SOUND PATTERNS IN LANGUAGE

InterSpeech, Singapore
September 14-18, 2014

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Chinese University of Hong Kong
Sound Patterns in Language

• How is speech possible?
• African origins, diversity in genes & words.
• Three case studies of sound patterns in motion.
  Consonants & Grimm’s Law.
  Vowels & the Great Vowel Shift in English.
  Tones & the Taiwanese Tone Circle.
• Speech & music, two cultural universals.
• Summary.
“Although humans make sounds with their mouths and occasionally look at each other, there is no solid evidence that they actually communicate among themselves.”
Language Diversity: an early account

Tower of Babel
圣经故事：古人建筑巴贝儿塔

Painting by Pieter Bruegel 1525-69

*Genesis* 11:7 “Go to, let us go down, and there confound their language, that they may not understand one another's speech.”
“An Englishman's way of speaking absolutely classifies him. The moment he talks he makes some other Englishman despise him. One common language I'm afraid we'll never get.

Oh, why can't the English learn to set a good example to people whose English is painful to your ears? The Scotch and the Irish leave you close to tears. There even are places where English completely disappears. In America, they haven't used it for years!”
Figure 3. 

Adaptations for bipedal posture in standing and walking.
Twin-tube vocal tract.
W.T. Fitch. 2010. *The Evolution of Language*. Fig. 8.5.
The Story of the Human Body: Evolution, health, and disease.
Pantheon.

Figure 16.
Cranial nerves emerge from the floor of the brain in pairs; each pair is numbered from the front of the brain (closest to the forehead) to the back (near the spinal cord). Cranial nerve zero (also called the terminal nerve) is not in typical textbooks. Anatomists historically missed the thin nerve, perhaps because it is often inadvertently pulled off along with the tough membranes that wrap the brain.

Sex & the secret nerve. 

- a: V trigeminal – jaw.
- b: VII facial – lips.
- c: X vagus, recurrent nerve - larynx.
- d: XII hypoglossal – tongue.

IX glossopharyngeal – tongue root.
• How is speech possible?
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Maximum likelihood tree constructed from 938 individuals from 51 populations at 650,000 common single-nucleotide polymorphism loci. Branches colored by regions. * indicates the root of the tree, also where the chimpanzee branch is located.

Li, J.Z. et al. 2008. Worldwide Human Relationships Inferred from Genome-Wide Patterns of Variation. *Science* Fig.1 & 4.
Language Families of the World (after Greenberg)
Table 1. Distribution of world languages by area of origin

<table>
<thead>
<tr>
<th>Area</th>
<th>Living languages</th>
<th>Number of speakers</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Count</td>
<td>Percent</td>
</tr>
<tr>
<td>Africa</td>
<td>2,146</td>
<td>30.2</td>
</tr>
<tr>
<td>Americas</td>
<td>1,060</td>
<td>14.9</td>
</tr>
<tr>
<td>Asia</td>
<td>2,303</td>
<td>32.4</td>
</tr>
<tr>
<td>Europe</td>
<td>285</td>
<td>4.0</td>
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<tr>
<td>Pacific</td>
<td>1,312</td>
<td>18.5</td>
</tr>
<tr>
<td>Totals</td>
<td>7,106</td>
<td>100.0</td>
</tr>
</tbody>
</table>

SIL International Publications
7500 West Camp Wisdom Road
Dallas, TX 75236-5629 USA

Ethnologue: Languages of the World.
17th edition.
Whence such diversity?


Language polygenesis: a probabilistic model.

*Anthropological Science*

104.2.131-8, 1996.


“.. Here I show that the number of phonemes used in a global sample of 504 languages is also clinal and fits a serial founder–effect model of expansion from an inferred origin in Africa. This result, which is not explained by more recent demographic history, local language diversity, or statistical non-independence within language families, points to parallel mechanisms shaping genetic and linguistic diversity and supports an African origin of modern human languages.”
Critiques from the 3 groups of scholars, as well as Atkinson’s response are available in *Science* 335, 657-b,c,d,e, Feb.10, 2012.
Fig.1. Areas of “origin” of various other inventory-like linguistic characteristics as identified using Atkinson’s methodology. Notably, the origins are dispersed over the whole globe & not concentrated in Africa. The dark red area in Africa is the origin of phoneme inventories as proposed by Atkinson. … The small red area on the eastern tip of New Guinea is the origin for the UPSID phoneme inventory data using a quadratic geographical distance model.
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• Summary.
Say it in Indo-European. The 144 languages of this family descend from one ancient mother tongue.
Languages of Western Europe & their times of divergence.

