The speech-music relationship:
Insights from congenital amusia (tone deafness)

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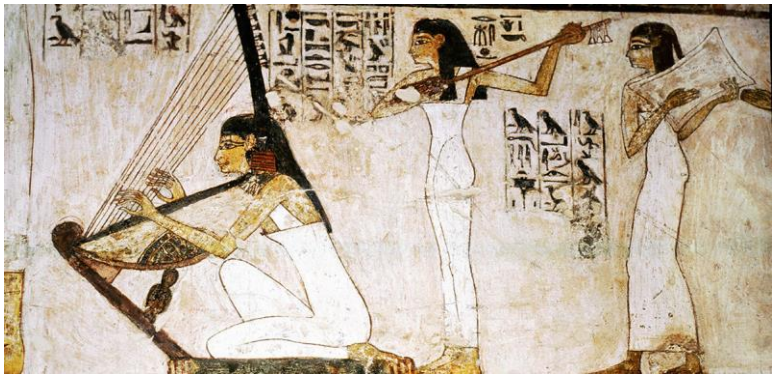
RCLCN seminar, 15 December 2021

Speech-music relationship

- **Speech** and **music** are both **evolutionarily old**, **universal** and **ubiquitous** across human populations.

贾湖骨笛 9000 yr old flute

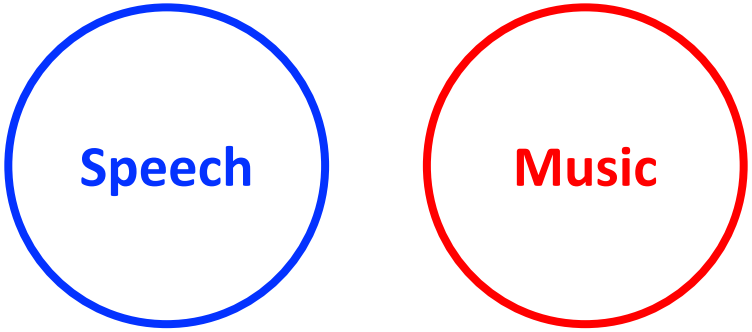


Theban tomb, 1425 BCE; women playing harp, lute and tambourine

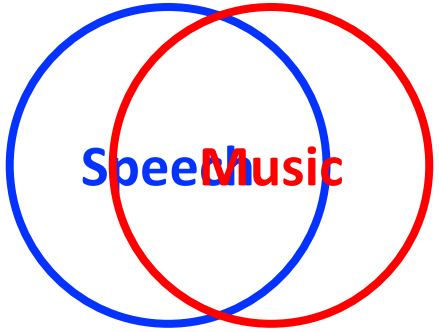
Night Revels of Han Xizai, Song Dynasty

Theories on the speech-music relationship

- One view
  - **Speech/language** and **music** are **modular**, **encapsulated** systems, independent from each other (e.g., Peretz, 2002; Fodor, 1983; Chomsky, 1981);



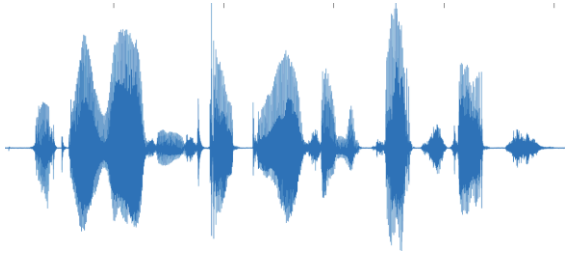
- Another view
  - **Speech/language** and **music** share processing resources or mechanisms (e.g., Patel, 2008; Fitch, 2006).



Close **parallels** between speech and music

- High-level structure/hierarchy
- Low-level acoustic attributes

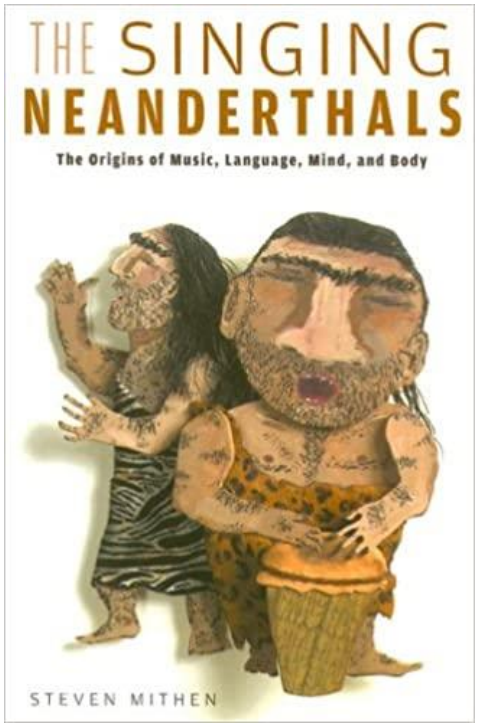
Speech		**Music**
Syntax	*Structure*	**Musical grammar**
…	…	…
…	…	…
Vowel length	*Duration*	**Rhythm**
Intonation, lexical tone	*Pitch*	**Musical notes**



Sources: Internet

Theories on the speech-music relationship

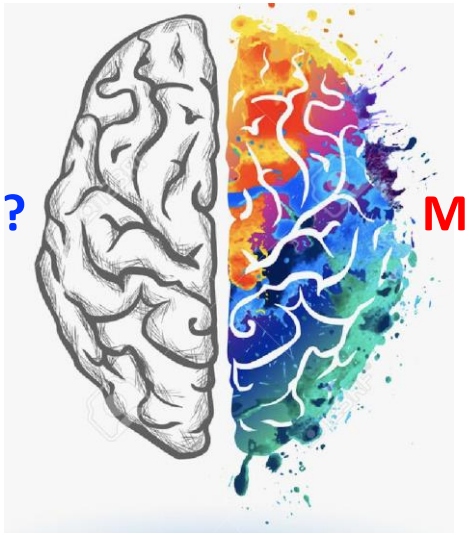
- Evolutionary origins of speech and music:
  - **Exaptation** or **neuronal recycling hypothesis** (e.g., Gould & Vrba, 1982; Dehaene & Cohen, 2007)
  - **Co-evolution** of speech and music (e.g., Darwin, 1871; Fitch, 2006 ; Mithen, 2011);
  - "**Musical protolanguage**" in courtship, territoriality and emotion expression.



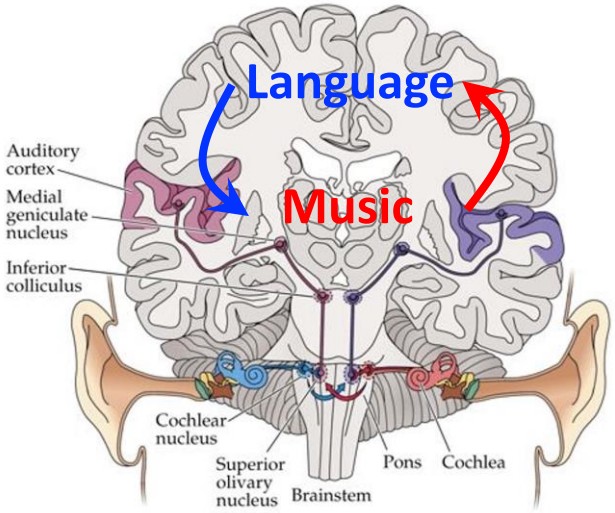
Sources: Internet

Neural bases and cross-domain transfer

Language?



Music?



Overlap

- Subcortical
  - Overlap in subcortical pitch tracking mechanism (frequency-following response) (Wong et al. 2007; Bidelman et al. 2011)
- Cortical
  - **Specificity** within **overlapping** neural network (bilateral superior temporal gyrus and inferior frontal gyrus) (Nan & Friederici, 2013; Norman-Haignere et al., 2015)

Bidirectional transfer

- **Music → Speech**
  - **Musicianship** (or musical aptitude) **advantage** in speech processing or speech learning (Chobert et al., 2012; Lee & Hung, 2008; Alexander et al., 2005; Delogu et al., 2006; 2010; Lee et al., 2014; Smayda et al., 2015)
- **Speech → Music**
  - **Tone language experience** associated with better musical perception abilities (Deutsch et al. 2006; Deutsch et al. 2009; Peng et al. 2013; Bidelman et al., 2013; Pfordresher & Brown, 2009)

Mechanisms for the cross-domain transfer

- **Music → Speech**
  - **Domain-general sharpening**:
    - Musical training fine tunes the **sensory encoding** of **auditory features** shared by speech and music through top-down feedback from the cortical-subcortical loop (Strait & Kraus, 2011; Kraus & Chandrasekaran, 2010);
  - **Domain-general and -specific influences**:
    - Long-term experience in one domain sharpens **acoustic processing** in the other domain (common processing), and affects the building-up of **abstract representations** in the other domain (transfer) (Besson et al. 2011);

Mechanisms for the cross-domain transfer

- **Music → Speech**
  - **Greater demand of music**: OPERA and expanded e-OPREA (Patel, 2010, 2014)
    - **O**verlap: Sensory or cognitive process shared by speech and music
    - **P**recision: Music places higher demands on those processes than speech
    - **E**motion: Emotional reward of music;
    - **R**epetition: Repetition of musical activities;
    - **A**ttention: Focused attention during musical activities.

