# Chapter 4

# Perception of word stress

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## 1 Introduction

"When the rain washés you clean, you'll know" sings Fleetwood Mac's Stevie Nicks in the song Dreams (Nicks 1977) and it sounds weird to all speakers of stress-timed languages. The weak second syllable in the trochaic word *washes* is assigned to a downbeat in the music and its musical note is longer and higher than the one on the strong initial syllable of the same word. This lyric set to music violates the Stress to Beat Matching Principle (Halle & Lerdahl 1993): stressed syllables in words should be assigned to strong beats in music in stress-timed languages (cf. also Beckman, 1986; Proto, 2015).

The second example is less clear: "is er leven op Pluto?" ('is there life on Pluto?') is a phrase from the Dutch song België (Temming & Westbroek 1982) by Het Goede Doel. Again, the way in which the trochaic word *Pluto* is set to music violates the Stress to Beat Matching Principle in that the weak syllable *to* is on the downbeat. *To* is also longer than *plu*, but in contrast to *washes* the higher pitch in *Pluto* is on the *first* (strong) syllable. As a consequence, there seems to be no consensus among native Dutch listeners as to whether the sung word is *Plúto* or *Plutó*: a preliminary investigation amongst first-year phonology students for the past 25 years by one of the authors reveals that approximately half of the group of roughly 100 students does not hear anything strange in the text setting, whereas the other half does. This clear

division did not change over the years, and it suggests that listeners may be sensitive to different acoustic cues in their perception of word stress.

Word stress is the emphasis given to a certain syllable in a word. The difference between stressed and unstressed syllables can be expressed by means of pitch, loudness, duration, and/or articulatory effort (Laver 1994), but languages differ widely as to which of these components (and to which extent) they apply. This has led to traditional typological classifications, such as the one into languages with intensity-based *dynamic accent* (also: *stress accent*) and those with pitch-based *melodic accent* (or *pitch accent*; see, e.g., Beckman, 1986, Ladd, 2008),[1] or the rhythm-based classification into syllable-timed and stress-timed languages (Pike 1945), with duration playing a prominent role to tell stressed from unstressed syllables in languages of the latter type.[2]

In this paper, we report the results of a pilot study testing how speakers from typologically different languages identify word stress in the trisyllabic nonsense word *tatata*. Our research question is whether participants from different stress-timed and syllable-timed languages have different preferences for pitch or duration as stress cues.

## 2 Method

We created seven variants of the nonsense word *tatata*. First, the non-word *ta* was recorded, copied and put twice behind the original fragment to create a trisyllabic nonsense word with phonetically identical syllables (called NNN in Table 1). This stimulus was used as a control item to check for language-specific positional preferences. The other six items were created from NNN by manipulating two of the three syllables, one for pitch (P in Table 1) and one for duration (D in Table 1). F0 was raised by 2.3% in P-syllables and duration was increased by 30% in D-syllables. The manipulation was performed in Adobe Audition (version 3.0).[3] Each of the seven different stimuli, shown in Table 1, was presented five times in isolation, i.e. listeners had to judge 35 items in total. Two lists were created in which the items were

[1] Stress accent languages do show pitch movements on stressed syllables, but pitch is not a property of stress in these languages, but a correlate of accent, i.e. pitch has a pragmatic function (such as focus marking) which happens to be realized on stressed syllables.

[2] Due to lack of space, we can only give a very simplified picture here of both the phonetics of stress and the different accent-based typologies. We refer the reader to Grabe & Low (2002) and Ortega-Llebaria & Prieto (2010) for more thorough and detailed discussions of these issues, including recent work on typologies.

[3] The manipulation can be based on just noticeable differences (JND). Of course, JND is listener-specific. Rietveld & van Heuven (2001: 201) claim that the JND for pitch is between 0,3 and 2,5% and for duration at least 10%. Jusczyk, Cutler & Redanz (1993) and Gut (2013), on the other hand, claim that in English the pitch of stressed syllables is 10% higher than the pitch of unstressed ones and the duration of stressed syllables is twice as long as in unstressed syllables. Because of this difference, a pilot study was performed in which different manipulated items were used to find out which minimal manipulation was noticeable for the participants. The results of this pilot study were that differences in pitch of 2,3% and differences in duration of 30% were still audible. Therefore, these norms were being used for the current study.

pseudo-randomized.

