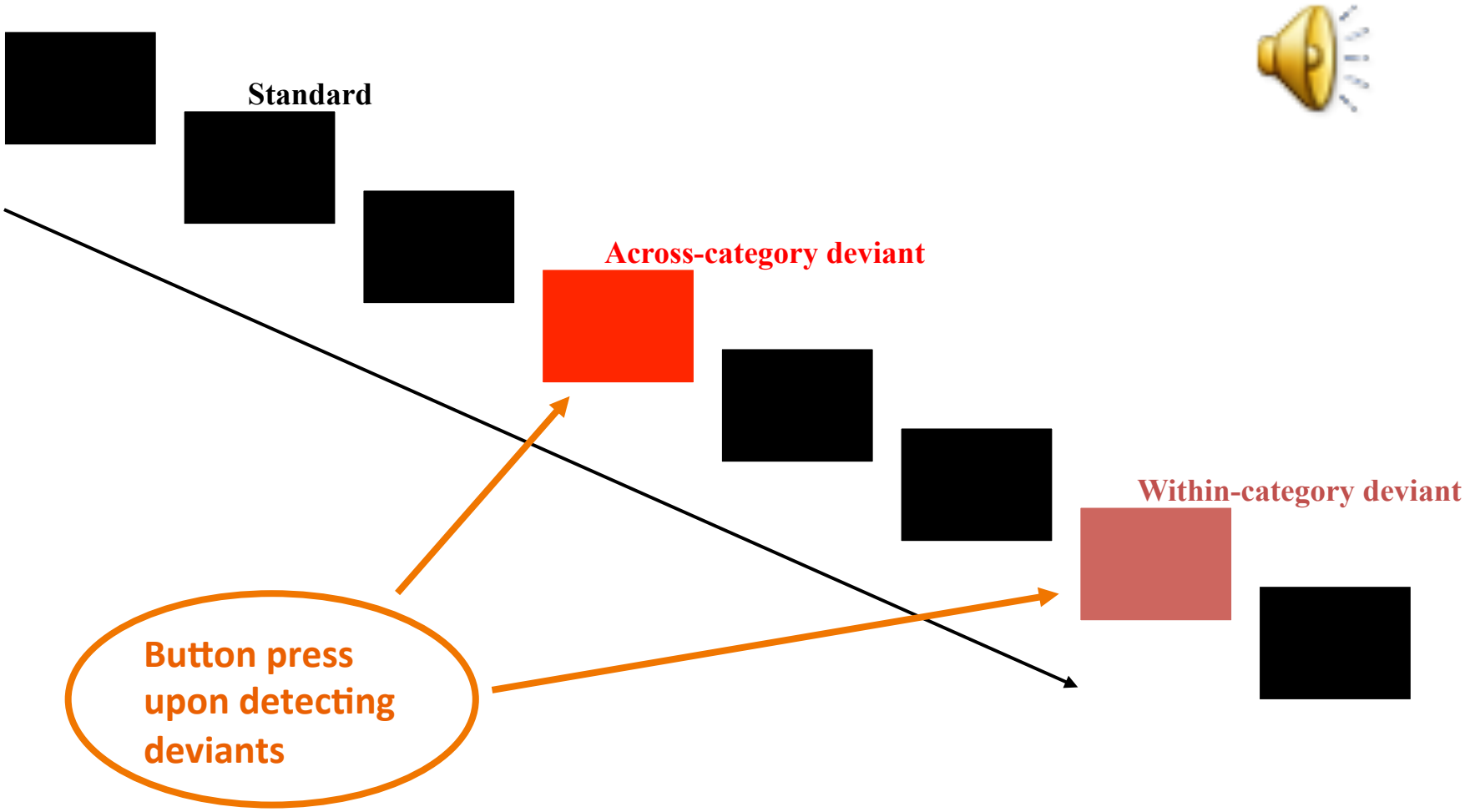
- For both:
  - **speech**
  - **non-speech**