Mechanisms for the cross-domain transfer

- **Speech → Music**
  - **Early exposure** (Deutsch et al. 2004)
    - Absolute pitch acquired during the critical period for speech acquisition;
    - **Early exposure to a tonal language** (pitch associated with verbal labels) allows the acquisition of absolute pitch during the critical period.

Congenital amusia (tone deafness)

- Innate neurogenetic disorder of musical pitch perception and pitch memory (Hyde & Peretz, 2003; 2004; Tillmann et al., 2009)
  - Difficulty in detecting out-of-tune melodies;
  - Memorizing familiar tunes;
  - 1.5-4% of the population (Peretz et al., 2002; Peretz & Vuvan, 2017);
  - Montreal Battery of Evaluation of Amusia (MBEA) (Peretz et al., 2002).

Source: Internet

走音歌后

Source: Internet

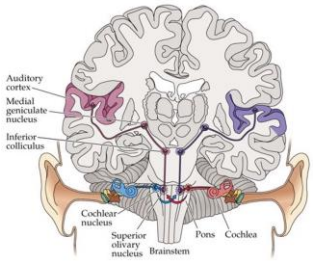
"Oh, you WERE singing?... Sorry, I thought you were clearing your throat."

Source: Internet

Road map

RQ1: Is congenital amusia a **domain-specific** or **domain-general** disorder?

RQ2: What are the **neural bases** of congenital amusia?



RQ3: Is congenital amusia **treatable**?

Source: Internet

RQ1. Is congenital amusia a domain-specific or domain-general disorder?

- Early findings indicate that amusia a **music-specific disorder**
  - Intact speech pitch processing
    - e.g., question/statement intonation and lexical stress perception (Ayotte et al., 2002; Peretz et al., 2002);
- Explanations:
  - Pitch changes are coarse-grained in speech;
  - "Semantic recoding" in speech (Patel, 2008).

RQ1. Is congenital amusia a domain-specific or domain-general disorder?

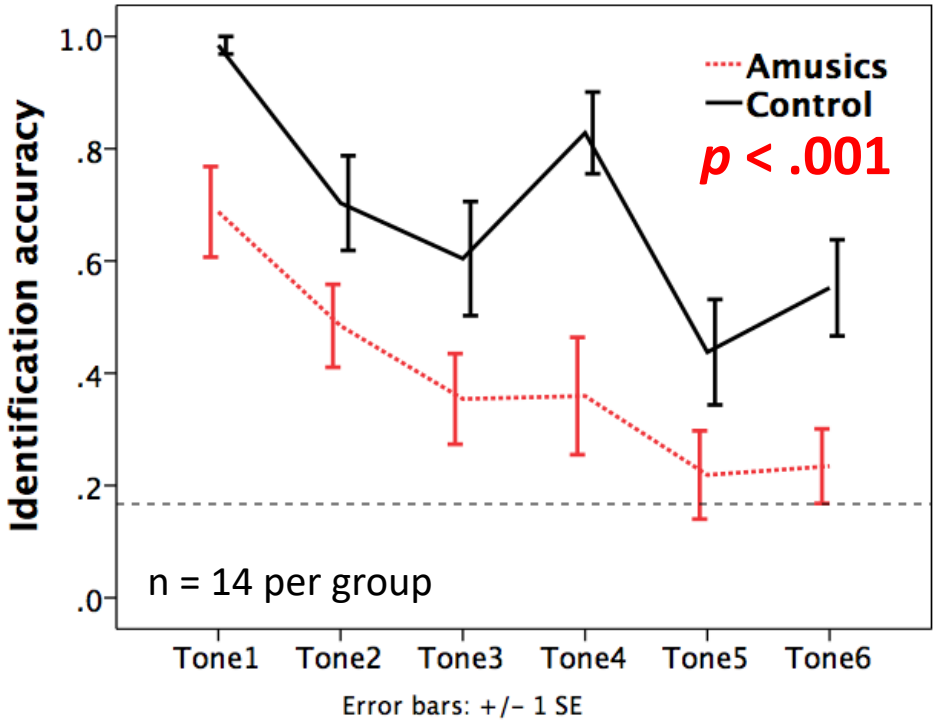
- Amusics do show **deficits in speech intonation processing**, when pitch differences are small (Liu et al., 2010);
- Amusics in non-tone languages (English/French) are impaired in perceiving **non-native lexical tone** (Mandarin Chinese and Thai) (Nguyen et al., 2009; Billmann et al., 2011);
- Amusics showed reduced sensitivity to **emotional prosody recognition** (Thompson et al. 2012);
- Mandarin amusics impaired in perceiving **native tones** (Nan et al., 2010; Jiang et al. 2012)

INTERSPEECH 2016
September 8–12, 2016, San Francisco, USA

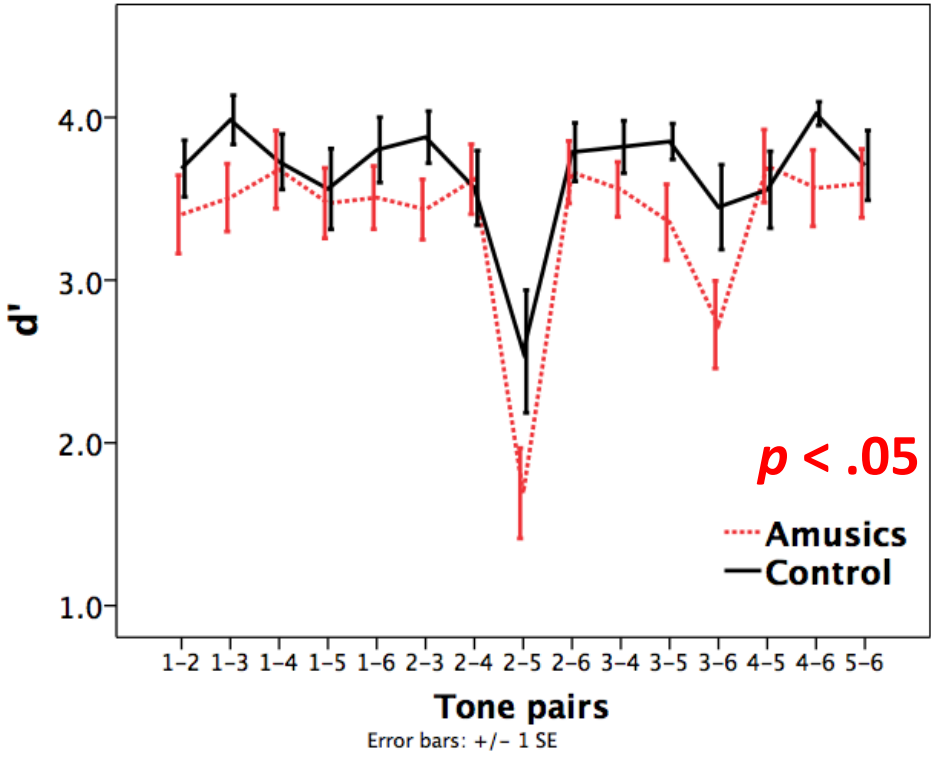
Effect of noise on lexical tone perception in Cantonese-speaking amusics

Jing Shao [1], *Caicai Zhang* [1,2], *Gang Peng* [1,2,3], *Yike Yang* [1], *William S-Y. Wang* [1,2]