Table 1: The seven stimuli created for this study.

| | | |
|---|---|---|
| 1 | Neutral-Neutral-Neutral | NNN |
| 2 | Neutral-Pitch-Duration | NPD |
| 3 | Neutral-Duration-Pitch | NDP |
| 4 | Pitch-Duration-Neutral | PDN |
| 5 | Pitch-Neutral-Duration | PND |
| 6 | Duration-Pitch-Neutral | DPN |
| 7 | Duration-Neutral-Pitch | DNP |

The experiment was conducted in a quiet room at the University of Groningen. The items were presented with PowerPoint 2013 on a laptop screen and audibly presented through headphones. All items could be repeated as often as possible. The participants were asked to identify one syllable in each word as the stressed one and write down their answers on an answer sheet.

## 3 The participants and their native languages

Six participants, aged between 22 and 27 years (mean age: 25), took part in the experiment. They were all exchange students from the University of Groningen with English as their second language (L2), but different native languages (L1): two stress-timed European languages (Dutch, German), two syllable-timed European languages (Spanish, Bosnian-Croatian-Serbian), and two (presumably) syllable-timed "Asian" languages (Mandarin Chinese, Singapore English). We give brief descriptions of the phonetic and phonological properties of stress in these languages below.

Dutch is a stress-timed language with dynamic word stress (Collins & Mees 1984). Sluijter & van Heuven (1996) find duration to be the most reliable correlate of stress in Dutch; overall intensity and vowel quality appear to be weaker cues.[4] Phonologically, stress in Dutch can fall on any of the last three syllables in a word; stress may not fall on the antepenultimate syllable, though, if the penultimate syllable is closed (Kager 1989; van Oostendorp 2012).

German is very similar to Dutch in both phonetic and phonological respects: like Dutch, German is a stress-timed language with dynamic stress, and like Dutch, duration appears as the most important cue for stress perception, followed by pitch,

[4] Intensity in the higher frequency regions of the spectrum (so called 'spectral balance') fares better than overall intensity. Notice that Sluijter & van Heuven do not take pitch (F0) into account "since we take the view that pitch movements are the correlate of accent rather than of stress." (Sluijter & van Heuven 1996: 2473).

intensity, and vowel quality (Jessen et al. 1995; Dogil & Williams 1999). Finally, German words are stressed on one of the last three syllables, with the restriction that the antepenultima may not be stressed if the penultima is closed (Wiese 2000).

Spanish is the prototypical language with a syllable-timed rhythm (e.g. Pike, 1945), and we would thus expect duration to play a minor role for stress at best. Indeed, Quilis (1971) and Llisterri et al. (2003) report pitch as the most prominent cue for the perception of stress in Spanish. Ortega-Llebaria (2006), however, identifies duration as another important cue. For stress in unaccented positions (i.e. without a pitch accent), duration turns out to be the most important cue, a finding that is in line with reports from Sluijter & van Heuven (1996) on Dutch, and Jessen et al. (1995) and Dogil & Williams (1999) on German. As in Dutch and German, the position of stress in Spanish is restricted to one of the last three-syllables: in non-verbs, stress typically falls on the final syllable if closed by a consonant (other than *-s*, *-n*), otherwise on the penultimate syllable (Harris 1992).

Bosnian-Croatian-Serbian (BCS) is usually classified as a syllable-timed language with a melodic accent (Josipović 1994). Yet, Lehiste & Ivić (1986) report increased relative duration as the most reliable phonetic correlate of stress. Pitch is less reliable, presumably because BCS is a pitch accent language (also called tonal accent language or restrictive tone language) and thus pitch has a distinctive function: all words in BCS have one of two melodies, one falling, the other rising, aligned with the stressed syllable[5] (Lehiste & Ivić 1986). So called falling accents reach their tonal peak on the stressed syllable, while rising accents reach them not before the poststressed syllable. As far as phonology is concerned, BCS stress can fall on any syllable but the last. Falling accents only occur on the first (or only) syllable, rising accents on any syllable but the last (i.e. they do not occur in monosyllabic words). Contrasts of falling and rising accents are thereby confined to the first syllable of polysyllabic words (Lehiste & Ivić 1986; Inkelas & Zec 1988).

Mandarin Chinese is a tone language with four lexical tones (Duanmu 2000). The language is said to have a melodic accent (Chao 1968) and a syllable-timed rhythm (Grabe & Low 2002; Lin & Wang 2007). Yet, acoustic studies (Moore 1993; Shen 1993) show that pitch, duration, intensity, and segmental quality all play a role in distinguishing stressed from unstressed syllables in Mandarin: stressed syllables are produced with a higher pitch range (i.e. raised F0 in high-toned syllables, lowered F0 in low-toned syllables, and so on), they are significantly longer, have a greater amplitude, and more peripheral vowels. Moreover, Shen (1993) reports that Mandarin stress can be identified even in the absence of pitch cues, with duration being more important than intensity. As for position, Duanmu (2000) analyzes Mandarin as a language with initial stress and syllabic trochees, built from left to right.