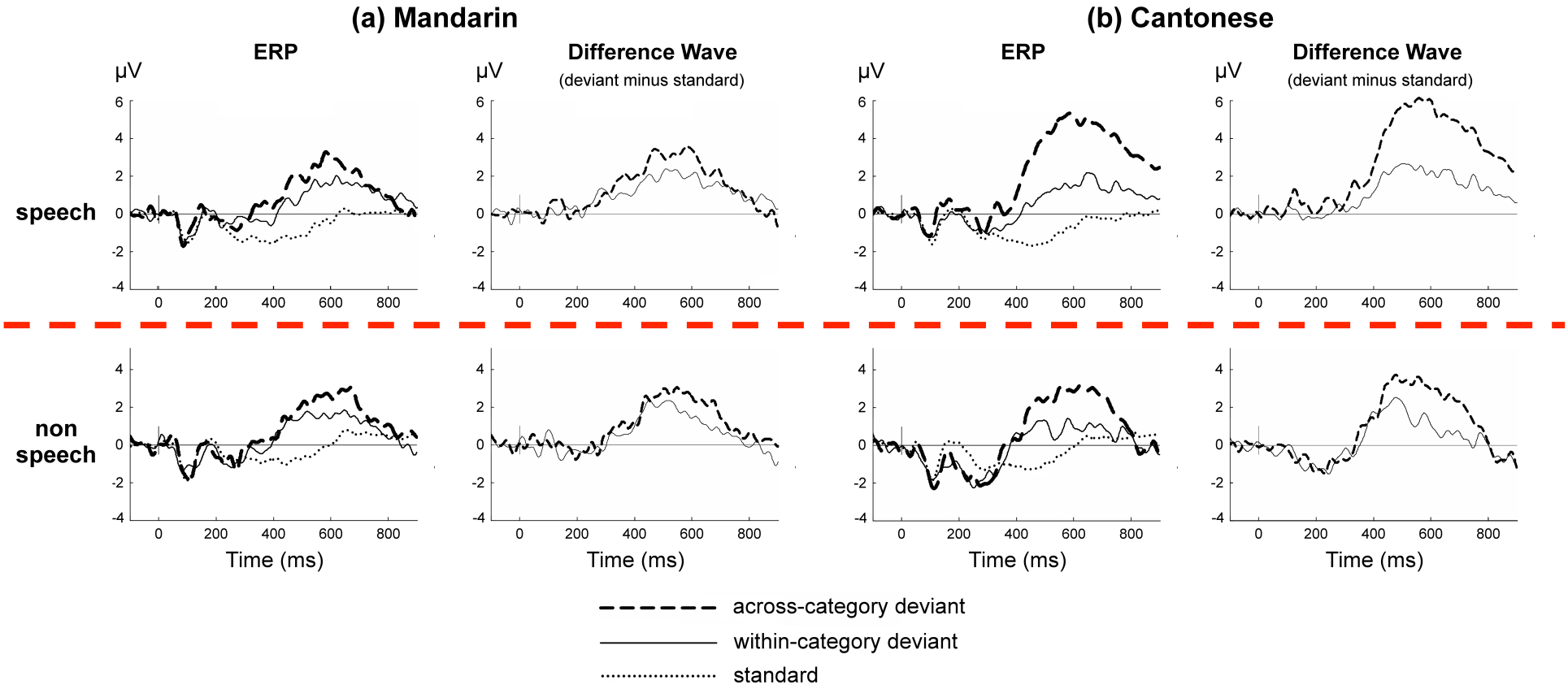
Speech

Complex tones

Procedure: Oddball Paradigm



Results



1. No significant differences in P300 amplitude between within-category and across-category deviants for nonspeech stimuli were elicited from both Mandarin and Cantonese subjects.
2. Significantly greater amplitude P300 responses were elicited for across-category deviant than for within-category deviant for speech stimuli only from Cantonese subjects, but not for Mandarin subjects.

Summary

- According to the context-updating hypothesis (Donchin, 1981), P300 amplitude reflects the ease with which subjects update mental schema of stimulus context in response to changes in stimulus attributes (Polich, 2007).
- Moreover, Frenck-Mestre et al. (2005) have shown that the P300 component indexes phonological processing, with P300 amplitude being greater for deviants that are perceived as phonologically distinct from the standard.
- Taken together, native Cantonese speakers are more sensitive in differentiating two types of deviants: **Acoustic Density Hypothesis**.

Donchin, E. (1981). Surprise! … Surprise? *Psychophysiology*, 18(5), 493-513.
Polich, J. (2007). Updating P300: An integrative theory of P3a and P3b. *Clinical Neurophysiology*, 118(10), 2128-2148.
Frenck-Mestre, C., Meunier, C., Espesser, R., Daffner, K., & Holcomb, P. (2005). Perceiving nonnative vowels: The effect of context on perception as evidenced by event-related brain potentials. *Journal of Speech, Language, and Hearing Research*, 48(6), 1496-1510.