Impaired tone identification



Impaired tone discrimination



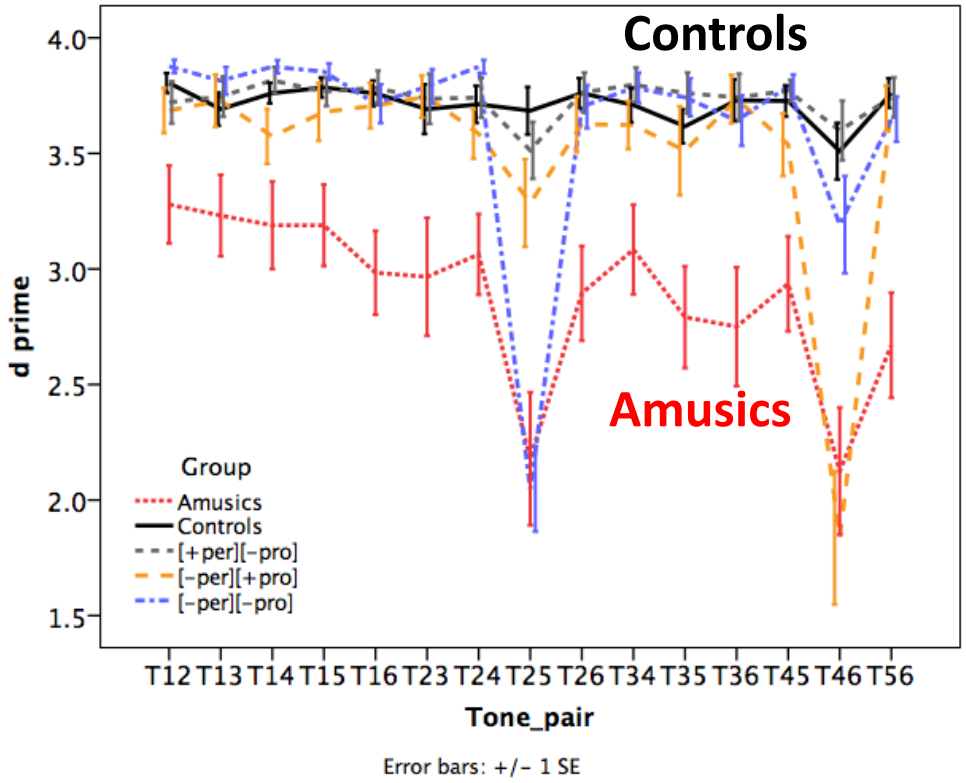
PLOS ONE

Dissociation of tone merger and congenital amusia in Hong Kong Cantonese

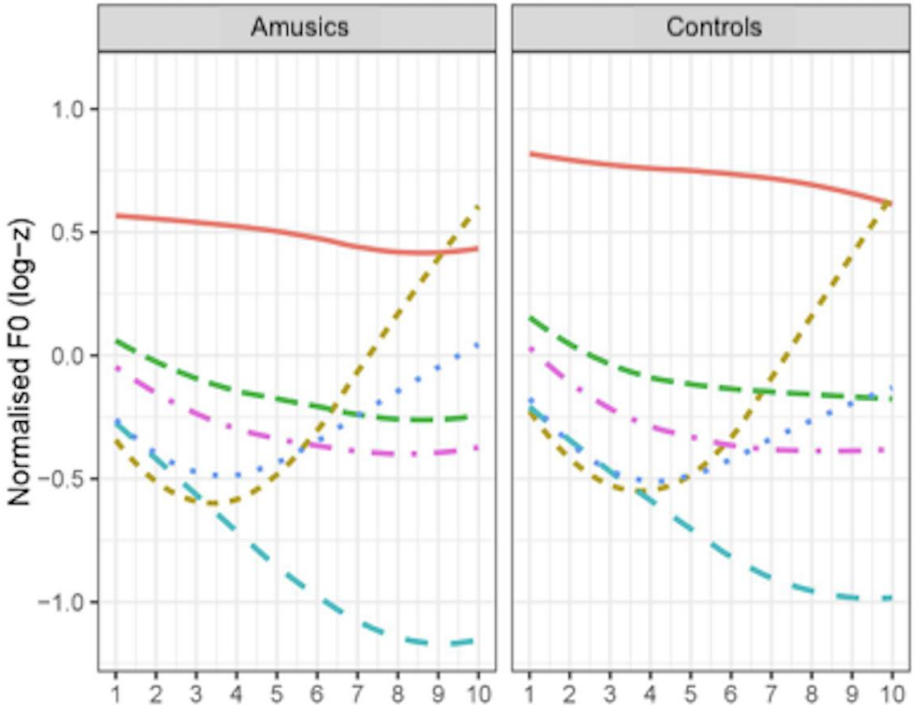
Caicai Zhang, Oi-Yee Ho, Jing Shao, Jinghua Ou, Sam-Po Law

Published: July 1, 2021 • https://doi.org/10.1371/journal.pone.0253982

Impaired tone discrimination



Intact tone production

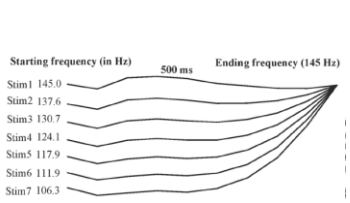


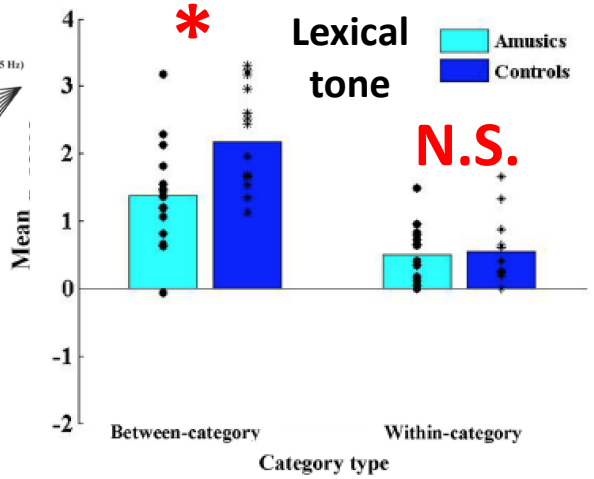
PLOS ONE

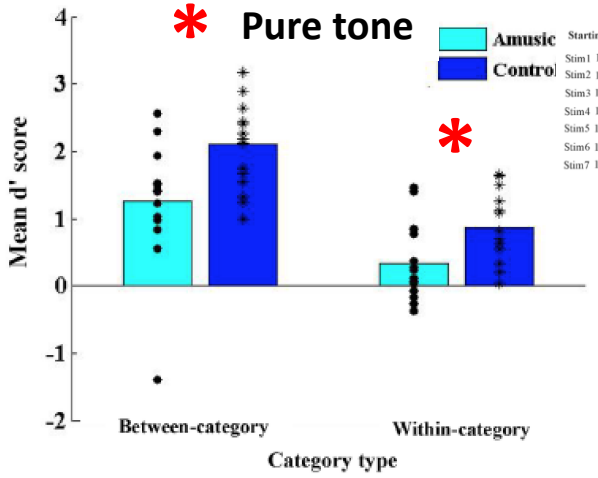
Deficits of congenital amusia beyond pitch: Evidence from impaired categorical perception of vowels in Cantonese-speaking congenital amusics

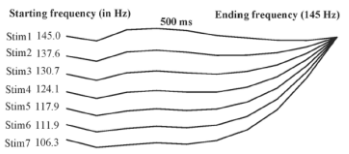
Caicai Zhang, Jing Shao, Xunan Huang

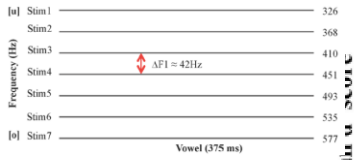
Published: August 22, 2017 • https://doi.org/10.1371/journal.pone.0183151

