The Effects of Tone Categories on the Perception of Mandarin Vowels

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Outline

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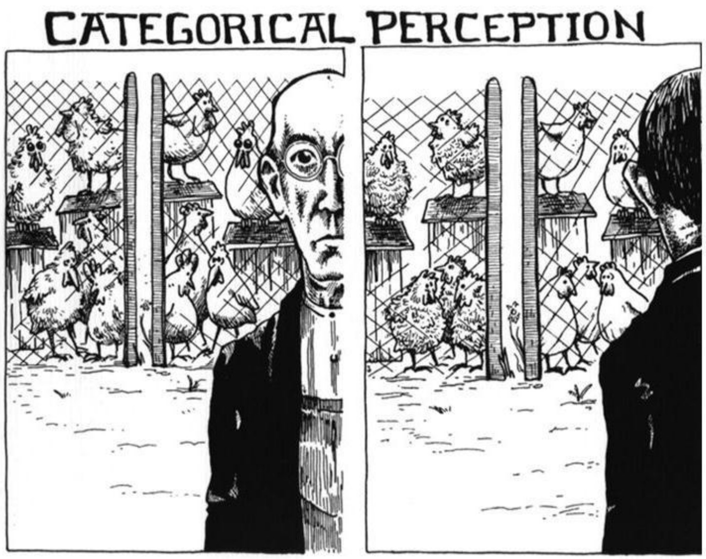
1. Introduction: Categorical Perception

Categorical perception (CP) is a very basic ability for people to sort the things in the world into their proper categories (*Harnad, 2003*).

Speech sounds are perceived categorically by human beings.

The acoustic differences between phonemic categories are more noticeable for us than within categories (*Reetz & Jongman, 2009*).



Differences among items that fall into different categories are exaggerated, and differences among items that fall into the same category are minimized.

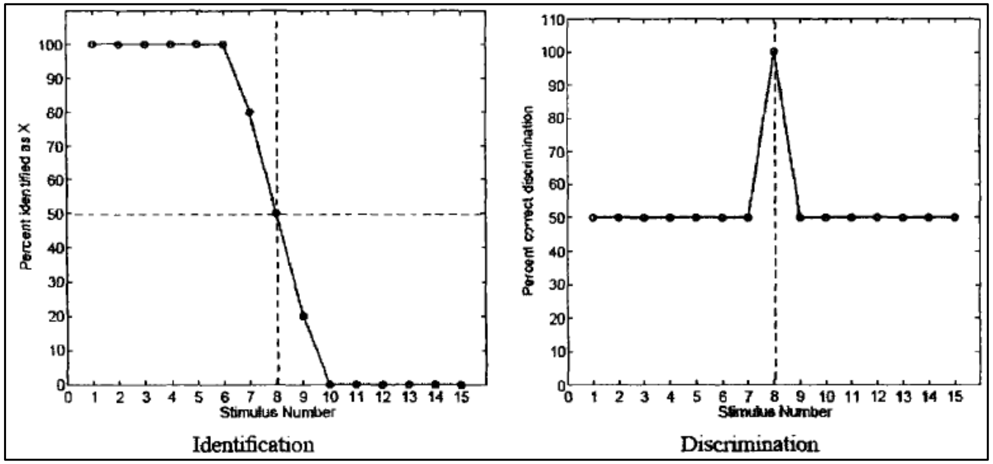
From Rob Goldstone, 2009

1. Introduction: Categorical Perception

Characteristics of categorical perception (*Liberman, 1957*) :

The categorical boundary was sharply defined by the identification function;

A marked accuracy peak in discrimination function was close to the position of categorical boundary.



Ideal diagrams of CP

1. Introduction: Categorical Perception

The perception of stop consonants and lexical tones are categorical perception *(Liberman, 1957; Wang, 1976).*

What about
vowel perception?

