ACOUSTIC AND PERCEPTUAL COMPARISON OF SPEECH AND DRUM SOUNDS IN THE NORTH INDIAN TABLA: AN EMPIRICAL STUDY OF SOUND SYMBOLISM

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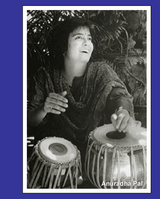


Introduction

Numerous cultures use nonsense syllables or "vocables" in systematic ways to represent musical sounds.

The mapping between speech sounds and musical sounds can be arbitrary (e.g. Solfège). Are there mappings which are based on acoustic/perceptual similarity? If so, what phonetic cues are used to symbolize musical sounds?

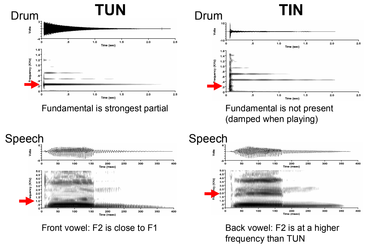
We investigated this question in North Indian tabla, a musical tradition in which drum sounds are given verbal labels.

The Tabla

Bayan (left hand, lower pitch)

Dayan (right hand, higher pitch)

Results: TUN vs TIN

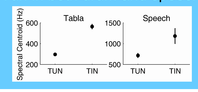


Comparison: Spectral Centroid

Drum: mean frequency of first four partials, weighted by their amplitudes

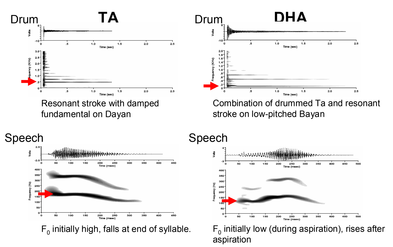
Speech: mean frequency of first three formants, weighted by their amplitudes

Centroid is higher for Tin than Tun in both drum and speech



(Speech F_0 did not differ between Tun and Tin.)

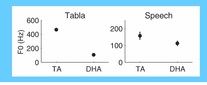
TA vs DHA



Comparison: Fundamental Frequency

Drum: Frequency of lowest partial: TA: Dayan 2nd partial; DHA: Bayan 1st partial.
Speech: Fundamental frequency F0 measured from narrowband spectrogram.

Fundamental is lower for Dha than Ta in both drum and speech



Anecdotal comments on cues used in perception experiment

Source: Web-based version of perceptual experiment (http://www.nsi.edu/tablaexp)
Subject pool: n = 64 subjects from 17 countries, broad range of backgrounds.

Subjects used a variety of criteria, including the ones we examined. Additional cues used by subjects:

TUN vs TIN

Attack in drum is sharper for Tin (amplitude of initial transient vs. tonal portion).

KAT vs GHE

Attack: closed stroke has sharper attack; **Pitch** lower for ghe; **Total duration** longer for ghe.

TRA vs KRA

Pitch differences noted, but were not used successfully; **Offset** (by the only subject to successfully match all pairs).

TA vs DHA

Attack: softer with aspiration.

Examples of drum strokes and vocables

Each drum stroke corresponds to a vocable, or 'bol'

From Courtney, D. (2000), *Fundamentals of Tabla*

Tabla bols use a subset of Hindi phonemes (mostly dental and velar consonants; full range of vowels)

Consonants

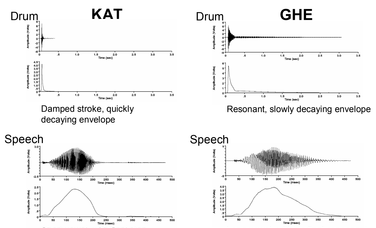
Stops:	Cerebral	Dental	Retroflex	Palatal	Velar	Post-velar
Voiceless	ʈ	त	ट	च	क	क़
Voiced	ɖ	द	ड	ज	ग	ग़
Voiceless aspirated	ʈʰ	थ	ठ	छ	ख	ख़
Voiced aspirated	ɖʱ	ध	ढ	झ	घ	ग़
Nasals(voiced):	ɳ	न	ण	ञ	ङ	
Spirants:						
Voiceless		स		श	ह	
Voiced		ज़				
Tapped (voiced):			ड़			
Flapped (voiced):			ढ़			
Aspirated voiced			ढ़			
Aspirated						
Lateral:		ल				
Semi-vowel:	व					

Vowels

Vowels:	Front	Central	Back
High	इ ई		उ ऊ
Lower High	ए		ओ
Mid	ऐ		औ
Lower Mid	अॅ	अ	अॉ
Low	आ		