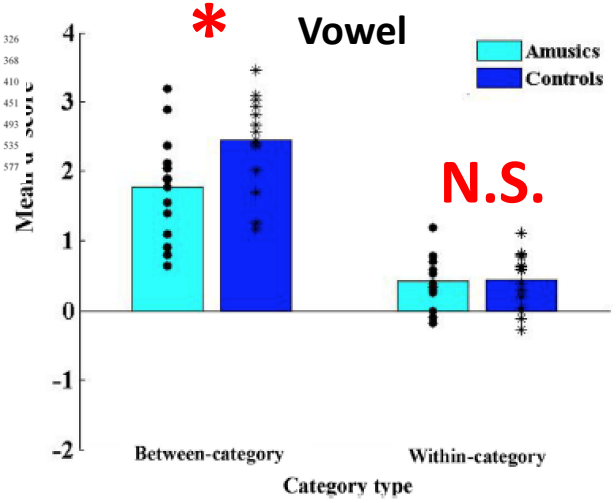


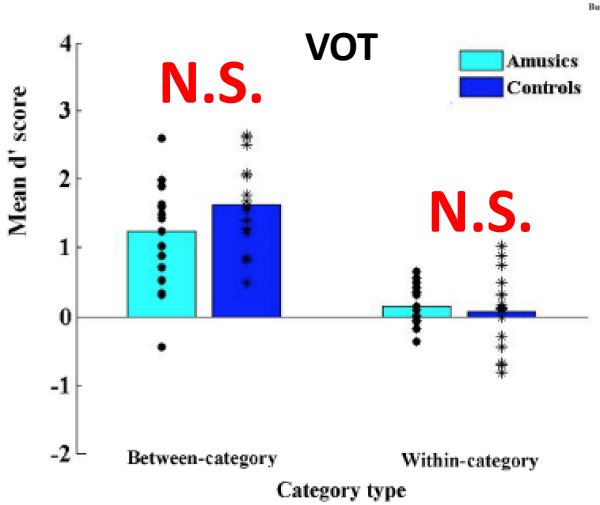


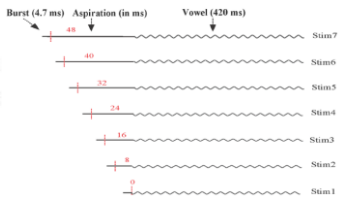


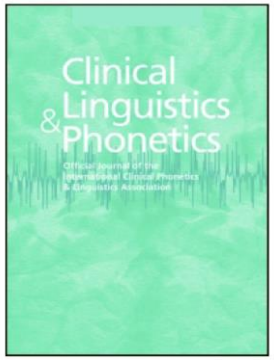










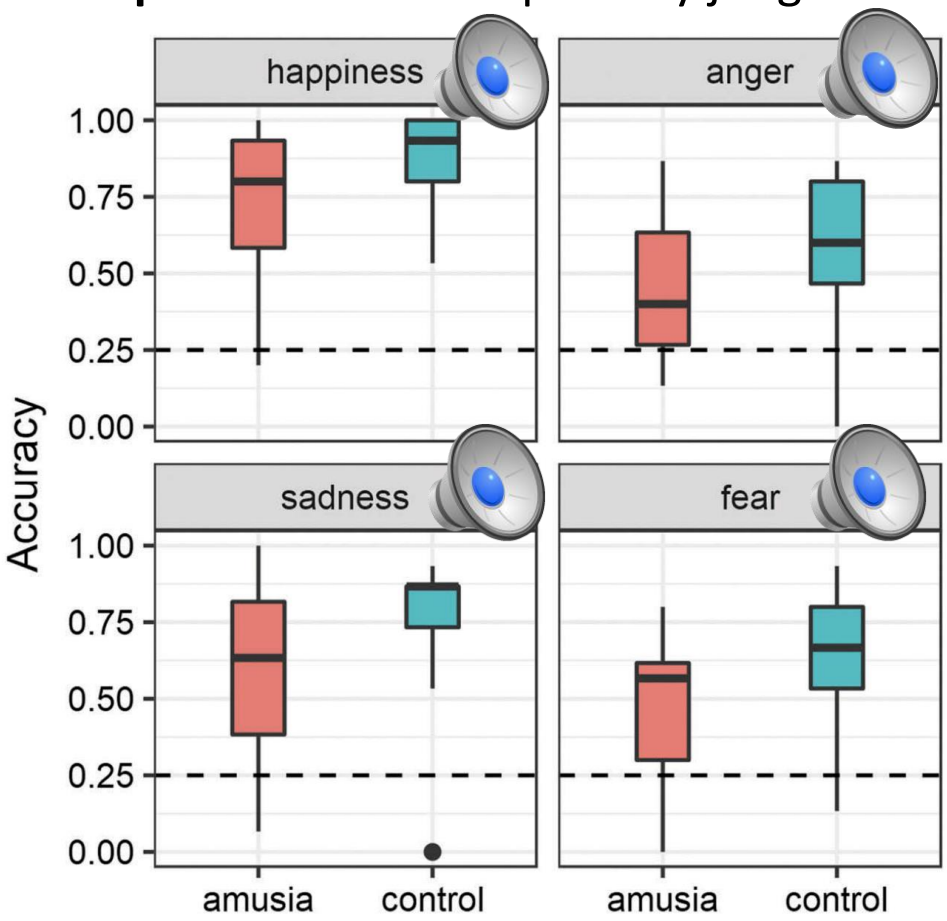


Emotion processing in congenital amusia: the deficits do not generalize to written emotion words

Yi Lam Cheung, **Caicai Zhang** & Yubin Zhang

Pages 101-116 | Received 14 Oct 2019, Accepted 17 Jan 2020, Published online: 27 Jan 2020

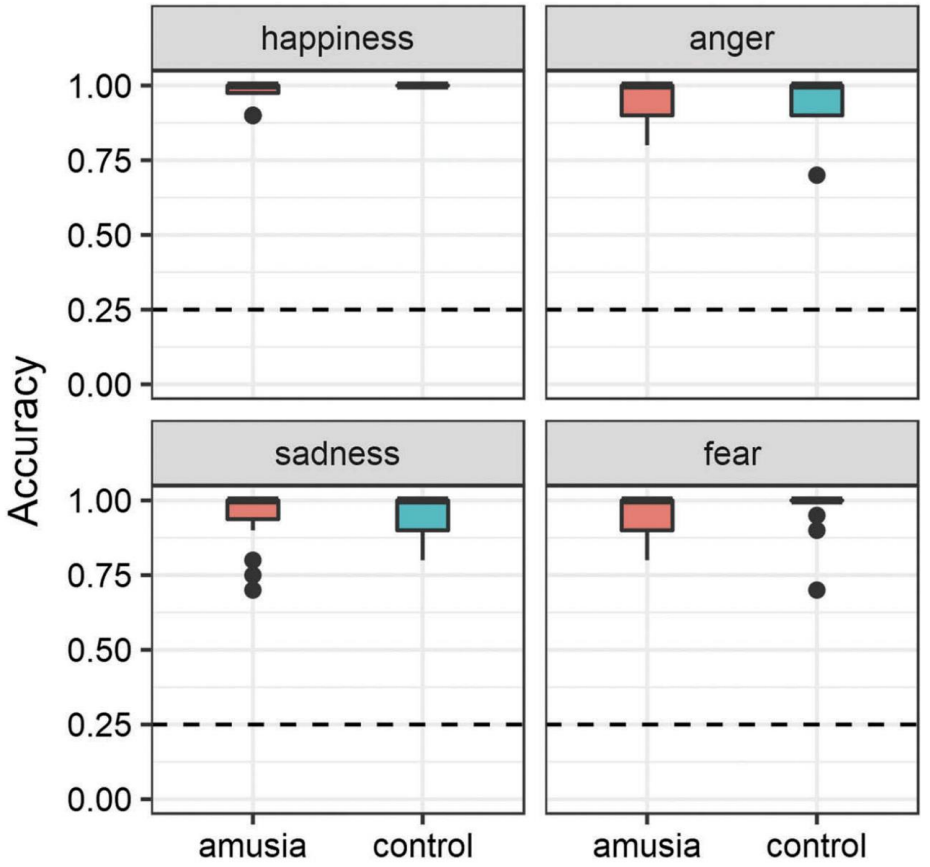
Impaired emotional prosody judgment



Example:
最近轉左天氣。

Amusics < controls:
$p < 0.001$

Intact written emotion word judgment



Example:
痛快、窩火 *n.s.*

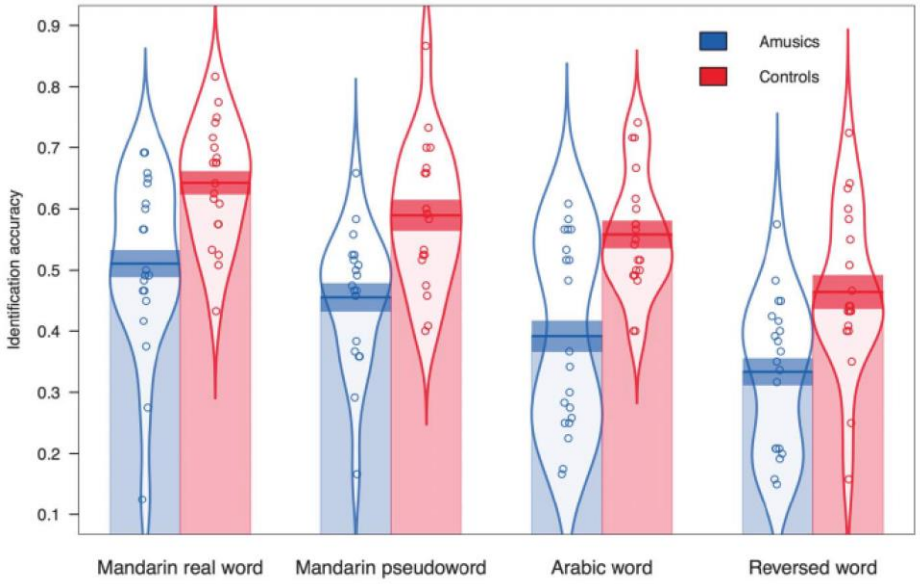
Amusics vs. controls:

Research Article

Talker Processing in Mandarin-Speaking Congenital Amusics

Jing Shao,[a,b] Lan Wang,[b] and Caicai Zhang[c,d]