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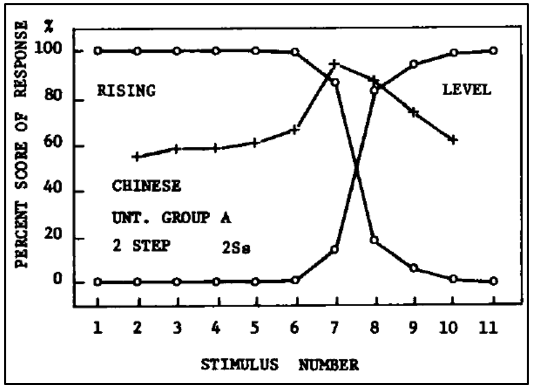
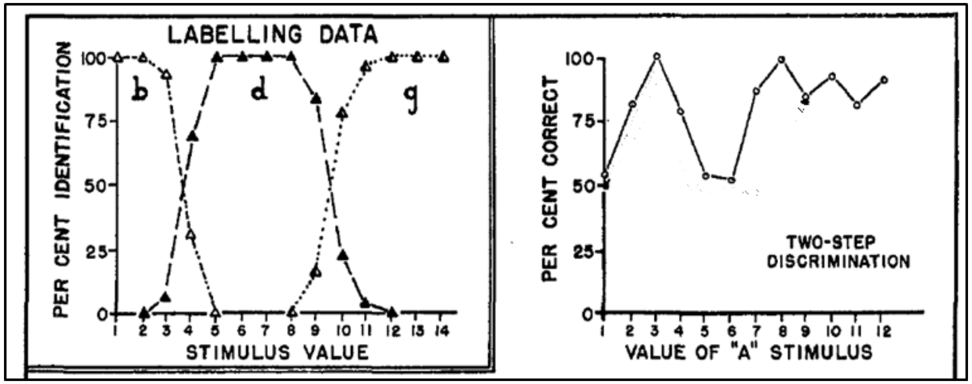


Lexical-tone perception (from Wang, 1976)

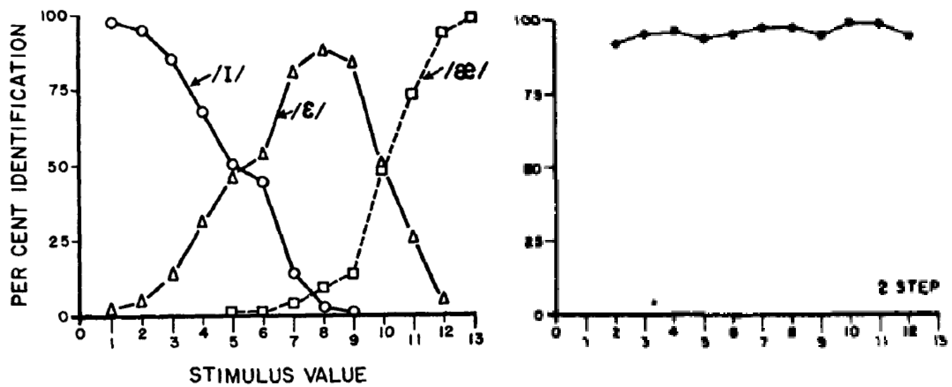


Stop-consonant perception (from Liberman, 1957)

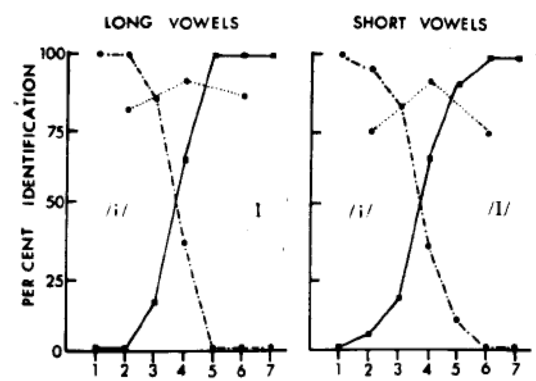
1. Introduction: Vowel Perception

Initially, vowel perception was dubbed "continuous perception" *(Fry et al., 1962).*