Character reading

Materials

- Written Chinese uses a logographic script with two variants:
  - **Traditional** characters: Hong Kong, Macau, Taiwan, etc.
  - **Simplified** characters: Mainland China, Singapore, Malaysia

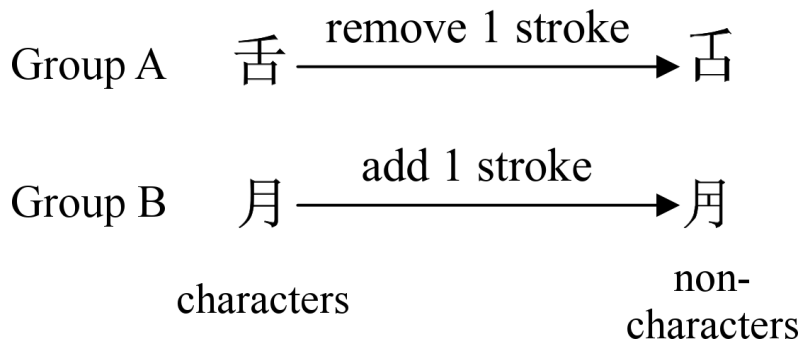
- In many cases, the Traditional and Simplified forms of a character **differ**, e.g., 東 versus 东.

- However, a subset of characters have the **same form** in both the Traditional and Simplified character sets, e.g., 心, 石:
  - we use such shared characters as stimuli

Materials

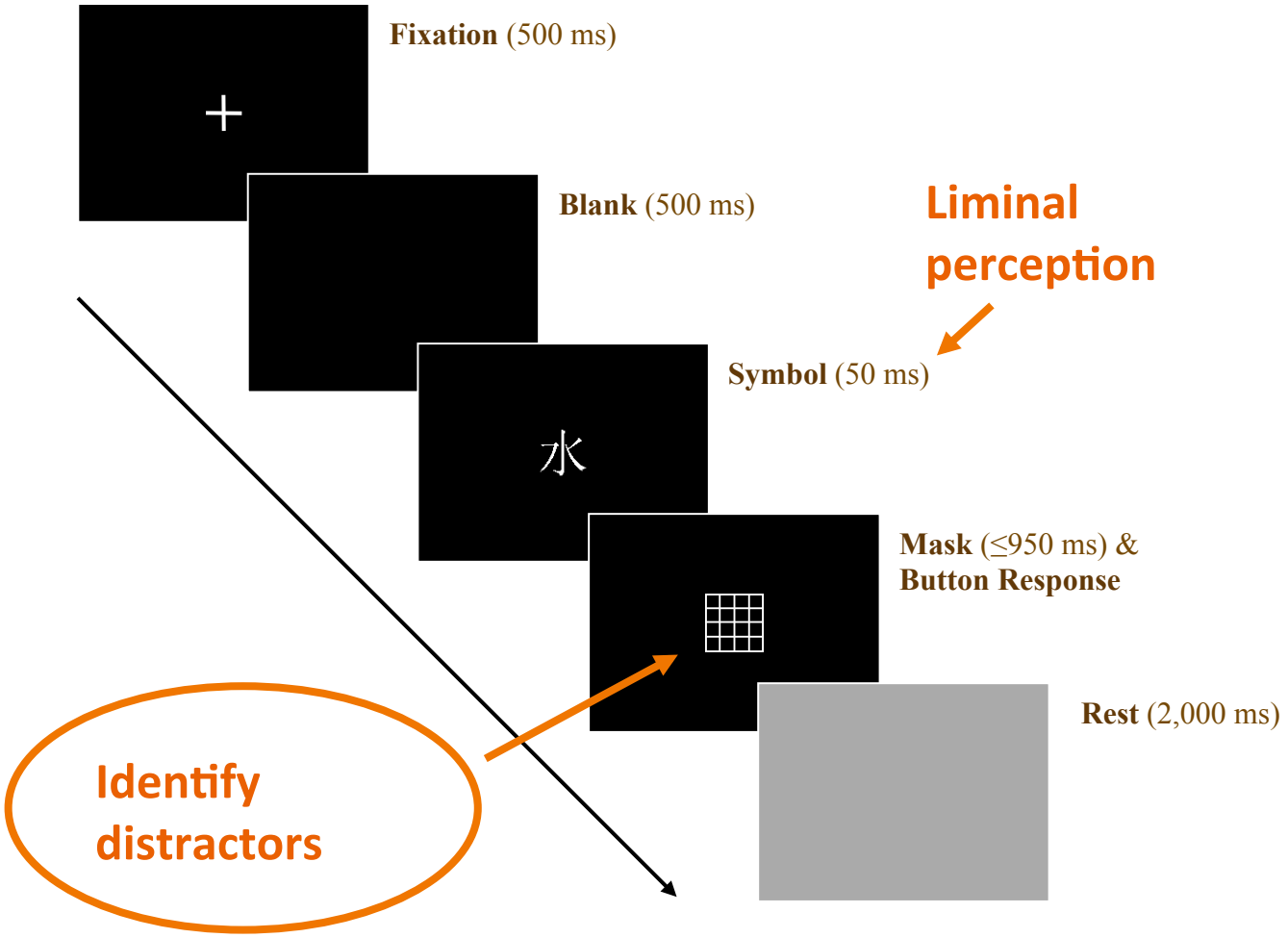
	Group A		Group B	
	character	non-character	character	non-character
1	舌	𠂒	人	亼
2	牙	𠂉	井	幵
3	心	心	水	水
4	米	米	石	石
5	冬	冬	尺	尸
6	屯	屯	月	月
7	民	民	田	田
8	式	式	豆	豆
9	史	史	女	女
10	西	西	子	子
11	卡	卡	夫	夫
12	内	内	王	王
13	右	右	户	户
14	左	左	方	方
15	令	令	包	包
16	央	央	本	本
17	五	五	支	支
18	甩	甩	升	升
19	立	立	上	上
20	老	老	走	走
21	吉	吉	古	古
22	更	更	又	又
23	勿	勿	未	未
24	且	且	全	全
25	由	由	乍	乍