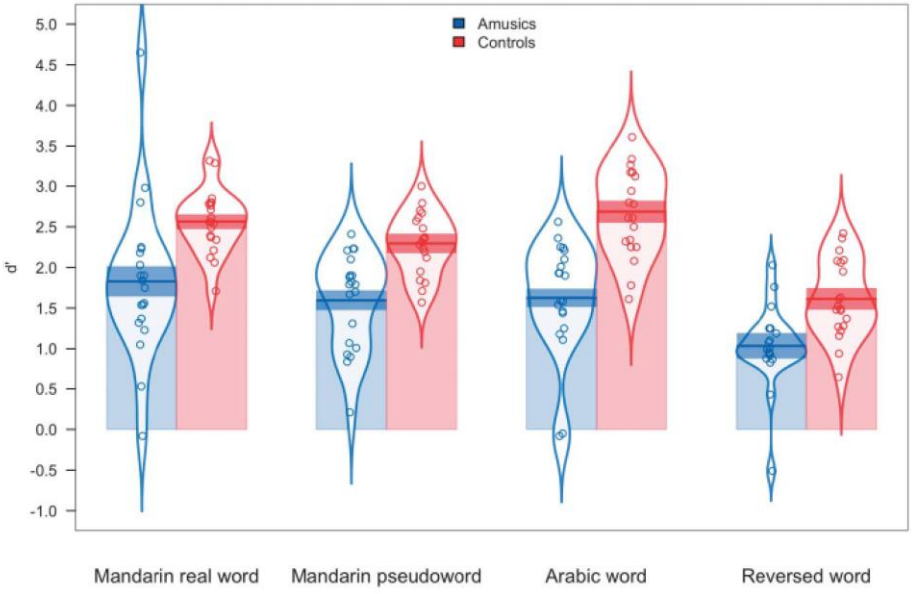
Impaired talker recognition



/nei35 min55/

Amusics < controls: $p < 0.001$

Impaired talker discrimination



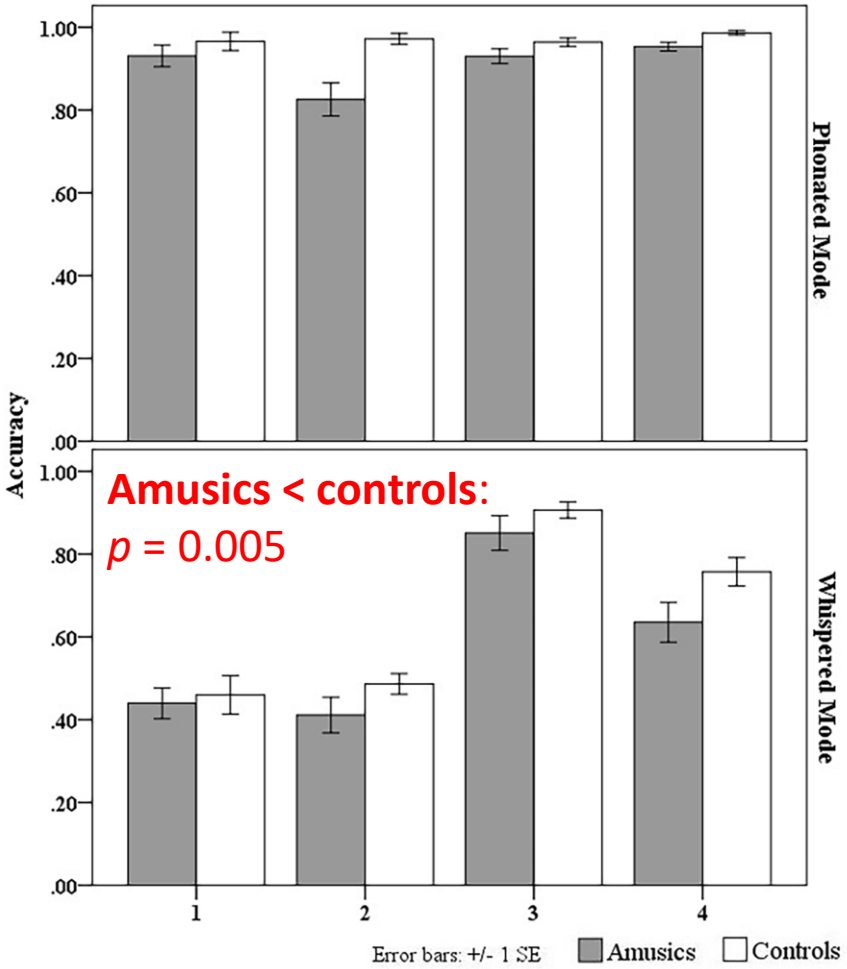
Amusics < controls: $p < 0.001$

JSLHR *Accepted*

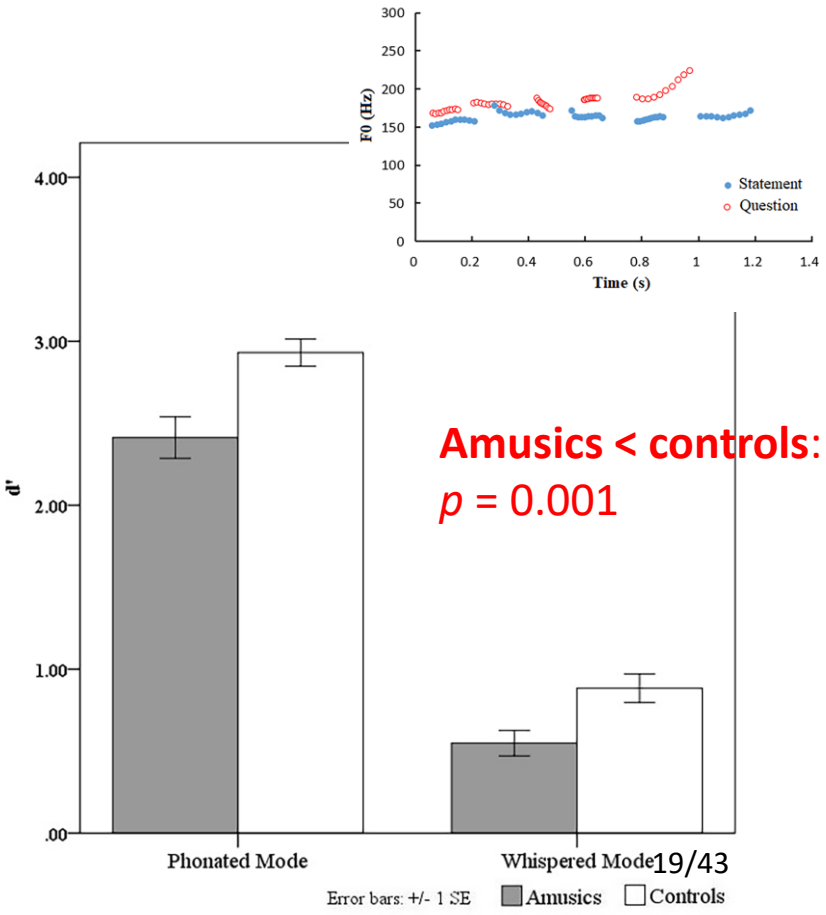
The Perception of Lexical Tone and Intonation in Whispered Speech by Mandarin-speaking Congenital Amusics

Gaoyuan Zhang[1], Jing Shao[2], Caicai Zhang[3*], Lan Wang[4]

Impaired tone identification across phonated and whispered mode



Impaired intonation identification across phonated and whispered mode



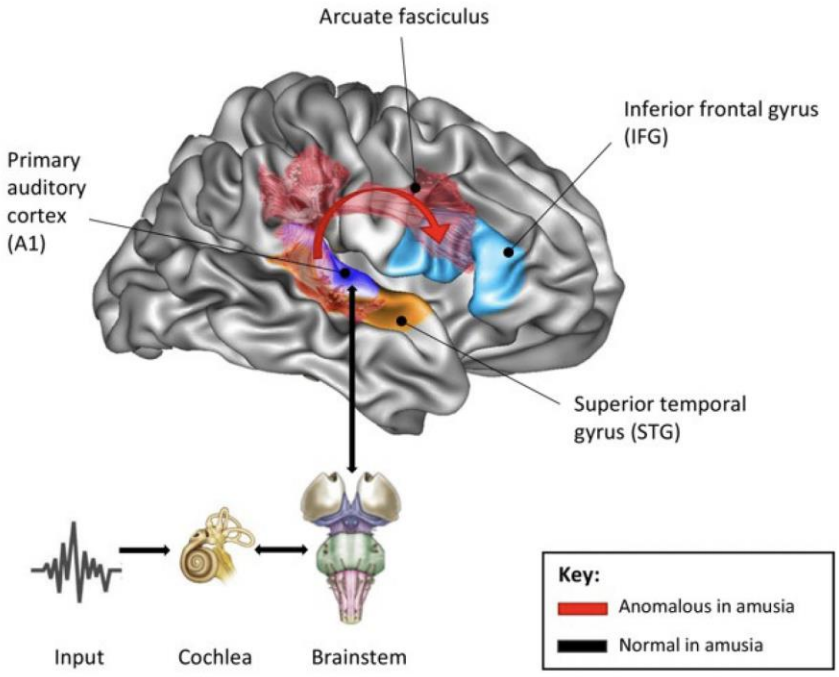
Interim summary I

- RQ1: Is congenital amusia a domain-specific or domain-general disorder?
  - Amusia affects a **broad range** of speech pitch processing:
    - Speech intonation (question/statement);
    - Lexical tone (in many listening conditions);
    - Emotional prosody;
    - Talker voice processing.
  - Among native Chinese speakers, amusia not only compromises low-level auditory pitch-processing, but also affects **phonological processing** of tones (Zhang et al., 2018; Shao et al., 2019).
  - Supports the **domain-general** hypothesis (Vuvan et al., 2015), but with **domain-specific** influence.
  - Amusia **affects** whispered tone and intonation identification
    - Possible auditory duration and amplitude processing deficits → subtypes of amusia (Phillips-Silver et al., 2011; Peretz & Vuvan, 2017).