HOWEVER, categorical-like perception of vowels was reported by some latter studies *(Pisoni, 1973, 1975).*



Vowel perception (from Fry et al., 1962)



Categorical-like vowel perception (from Pisoni., 1973)

1. Introduction: Influence Factors

Factors influencing vowel perception:

Vowels tend to be perceived more categorically if they are short in duration, or presented in specific experimental procedures such as ABX or 2IFC discrimination tasks, or perceived in an fixed context *(Pisoni, 1973, 1975; Gerrits & Schouten, 2004;).*

Different neighboring spectral contents could generate a significant shift on categorical boundary of vowels *(Holt et al., 2004).*

1. Introduction: Influence Factors

Vowel production:

There was a strong correlation between pitch changes and formant frequencies, especially between F0 and F1. *(Gottfried & Chew, 1986; Benett & Weinberg, 1979).*

Vowel perception:

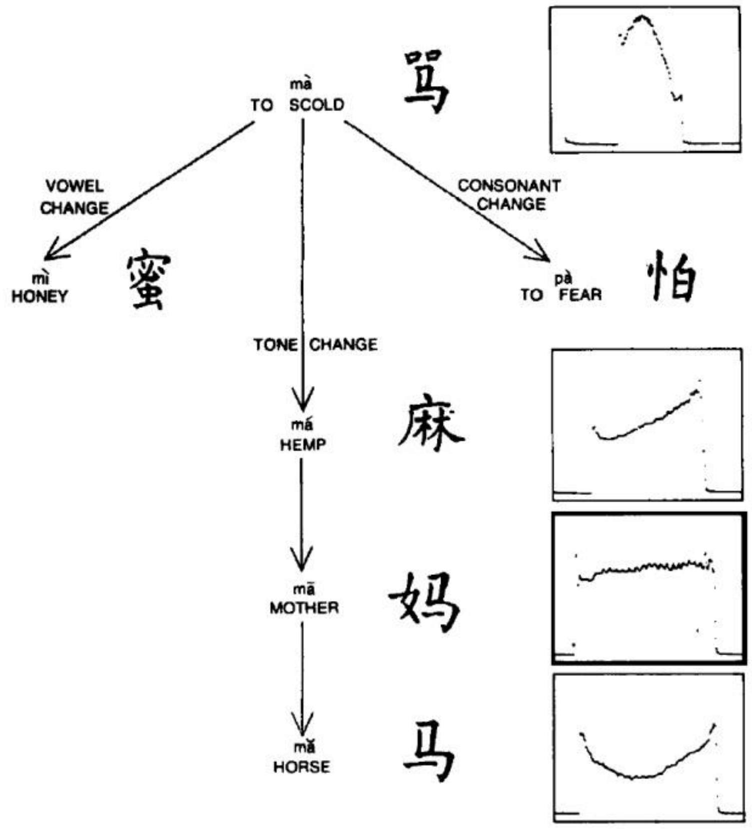
Categorical boundaries in F1 were strongly affected by F0 in the perception of vowels. *(Traunmüller, 1981).*

1. Introduction: Influence Factors

Lexical meanings of Chinese words can be distinguished by different pitch patterns (*Wang, 1976*).

The main difference among the four Mandarin tones lies in pitch contours and values of fundamental frequency (F0).

Therefore, Mandarin could provide us a chance to investigate the effect of pitch contours on vowel perception for tonal language.