<table>
<thead>
<tr>
<th>ENGLISH</th>
<th>GOTHIC</th>
<th>LATIN</th>
<th>GREEK</th>
<th>SANSKRIT</th>
<th>JAPANESE</th>
</tr>
</thead>
<tbody>
<tr>
<td>ONE</td>
<td>AINS</td>
<td>UNUS</td>
<td>HEIS</td>
<td>EKAS</td>
<td>HITOTSU</td>
</tr>
<tr>
<td>TWO</td>
<td>TWAI</td>
<td>DUO</td>
<td>DUŌ</td>
<td>DVĀ</td>
<td>FUTATSU</td>
</tr>
<tr>
<td>THREE</td>
<td>THREIS</td>
<td>TRS</td>
<td>TREIS</td>
<td>TRAYAS</td>
<td>MITTSU</td>
</tr>
<tr>
<td>FOUR</td>
<td>FIDWOR</td>
<td>QUATTUOR</td>
<td>TETTARES</td>
<td>CATVĀRAS</td>
<td>YOTTSSU</td>
</tr>
<tr>
<td>FIVE</td>
<td>FIMF</td>
<td>QUINQUE</td>
<td>PENTE</td>
<td>PANCA</td>
<td>ITSUTSU</td>
</tr>
<tr>
<td>SIX</td>
<td>SAIHS</td>
<td>SEX</td>
<td>HEKS</td>
<td>ŞAT</td>
<td>MUTTSU</td>
</tr>
<tr>
<td>SEVEN</td>
<td>SIBUN</td>
<td>SEPTEM</td>
<td>HEPTA</td>
<td>SAPTA</td>
<td>NANATSU</td>
</tr>
<tr>
<td>EIGHT</td>
<td>AHTAU</td>
<td>OCTO</td>
<td>OKTŌ</td>
<td>AŞTU</td>
<td>YATSU</td>
</tr>
<tr>
<td>NINE</td>
<td>NIUN</td>
<td>NOVEM</td>
<td>ENNEA</td>
<td>NAVA</td>
<td>KOKONOTSU</td>
</tr>
<tr>
<td>TEN</td>
<td>TAIHUN</td>
<td>DECEM</td>
<td>DEKA</td>
<td>DAŚA</td>
<td>TO</td>
</tr>
<tr>
<td>Integer</td>
<td>English Gothic</td>
<td>Latin</td>
<td>Greek</td>
<td>Sanskrit</td>
<td></td>
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<tr>
<td>-----------</td>
<td>----------------</td>
<td>-------</td>
<td>-------</td>
<td>----------</td>
<td></td>
</tr>
<tr>
<td>two, ten</td>
<td>t-</td>
<td>t-</td>
<td>d-</td>
<td>d-</td>
<td></td>
</tr>
<tr>
<td>three</td>
<td>th-</td>
<td>th-</td>
<td>t-</td>
<td>t-</td>
<td></td>
</tr>
<tr>
<td>eight, ten</td>
<td>‘-gh-’</td>
<td>-h-</td>
<td>-k-</td>
<td>-k-</td>
<td></td>
</tr>
<tr>
<td>six, seven</td>
<td>s-</td>
<td>s-</td>
<td>s-</td>
<td>h-</td>
<td></td>
</tr>
</tbody>
</table>

*Indo-European correspondences in low integers.*
Grimm’s Law: PIE > Germanic

\[ b^h \rightarrow b \quad b \rightarrow p \quad p \rightarrow f \]
- \( b^h \)ratr, brother
- lab-, lip
- ped-, foot

\[ d^h \rightarrow d \quad d \rightarrow t \quad t \rightarrow \theta \]
- mad\( ^h \)u, mead
- dec-, ten
- dent-, tooth

\[ g^h \rightarrow g \quad g \rightarrow k \quad k \rightarrow h \]
- genu, knee
- canis, hound
Great Vowel Shift.