RQ2: What are the **neural bases** of congenital amusia?

- **Subcortical**: INTACT pitch encoding (Liu et al., 2015; but see Lehmann et al. 2015)
- **Cortical**: Impairment in a network of right inferior frontal gyrus (IFG) and right auditory cortex (AC)/superior temporal gyrus (STG)
  - Structurally:
    - Right IFG: reduction in white matter concentration and thicker cortex (Hyde et al., 2006, 2007; Albouy et al., 2013);
    - Right AC/STG – **inconsistent** findings: thicker cortex (Hyde et al., 2007) vs. reduced grey matter (Albouy et al., 2013; Jin et al. 2021);
  - Functionally:
    - Right IFG: abnormal lack of activation (Hyde et al., 2011);
    - Right AC/STG – **inconsistent** findings: intact function (Hyde et al., 2011; Norman-Haignere et al., 2016) vs. abnormal N100m traced back to the ACs (Albouy et al., 2013);
  - Disrupted functional and structural (arcuate fasciculus) connectivity between the right IFG and AC/STG (Hyde et al., 2011; Albouy et al., 2013; Loui et al., 2011; Chen et al., 2018).

Right fronto-temporal network



Marin. (2019).

RQ2: What are the **neural bases** of congenital amusia?

- Conscious pitch disorder hypothesis (EEG studies)
  - Amusics' brain can detect musical pitch deviations or tonal violations **without focal attention** (i.e., showing normal mismatch negativity or MMN) (Peretz et al., 2009; Moreau et al., 2013; Zendel et al., 2015; Nan et al., 2016);
- Taken to support normal functioning of auditory cortex (Hyde et al., 2011; Norman-Haignere et al., 2016).
- Causal role of the right fronto-temporal network
  - Cathodal (inhibitory) transcranial direct current stimulation (tDCS) over both right frontal and temporal regions induced amusia-like electrophysiological patterns in typical listeners (Royal et al., 2018);
  - Transcranial alternating current stimulation (tACS) of the right dorsolateral prefrontal cortex (DLPFC) improved pitch memory in amusics (Schaal al., 2015).

Unresolved issues

1. Whether the auditory cortex functions normally or not remains debated;
2. The neural bases of **lexical tone** processing deficit remain unknown.

Contents lists available at ScienceDirect

Neuropsychologia

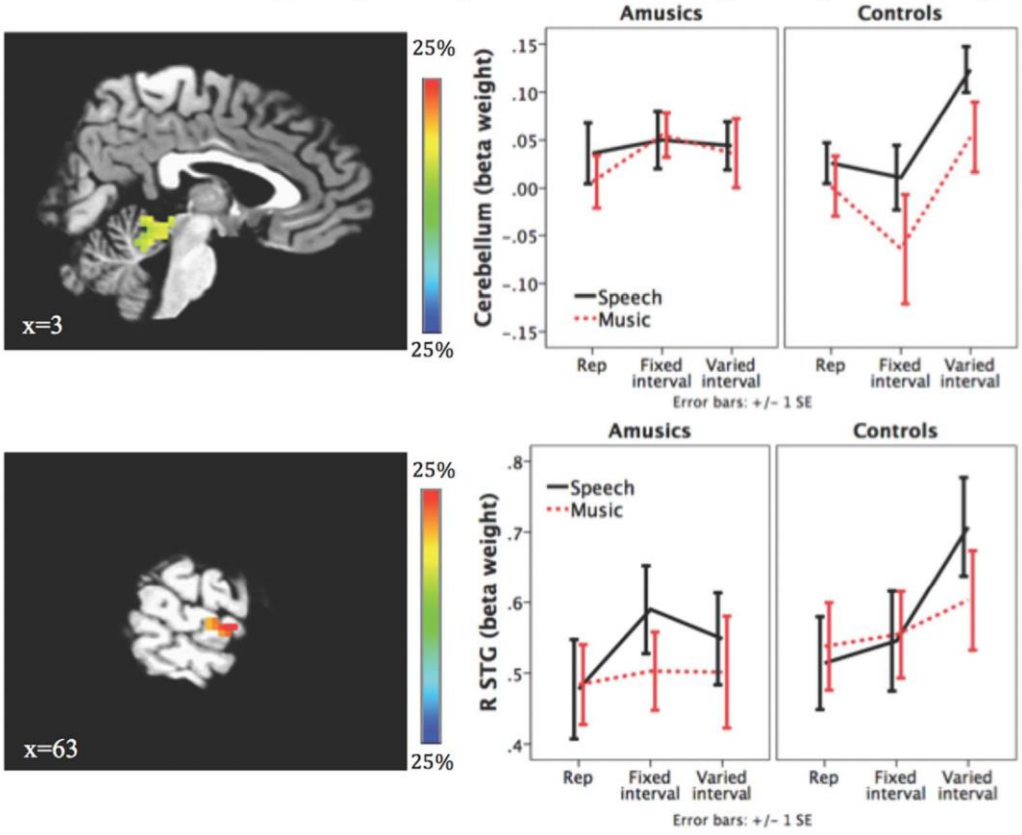
journal homepage: www.elsevier.com/locate/neuropsychologia

Neural bases of congenital amusia in tonal language speakers

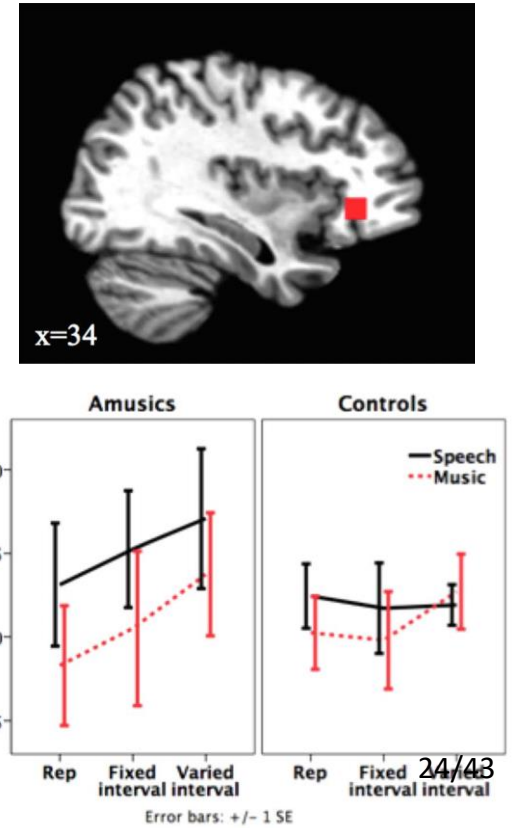
Caicai Zhang[a,b,*], Gang Peng[a,b,**], Jing Shao[a], William S.-Y. Wang[a,b]

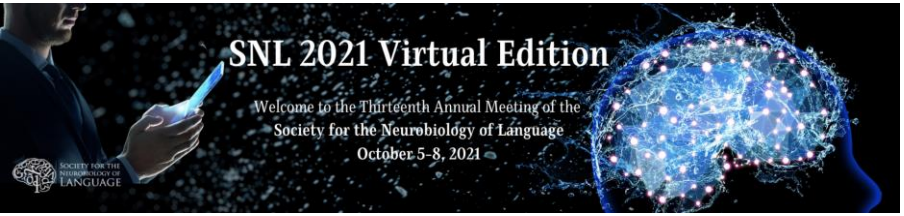
[a] Department of Chinese and Bilingual Studies, The Hong Kong Polytechnic University, Hong Kong SAR, China
[b] Shenzhen Institutes of Advanced Technology, Chinese Academy of Sciences, Shenzhen 518055, China

B. Within-group analyses of relative pitch processing



No group difference in right IFG

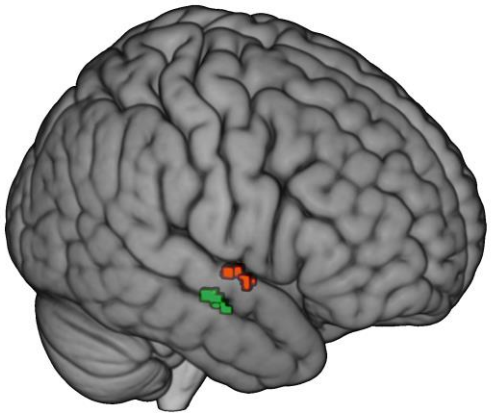




Neural responses to explicit processing and implicit representation of lexical tones in Mandarin speakers with Amusia