From Chandola, A. (1985) *Music as Speech*

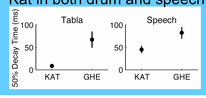
KAT vs GHE



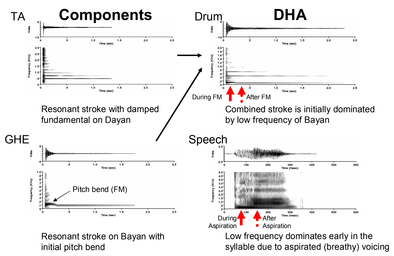
Comparison: Envelope decay time

Drum and **speech**: duration between envelope peak and point at which envelope decays to 50% of peak value

Decay time is longer for Ghe than Kat in both drum and speech



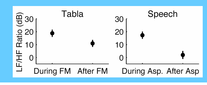
DHA (= TA + GHE)



Comparison: How balance of low and high frequency energy changes across a salient acoustic boundary

Drum: Ratio of energy in Bayan fundamental to average energy in first three partials of Dayan during initial pitch bend, and soon after onset of steady-state
Speech: Ratio of energy in fundamental to average energy in F1/F2 frequency band (515 to 1551 Hz) during aspiration and soon after onset of vowel steady state

Low frequencies dominate initially in both drum and speech



Conclusions

- Vocables of North Indian tabla are a clear case of sound symbolism.
- Acoustic properties of drums are reflected in a variety of phonetic components of vocables
  - Spectral centroid
  - Rate of amplitude envelope decay
  - Duration between releases of consonants in a cluster
  - Fundamental frequency (Fo)
  - Influence of aspiration on the balance of low vs. high frequency energy in a vowel
- Individuals without knowledge of Indian music can match drum sounds and speech sounds in a simple two-alternative forced-choice paradigm.

Methods

Data Collection

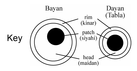
- 6 Professional tabla players (1 female) were recorded in Bombay, April 2002 in a professional sound studio. Recordings saved directly to disk as .wav files (Protools). All players used the same set of drums
- Each player was asked to play and speak all basic strokes 5 times each
- 8 bols were analyzed in this study, organized into four contrasts.

Analysis

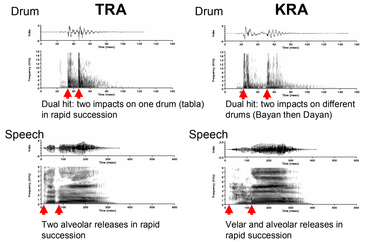
- Quantitative measures of waveforms and spectrograms were compared

Drum strokes analyzed

Bol	Manner of playing
TIN /tɪn/	*Dayan*: Index finger strikes head. Third finger damps the fundamental by resting on head.
TUN /tʊn/	*Dayan*: Index finger strikes patch; no damping.
KAT /kət/	*Bayan*: Damped stroke played with flat hand across rim, head, and patch.
GHE /gˈeˑ/	*Bayan*: Index finger strikes head at far edge of patch. Heel of hand, on head, can alter pitch.
TRA /trə/	*Dayan*: Damped stroke: middle and index fingers strike patch in rapid succession, and remain on drum.
KRA /krə/	*Bayan*: Damped flat-hand stroke similar to KAT. *Dayan*: Damped stroke. Fingers strike patch together and remain in contact.
TA /tə/	*Dayan*: Index finger strikes rim. Third finger damps fundamental by resting on head.
DHA /dˈə/	Simultaneous striking of TA and GHE.



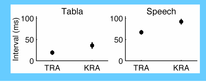
TRA vs KRA



Comparison: Interval between events

Drum and **speech**: duration between first and second impact / release.

Interval is shorter for Tra than Kra in both drum and speech



Perception Experiment

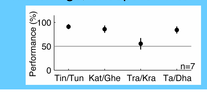
- Can naive listeners match vocables to drum sounds?
- If so, it shows that the mapping is guided by perceptual similarity independent of cultural convention, and that there are reliable phonetic cues to drum sounds.
- **Design**: Present two speech and two drum sounds, freely listen, then choose mapping between speech and drum (2AFC)

–32 trials (8 for each contrast pair, each trial presents speech and drum sounds from the same musician.)
–7 subjects unfamiliar with Hindi or Tabla drumming.

Perception Results

We measured percent correct matches between drum and speech for each contrast pair in the study

Naive subjects made correct matchings, except for Tra/Kra.



It remains to be tested if subjects can still make correct matches in a less constrained experimental paradigm.

Future studies

- Cross-cultural comparison of phonetic cues used to symbolize different drum sounds (e.g. Chinese Opera percussion, African drumming)
- Does verbal encoding with sound symbolism enhance learning and memory of drum sequences?

References

A. Chandola, *Music as Speech: An Ethnomusicolinguistic Study of India*, New Delhi:Navrang, 1988.

D. Courtney, *Advanced Theory of Tabla*, Houston: Sur Sangeet Services, 2000.

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