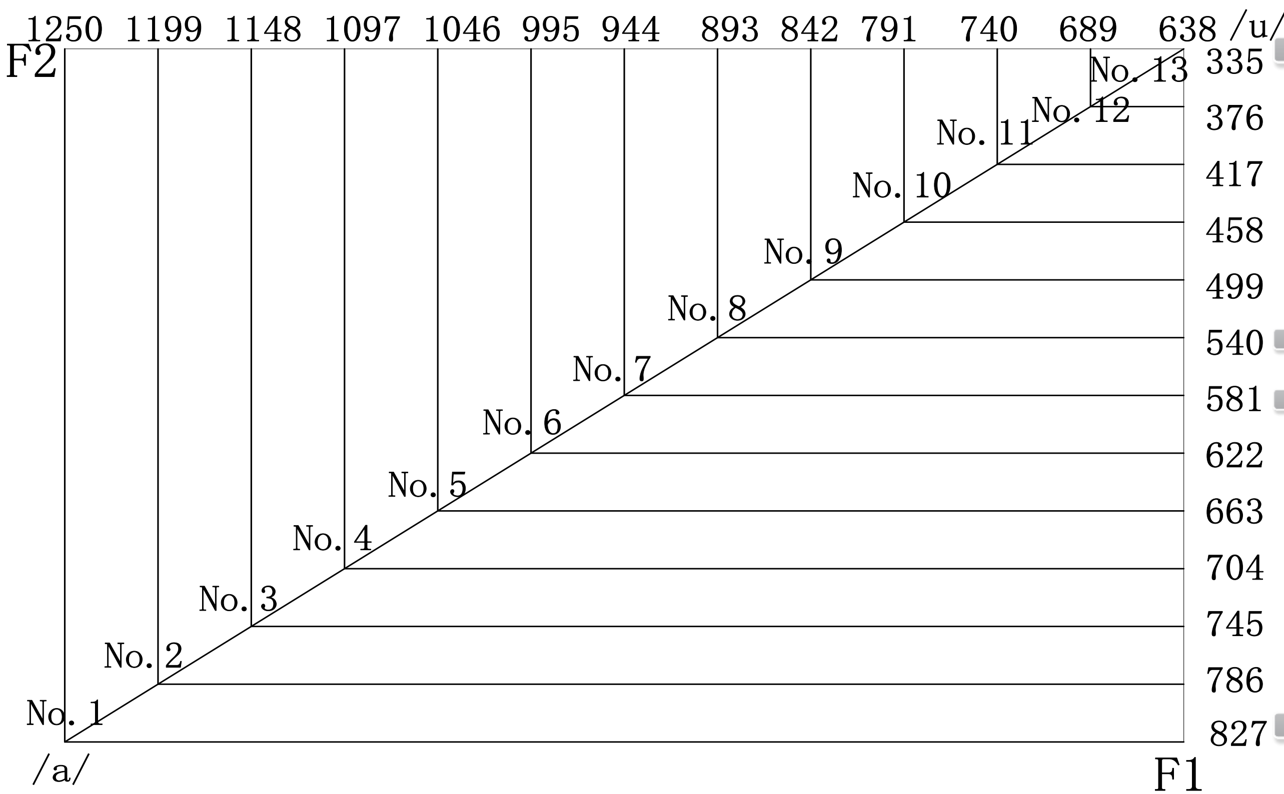
Tones in Mandarin Chinese
(From Wang, 1976)

2.1. Participants

Sixteen volunteers (8 females, M = 21.04 years, SD = 1.08 years) who were born and grew up in Beijing, with Mandarin as native language for both the participants and their parents, were paid for their participation in this study.

All them reported no history of speech or hearing difficulties.

2.2. Materials



Schematic diagram of the vowel stimuli along each continuum.

2.3. Procedure

Identification task AND Discrimination task

Identification task: identify each stimulus presented through a headphone as one of the three categories: /a/, /ɜ/, and /u/;

Discrimination task: decide whether the two stimuli in each pair were the “same” or “different”.

The sequence of these two tasks was counterbalanced among the participants, and all stimuli in both tasks were presented in a random order.

2.4. Data Analyses

Identification data: (I) position of category boundary, (II) width of category boundary, (III) maximum identification score.