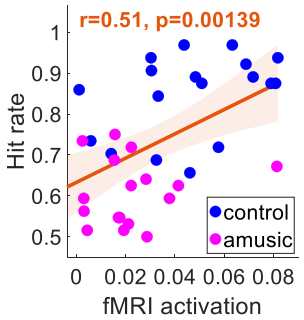
Nikolay Novitskiy[1], Caicai Zhang[2], Fang Liu[3], Patrick Wong[1], Alice Chan[4]; [1]Department of Linguistics & Modern

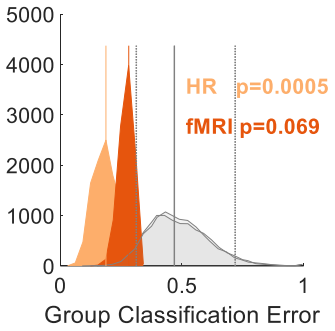
Explicit processing task (music and lexical tone discrimination)

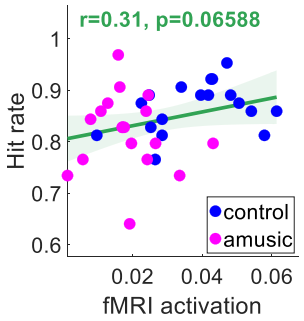


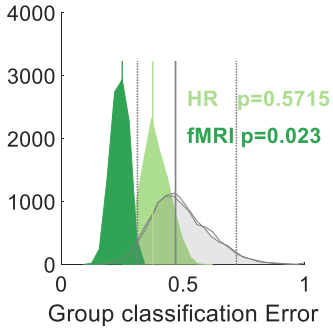
Controls-amusics, music

Controls-amusics, tone

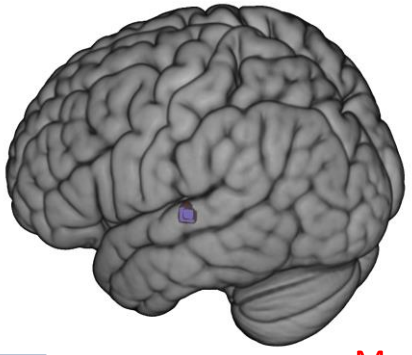




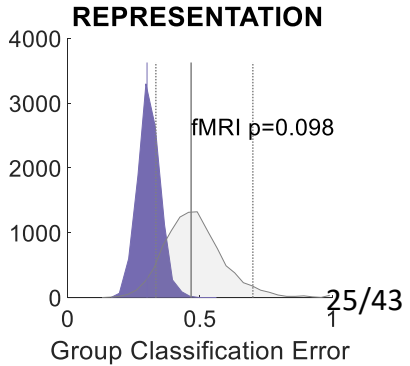




Implicit representation task (loudness judgment)



Controls-amusics, repeat-nonrepeat Marginally significant

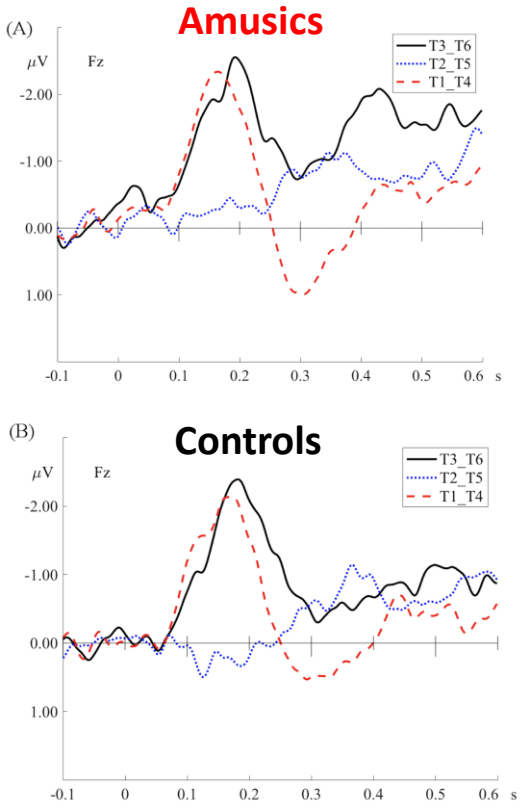


SCIENTIFIC REPORTS

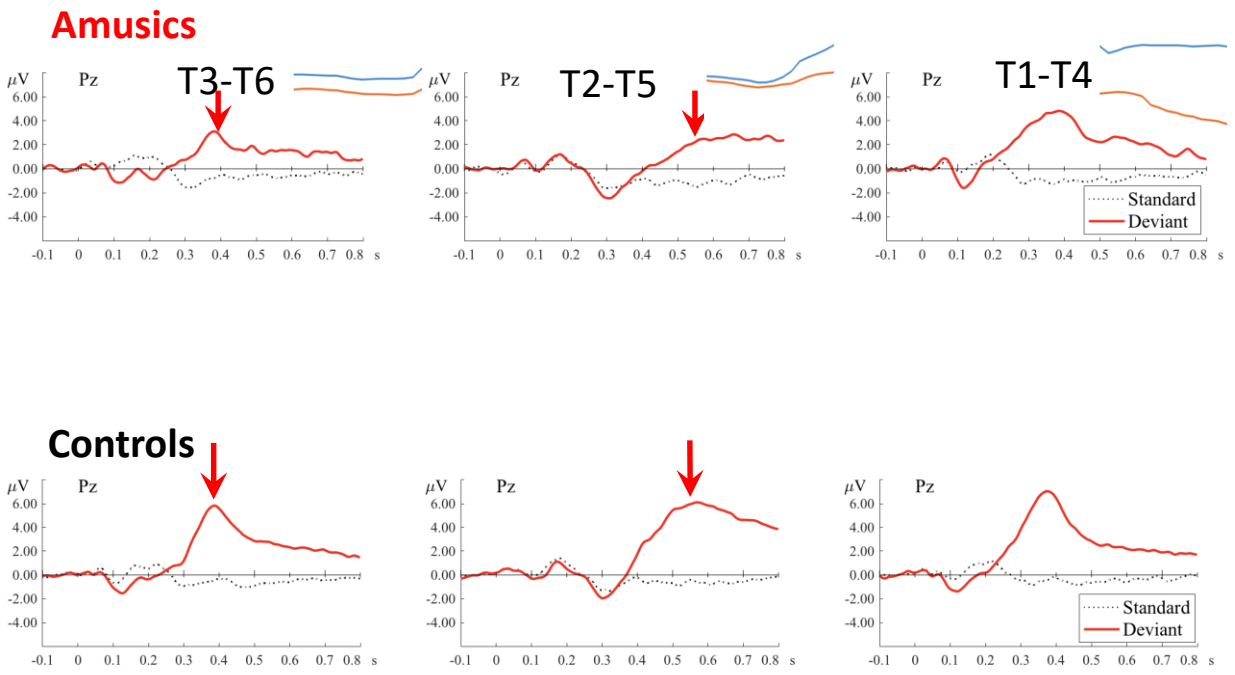
Normal pre-attentive and impaired attentive processing of lexical tones in Cantonese-speaking congenital amusics

Caicai Zhang[1,2] and Jing Shao[1,2]

Intact pre-attentive tone processing (MMN)



Impaired attentive tone processing (P300)