Characters and non-characters differ by a single stroke:



1:43:30

Procedure



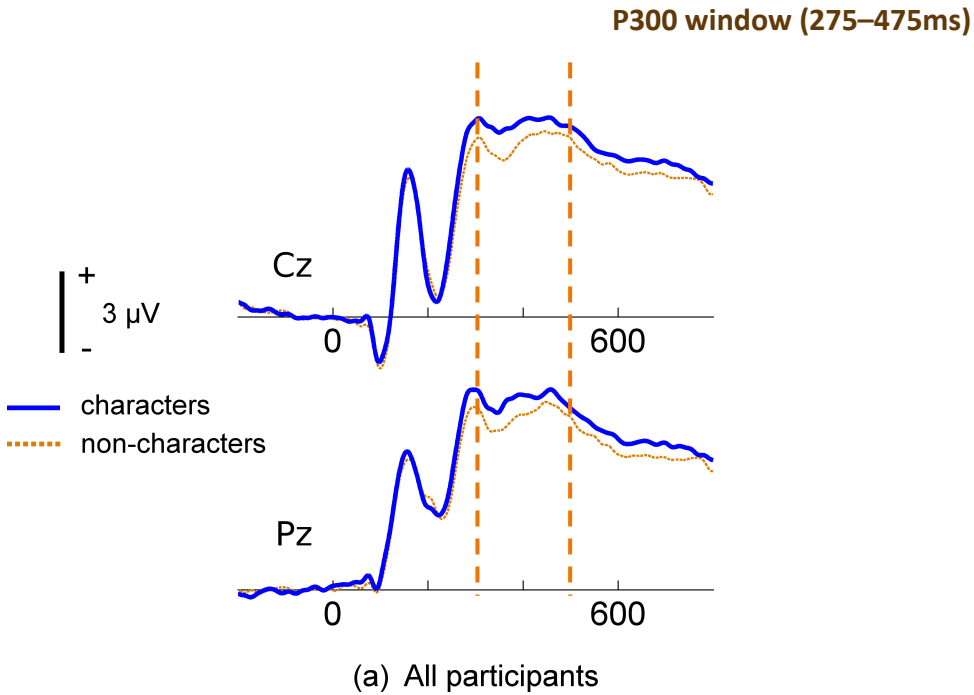
SYMBOLS COMPRISE:

Set A — remove 1 stroke:
(character / non-character)

Set B — add 1 stroke:
(character / non-character)

Distractors:

ERPs (character versus non-character)



(a) All participants

Statistical analysis on **P300** amplitude (C3, C4, Cz, P3, P4, Pz) showed:

- A significant main effect of contrast ($F(1,34) = 25.45$, $p < .0001$)
- And a significant interaction between contrast and language background ($F(1,34) = 6.71$, $p = .014$)

Summary: Liminal Perception of Chinese Characters



- **Character–non-character distinction** (McBride-Chang et al., 2005):
  - **Simplified** characters have fewer strokes on average than Traditional characters, hence they comprise **fewer visual features** by which to discriminate them.
  - Early simplified character readers must therefore develop stronger **visual skills** than early Traditional character readers to learn to read.
  - We speculate that this stronger skill extends into **adulthood**.

McBride-Chang, C., Chow, B. W.-Y., Zhong Y., Burgess, S., & Hayward, W. G. (2005). Chinese character acquisition and visual skills in two Chinese scripts. *Reading and Writing*, *18*, 99–128

To sum up...

- Native German speakers produced behaviors which were typical for native non-tone language speakers in tone perception experiment.
- Native Mandarin speakers produced Mandarin-style behaviors in tone perception and character reading experiments.
- Native Hong Kong Cantonese speakers produced Cantonese-style behaviors in tone perception and character reading experiments.

Limitations and future directions

- *Isolated syllables*
- *Neutralization of secondary cues*
- *Single characters*
- *…*

However, during daily communication, we usually do not process each syllable individually, where top-down effect may take a major role in normal cases.

"in certain normal, easy conversations at least, one may interpret the meaning of an utterance directly from the global sound pattern; reference to formal linguistic units of analysis, such as phonemes, words, and grammar, is incidental."

Sarah Hawkins, (2003). Roles and representations of systematic fine phonetic detail in speech understanding. Journal of Phonetics 31, 373-405.

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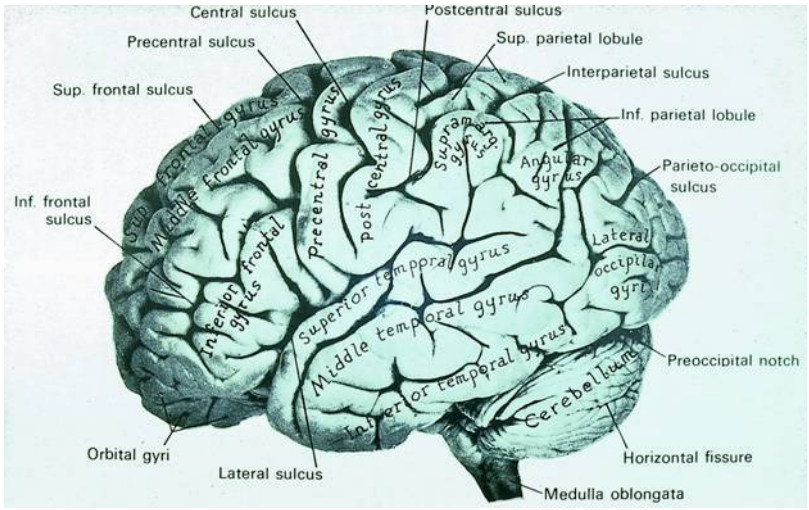

Different **LANGUAGES** shape different **BRAINS**;

different brains produce different perceptions;

different perceptions produce different **BEHAVIORS**.

The current skewed sampling

Joint Research Centre for
Language and Human Complexity

"An analysis of the top journals … from 2003-2007 revealed that … a full 96% of subjects were from **W**estern **E**ducated **I**ndustrialized **R**ich and **D**emocratic (WEIRD) countries, specifically North America, Europe, Australia, and Israel. … **This means that 96% of psychological samples come from countries with only 12% of the world's population."**

Henrich, J., S J. Heine & A. Norenzayan.(2010). **The Weirdest People in the World?** *Behavioral and Brain Sciences,* 33, 61-135.

Henrich, J., S J. Heine & A. Norenzayan.(2010). **Most people are not WEIRD**. *Nature,* 466: 29.

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Joint Research Centre for
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Thank you!