I. Two categorical boundary positions were obtained: the crossover point of identification curves between /a/ and /ɜ/, and between /ɜ/ and /u/;
II. The widths of the two categorical boundaries were the linear distance between 25% and 75% of identification percentiles between /a/ and /ɜ/, and between /ɜ/ and /u/;
III. The maximum identification score was defined as the maximum identification percentile for /a/, /ɜ/, and /u/.

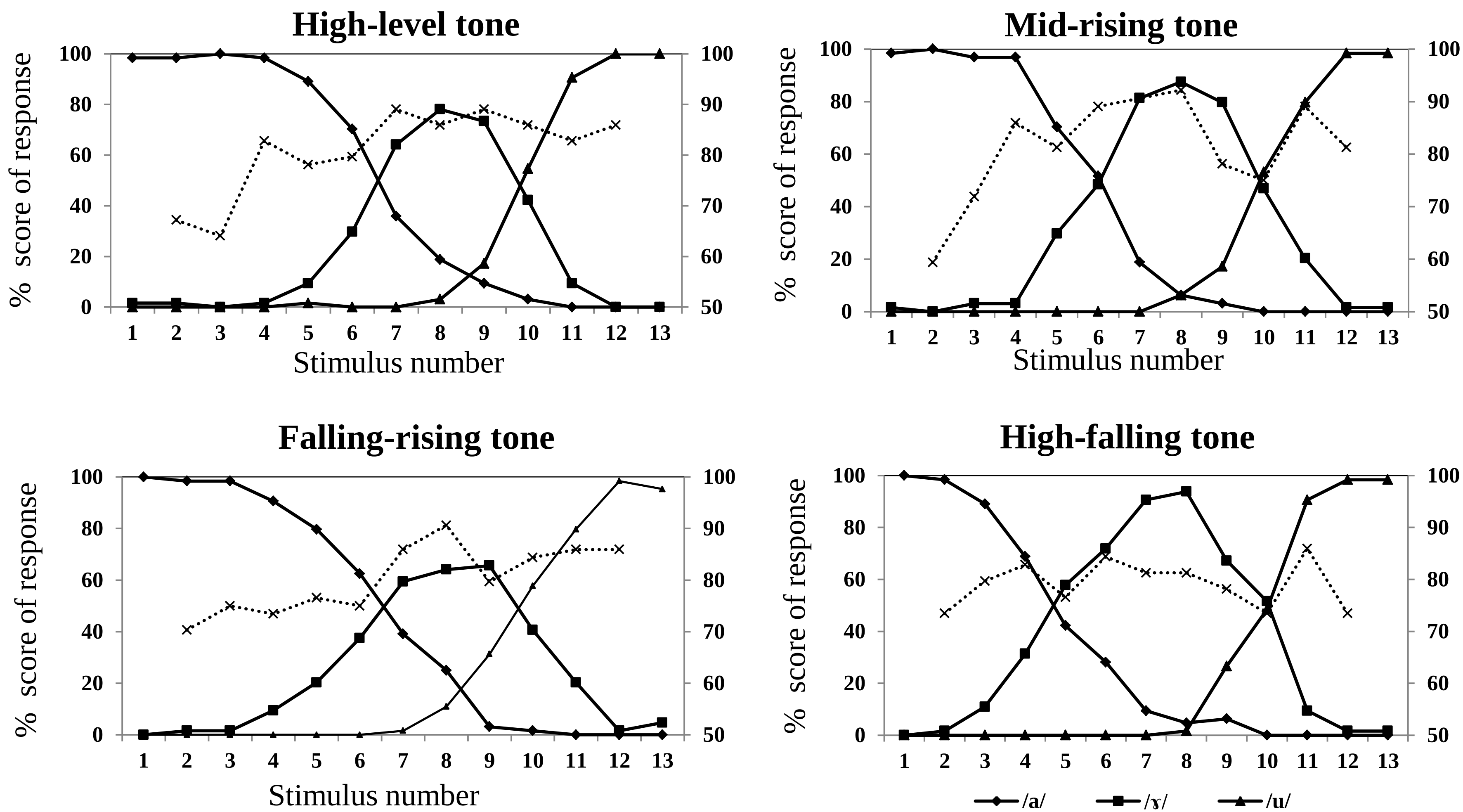
2.4. Data Analyses

Discrimination data: discrimination accuracy.