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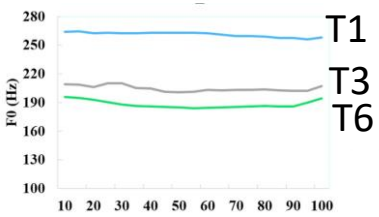
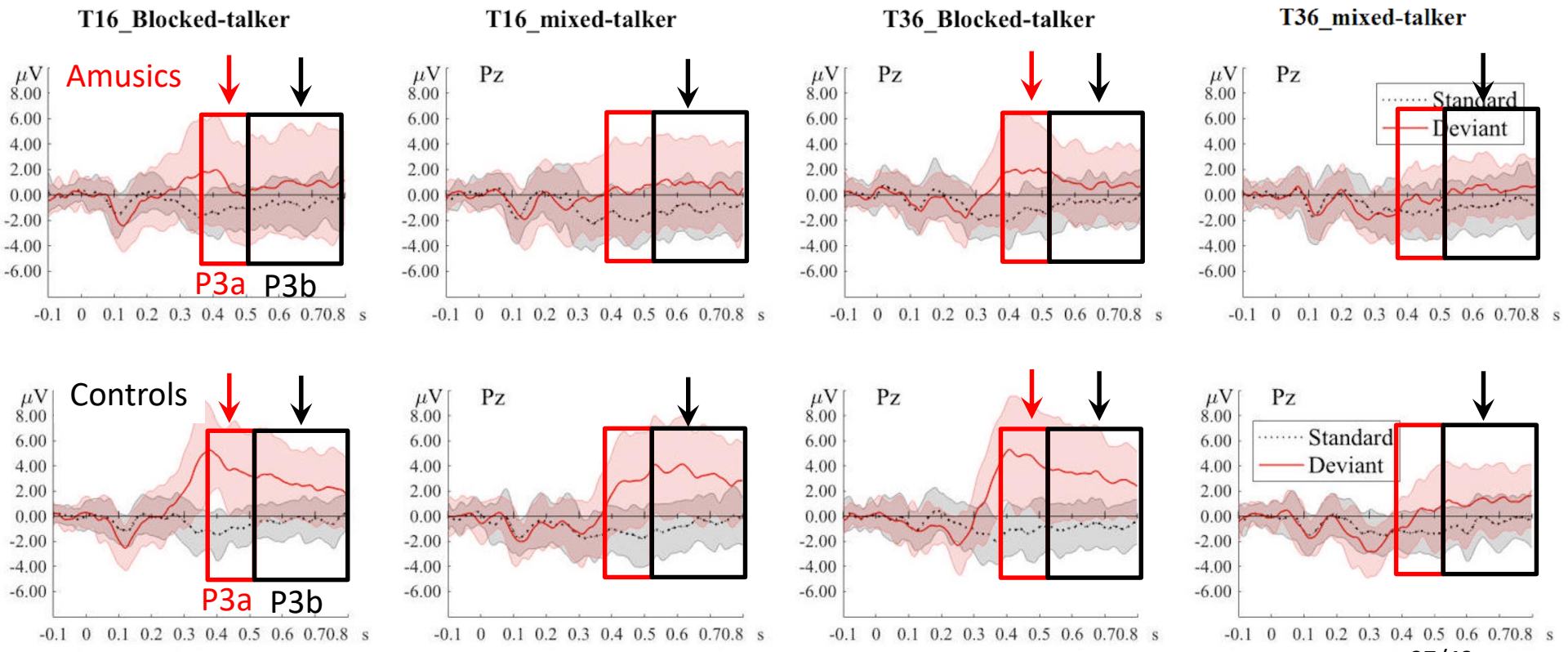
Talker normalization in typical Cantonese-speaking listeners and congenital amusics: Evidence from event-related potentials

Jing Shao[a,b], Caicai Zhang[a,b,*]





Interim summary II

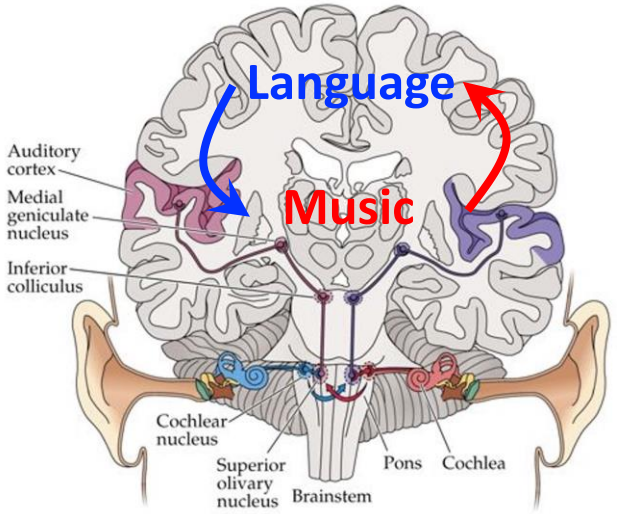
- RQ2: What are the neural bases of congenital amusia?
  - The right STG showed abnormal activity in the amusical brain:
    - possible division into dorsal and ventral parts that are responsive to musical and lexical tone stimuli respectively;
    - only when attention to or judgment of pitch is required.
  - Largely consistent with the **right fronto-temporal network hypothesis** (Hyde et al., 2006, 2007, 2011; Albouy et al., 2013; Loui et al., 2011; Chen et al., 2018; Marin, 2019)**.**
  - Confirmed P300 amplitude reduction in the active listening condition.
  - Supports the **conscious pitch disorder hypothesis** (Peretz et al., 2009; Moreau et al., 2013; Zendel et al., 2015) and expands it to speech (lexical tone) processing.

Recap

1. Is congenital amusia a **domain-specific** or **domain-general** disorder?
   - Amusia is a **domain-general** disorder that affects a broad range of speech pitch processing (intonation, lexical tone, emotional prosody and talker voice), but with **domain-specific** influence.
2. What are the **neural bases** of congenital amusia?
   - Does not refute the right fronto-temporal network hypothesis;
     - Implicates the abnormal function of the right STG (rather than right IFG);
   - Supports the conscious pitch disorder hypothesis.
3. Is congenital amusia **treatable**?
   - Amusia appears to be treatable.

General discussion

- Studies on amusia provided substantial evidence for the **music-to-speech transfer**, especially its **causality** (RQ3 - training study)
  - A large number of studies reporting a musician advantage in speech processing or speech learning (Chobert et al., 2012; Lee & Hung, 2008; Alexander et al., 2005; Delogu et al., 2006; 2010; Lee et al., 2014; Smayda et al., 2015).
  - But these studies are mostly correlational and cannot exclude pre-existing advantages in musicians.



General discussion

- Mechanisms of cross-domain transfer
  - **Music → Speech**
    - **Domain-general sharpening** (Strait & Kraus, 2011; Kraus & Chandrasekaran, 2010)
    - **Domain-general and -specific influences** (Besson et al. 2011)
    - **Greater demand of music**: OPERA and e-OPREA (Patel, 2010, 2014)
  - ~~**Speech → Music**~~
    - ~~**Early exposure** (Deutsch et al. 2004)~~

Domain-general and **domain-specific** influences (e.g., phonological processing of native tones).

General discussion

- **Depth of influence** differs between musical training and musical disorder
  - **Musical training** affects subcortical to cortical processing ("**deep**" influence);
  - The influence of **amusia** appears restricted to cortical, conscious processing ("**shallow**" influence);
    - Intact subcortical pitch encoding (FFR) (Liu et al., 2015) and cortical preattentive pitch processing (MMN).

Speech-music relationship

Brain

source: Internet

Speech

Music

source: Internet

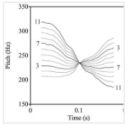
source: Internet

Research Topic

Relationship of Language and Music, Ten Years After: Neural Organization, Cross-domain Transfer and Evolutionary Origins

Articles

By Views By Type By Date



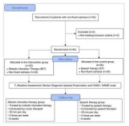
Effects of Amateur Musical Experience on Categorical Perception of Lexical Tones by Native Chinese Adults: An ERP Study

Jiaqiang Zhu , Xiaoxiang Chen and Yuxiao Yang

Original Research Music impacting on speech processing is vividly evidenced in most reports involving professional musicians, while the question of whether the facilitative effects of music are limited to experts or may extend to amateurs remains to be resolved. ...

Published on 15 March 2021
Front. Psychol. doi: 10.3389/fpsyg.2021.611189

1,681 total views Altmetric 2



Effectiveness of Melodic Intonation Therapy in Chinese Mandarin on Non-fluent Aphasia in Patients After Stroke: A Randomized Control Trial

Xiao-Ying Zhang , Wei-Yong Yu, Wen-Jia Teng, Meng-Yang Lu, Xiao-Li Wu, Yu-Qi Yang, Chen Chen, Li-Xu Liu, Song-Huai Liu and Jian-Jun Li

Original Research Melodic intonation therapy (MIT) positively impacts the speech function of patients suffering from aphasia and strokes. Fixed-pitch melodies and phrases formulated in MIT provide the key to the target language to open the language pathway. This ...

Published on 23 July 2021
Front. Neurosci. doi: 10.3389/fnins.2021.648724

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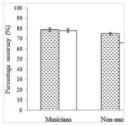

Musicianship Influences Language Effect on Musical Pitch Perception

William Choi

Original Research Given its practical implications, the effect of musicianship on language learning has been vastly researched. Interestingly, growing evidence also suggests that language experience can facilitate music perception. However, the precise nature of this ...

Topic Editors

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Acknowledgements

- **Research Grants Council of Hong Kong**, University Grants Committee. Early Career Scheme (No. 25603916).
- **National Natural Science Foundation of China** (No. 11504400).
- **PolyU** Start-up Fund for New Recruits, and **CBS** Departmental General Research Funds (Cross-institutional collaboration).

- **Collaborators**
  - Sam-Po LAW
  - Fang LIU
  - Jinghua OU
  - Lan WANG
  - Patrick WONG

- **Postdoc and students**
  - Jing SHAO
  - Claire CHEUNG
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  - Gaoyuan ZHANG
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  - Shixuan WANG
  - Shirley CHAN

Source: Internet

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