<table>
<thead>
<tr>
<th>a &gt; e</th>
<th>e &gt; i</th>
<th>i &gt; ai</th>
</tr>
</thead>
<tbody>
<tr>
<td>sanity &gt; sane</td>
<td>serenity &gt; serene</td>
<td>divinity &gt; divine</td>
</tr>
<tr>
<td>gratitude &gt; grateful</td>
<td>kept &gt; keep</td>
<td>Christmas &gt; Christ</td>
</tr>
<tr>
<td>opacity &gt; opaque</td>
<td>shepherd &gt; sheep</td>
<td>hid &gt; hide</td>
</tr>
<tr>
<td>tabular &gt; table</td>
<td>obscenity &gt; obscene</td>
<td>linear &gt; line</td>
</tr>
<tr>
<td>chastity &gt; chaste</td>
<td>leapt &gt; leap</td>
<td>fifth &gt; five</td>
</tr>
</tbody>
</table>


- gu⁵ du⁵ ?we⁵ ku¹ ‘I will see bones’
- gu⁵ du⁵ ?we⁵ jo² ‘I will see palm baskets’
- gu⁵ du⁵ ?we⁵ ka³ ‘I will see squash’
- gu⁵ du⁵ ?we⁵ ?a⁴ ‘I will see nine’
- gu⁵ du⁵ ?we⁵ za⁵ ‘I will see eleven’

In these examples from Trique, 1 indicates high pitch.

### /kl-/ clusters in Old Chinese

<table>
<thead>
<tr>
<th>粵語</th>
<th>普通話</th>
<th>傳統中文</th>
</tr>
</thead>
<tbody>
<tr>
<td>京</td>
<td>ging¹</td>
<td>capital</td>
</tr>
<tr>
<td>各</td>
<td>gok³</td>
<td>each</td>
</tr>
<tr>
<td>監</td>
<td>gaam¹</td>
<td>oversee</td>
</tr>
<tr>
<td>見</td>
<td>gin³</td>
<td>see</td>
</tr>
<tr>
<td>涼</td>
<td>loeng⁴</td>
<td>cool</td>
</tr>
<tr>
<td>路</td>
<td>lou⁶</td>
<td>road</td>
</tr>
<tr>
<td>藍</td>
<td>laam⁴</td>
<td>blue</td>
</tr>
<tr>
<td>覽</td>
<td>laam⁵</td>
<td>view</td>
</tr>
</tbody>
</table>

*粵語拼音字表，第二版*

<table>
<thead>
<tr>
<th>CONTOUR</th>
<th>1</th>
<th>2</th>
<th>3</th>
<th>4</th>
<th>5</th>
<th>6</th>
<th>7</th>
<th>8</th>
<th>9</th>
<th>10</th>
<th>11</th>
<th>12</th>
<th>13</th>
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</thead>
<tbody>
<tr>
<td>HIGH</td>
<td>+</td>
<td>-</td>
<td>+</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>+</td>
<td>-</td>
<td>+</td>
<td>-</td>
<td>+</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>CENTRAL</td>
<td>-</td>
<td>-</td>
<td>+</td>
<td>+</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
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<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
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<td>RISING</td>
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<td>-</td>
<td>-</td>
<td>+</td>
<td>+</td>
<td>+</td>
<td>+</td>
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<tr>
<td>FALLING</td>
<td>-</td>
<td>-</td>
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<td>+</td>
<td>+</td>
<td>+</td>
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<tr>
<td>CONVEX</td>
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<td>-</td>
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<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>+</td>
<td>+</td>
</tr>
</tbody>
</table>

Middle Chinese tones in modern dialects.