We divided the discrimination trials into 11 comparison cohorts. The discrimination accuracy (P) for each comparison cohort was counted according to the formula *(cf. Xu et al., 2006)*:

$$\mathbf{P = P(''S''|S) \cdot P(S) + P(''D''|D) \cdot P(D)}$$

3. Results


High-level tone
Mid-rising tone
Falling-rising tone
High-falling tone
% score of response
Stimulus number
/a/
/ɤ/
/u/

3. Results

Tone Category	Position		Width	
	/a/-/ɤ/	**/ɤ/-/u/**	**/a/-/ɤ/**	**/ɤ/-/u/**
High-level	6.59	9.85	1.89	1.36
Mid-rising	6.05	9.91	1.99	1.6
Falling-rising	6.57	9.67	2.73	2.09
High-falling	4.71	10.04	2.47	1.69

Derived categorical boundary positions and widths of /a/-/ɜ/ and /ɜ/-/u/ in each tone category

For boundary positions, ANOVA analysis revealed that the boundary position of /a/-/ɤ/ occurred consistently at a smaller stimulus number under the high-falling tone circumstance than the other three tones ($p < 0.05$).

For boundary widths, pared-samples T test revealed that the boundary width of /a/-/ɤ/ was significantly wider than that of /ɤ/-/u/ ($t(63) = 3.37$, $p = 0.001$).

3. Results

Tone Category	**/a/**	**/ɤ/**	**/u/**
High-level	100%	78.1%	100%
Mid-rising	100%	87.5%	98.4%
Falling-rising	100%	65.6%	98.4%
High-falling	100%	93.7%	98.4%

The maximum identification rate for /a/, /ɤ/, and /u/ under different tone categories

For the maximum identification score, repeated measures ANOVA indicated that the maximum identification scores of /ɤ/ were consistently smaller than the other two Mandarin vowels, and the scores of /ɤ/ under the falling-rising tone were significantly smaller than other tones (all *p*s < 0.05).

4. Discussion

Effects of Tone Categories on Boundary Positions

A higher degree of articulatory discontinuity between phonemes might account for a sharper categorical boundary *(Fry et al., 1962).*

- It is much less prominent for the articulatory transition from /a/ to /ɤ/ in comparison with /ɤ/ to /u/.
- Much narrower boundary widths of /ɤ/-/u/ than /a/-/ɤ/ was detected in this study.

The much sharper categorical boundary of /ɤ/-/u/ might lead to a more stable boundary position which might be immune to the effect of tone categories.

4. Discussion

Effects of Tone Categories on Boundary Positions

F0 could exert significant effects on the vowel perception in terms of F1 boundaries *(Fujisaki & Kawashima, 1968; Traunmüller, 1981).*

Vowels with a full octave change in F0 could lead to about 10% increase in F1 values *(Gottfried & Chew, 1986).*

F0 value of the high-falling tone ranges from the maximum to the minimum, so the dynamic property of the pitch contour for the high-falling tone could result in a lager F1 value of vowels.

4. Discussion

Effects of Tone Categories on the Maximum Identification Scores

The substantial characteristic of the falling-rising tone in Mandarin is low and level *(Shi & Ran, 2011)*.

This low and level pitch counter can lead to creaky voices in articulation, which were manifested by breakages in the pitch counter *(Xu., 2006)*.

The creaky voice could cause damage to acoustic quality of the vowel stimuli under the falling-rising tone condition.

Thus, the maximum identification scores of /ɤ/ under the falling-rising tone were significantly smaller than other tone conditions.

5. Acknowledgements

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Our group

Thank You

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