In Honor of Ilse Lehiste
Four tones of Putonghua

<table>
<thead>
<tr>
<th>平 I</th>
<th>上 II</th>
<th>去 III</th>
<th>入 IV</th>
</tr>
</thead>
<tbody>
<tr>
<td>平 U</td>
<td>上 U</td>
<td>去 U</td>
<td>入 U</td>
</tr>
<tr>
<td>平 V</td>
<td>上 V</td>
<td>去 V</td>
<td>入 V</td>
</tr>
</tbody>
</table>
## Nine tones of Hong Kong Cantonese

<table>
<thead>
<tr>
<th>阴</th>
<th>平</th>
<th>55</th>
</tr>
</thead>
<tbody>
<tr>
<td>詩</td>
<td>上</td>
<td>35</td>
</tr>
<tr>
<td>陽</td>
<td>去</td>
<td>33</td>
</tr>
<tr>
<td>時</td>
<td>入</td>
<td>5</td>
</tr>
<tr>
<td>市</td>
<td>錫</td>
<td>3</td>
</tr>
<tr>
<td>是</td>
<td>食</td>
<td>2</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>阴</th>
<th>21</th>
</tr>
</thead>
<tbody>
<tr>
<td>去</td>
<td>22</td>
</tr>
<tr>
<td>入</td>
<td>2</td>
</tr>
</tbody>
</table>
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)
The Mandarin tones are relatively compact and discretely distributed, which allows for more successful tone recognition.
<table>
<thead>
<tr>
<th>Citation tone</th>
<th>Sandhi tone</th>
<th>Example</th>
</tr>
</thead>
<tbody>
<tr>
<td>lu 1 (55)</td>
<td>˧ (33)</td>
<td>開 khui</td>
</tr>
<tr>
<td>lv 1 (24)</td>
<td>˧ (33)</td>
<td>還 hîng</td>
</tr>
<tr>
<td>˨ 1 (51)</td>
<td>˥ (55)</td>
<td>買 bé</td>
</tr>
<tr>
<td>IIIu ˧ (21)</td>
<td>˥ (51)</td>
<td>看 khuànn</td>
</tr>
<tr>
<td>IIIv ˩ (33)</td>
<td>˨ (21)</td>
<td>賣 bē</td>
</tr>
<tr>
<td>lv ˨ (51)</td>
<td>˥ (55)</td>
<td>車 tshia</td>
</tr>
</tbody>
</table>

教育部长期以来对台湾閩南語常用詞辭典的不懈努力。
Tone circle in Taiwanese

Iu

Iv

II

IIIu

IIIv
Feature analysis of Taiwanese tone circle.

\[ 1,1 > V > V > V > 1 \]

+ high ........ - high - high ...... + high + high
- falling - falling ........ + falling + falling ...... - falling

\[ [\alpha_{\text{high}} \atop \beta_{\text{falling}}] > [\beta_{\text{high}} \atop -\alpha_{\text{falling}}] \]
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- Summary.


Trehub, S. E. 2003.
The developmental origins of musicality.

Language, music, syntax & the brain.
*Nature Neuroscience.*

**Parsing in music:**

*Christus, der ist mein Leben* 1st phrase (J.S. Bach)
A simplified grammar tree

Analysis of a phrase from Bach Menuet in G Major Anh 114 by Gary Lam, Chinese University of Hong Kong
"Music perception showed no overlap whatsoever with this network. Broca’s area was not robustly activated by any stimulus type. Overall, these findings suggest that basic hierarchical processing for music and speech recruit distinct cortical networks, neither of which involve Broca’s area. We suggest that previous claims are based on data from tasks that tap higher-order cognitive processes, such as working memory and/or cognitive control, which can operate in both speech and music domains.” from the Abstract.
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Summary-1.

The roots of language reach back over 3 million years, when our remote ancestors transitioned to bipedal posture, restructuring the hands, the vocal tract, and the brain.

Speech, with its building blocks of syllables, vowels, consonants, and tones, is a powerful vehicle for language, and emerged over 100,000 years ago.

Language and music are both universal to our species and share evolutionary roots; they have similar functions of communication, and similar principles of organization.
Diversity in language is the cumulative product of culturally selected innovations made by numerous generations of speakers.

Spoken language has spawned various auxiliary forms, such as written language, signed language, & various electronic media, providing additional windows for studying how we communicate.

Ever more powerful technology of brain imaging & computer analysis for spoken language & music is already shedding much light on our mind, & promises to reveal much more..
谢谢！

THANK YOU!

pdf available from
wsywang@ee.cuhk.edu.hk