Singapore English (SE) is classified as a syllable-timed language, by Ling, Grabe & Nolan (2000), mainly because vowels in unstressed syllables in SE are much less reduced in both duration and quality compared to stress-timed British English. Still, intensity and duration seem to be the most important phonetic cues to stress percep-

[5] In fact, most researchers assume that tone is primary to stress in BCS, i.e. the position of stress depends on the position of lexical tones (Inkelas & Zec 1988; Zec 1999).

tion, at least for the Chinese ethnic group of SE speakers (Tan 2002), the group our participant belongs to. The position of stress in SE seems to be largely restricted to one of the first two syllables in a word.

Table 2 summarizes the most important stress properties of our six participants' native languages according to the literature.

Table 2: Summary of important stress properties of the six languages.

| Language | Stress- vs. syllable-timed | Dynamic vs. melodic stress | Important cues for stress | Position of the stressed syllable |
|---|---|---|---|---|
| **Dutch** | Stress-timed | Dynamic stress | Duration and intensity | One of the last three syllables |
| **German** | Stress-timed | Dynamic stress | Duration and intensity | One of the last three syllables |
| **Spanish** | Syllable-timed | Melodic stress | Pitch and duration | One of the last three syllables |
| **BCS** | Syllable-timed | Melodic stress | Duration | Any syllable but the last |
| **Mandarin** | Syllable-timed | Dynamic stress? | Duration, intensity, pitch | First syllable |
| **Singapore English** | Syllable-timed | Dynamic stress? | Duration and intensity | First or second syllable |

# 4 Results

The major results of the experiment are summarized in Table 3, Table 4 and Figure 1. Table 3 reports how often our participants perceived which syllable type (lengthened, raised pitch, or neutral) as stressed. As can be seen, the German speaker shows by far the strongest preference for duration (80%), followed by, in descending order, the L1 speakers of Spanish, Singapore English, and Mandarin. The Dutch speaker shows only a slight preference for duration (53.3%, as against 40% for pitch). The BCS speaker is the only participant with a preference for pitch; but at the same time, this preference is also the most distinct of all (93.3%).

The very small share of neutral syllables perceived as stressed proves that our participants did hear a difference; and the fact that the BCS speaker identified higher

pitched syllables as stressed in almost all items proves that raising F0 by only 2.3% *is* perceptible.

Table 3: Perceived stress as a function of different syllable types.

| L1 | Duration | | Pitch | | Neutral | |
|---|---|---|---|---|---|---|
| **Dutch** | 16 | (53.3%) | 12 | (40%) | 2 | (6.7%) |
| **German** | 24 | (80%) | 6 | (20%) | 0 | (0%) |
| **Spanish** | 20 | (66.7%) | 5 | (16.7%) | 5 | (16.7%) |
| **BCS** | 2 | (6.7%) | 28 | (93.3%) | 0 | (0%) |
| **Mandarin** | 18 | (60%) | 10 | (33.3%) | 2 | (6.7%) |
| **Singapore English** | 19 | (63.3%) | 9 | (30%) | 2 | (6.7%) |

Positional preferences for stress can be deduced from the speakers' judgments on the five non-manipulated items (NNN), displayed in Table 4.

Table 4: Perceived stress as a function of position (non-manipulated items).

| L1 | σ1 | σ2 | σ3 |
|---|---|---|---|
| **Dutch** | 1 | 4 | - |
| **German** | 2 | - | 3 |
| **Spanish** | 1 | 4 | - |
| **BCS** | 2 | 2 | 1 |
| **Mandarin** | 3 | - | 2 |
| **Singapore English** | 5 | - | - |

The SE speaker perceived these items consistently with initial stress, the Dutch and Spanish speakers show a strong preference for the second (= penultimate) syllable, our German and Mandarin speakers picked the first or last syllable as stressed, and the BCS speaker shows no preference for a particular position.

The full picture of stress judgments ordered by stimuli and speakers is shown in Figure 1. Starting again with the Dutch speaker (top on page 39), we see that the slight preference for duration over pitch (see Table 3) is unevenly spread over the different stimuli due to an effect of position. Thus, the lengthened syllable is most often perceived as stressed if (a) in second position (third and fifth bar) or (b) in first position with the neutral syllable in second position (second bar). Something similar applies to the higher pitched syllables (see bars 1 and 4), with the notable exception of NPD (bar 6), where a higher pitched σ2 is outranked by a lengthened σ3.

For the German speaker (mid on page 39), duration outranks both pitch and position by far, again with NPD (bar 6) as the one notable exception: contrary to the general trend ('duration rules') and default positions ('stress the first or last syllable'),

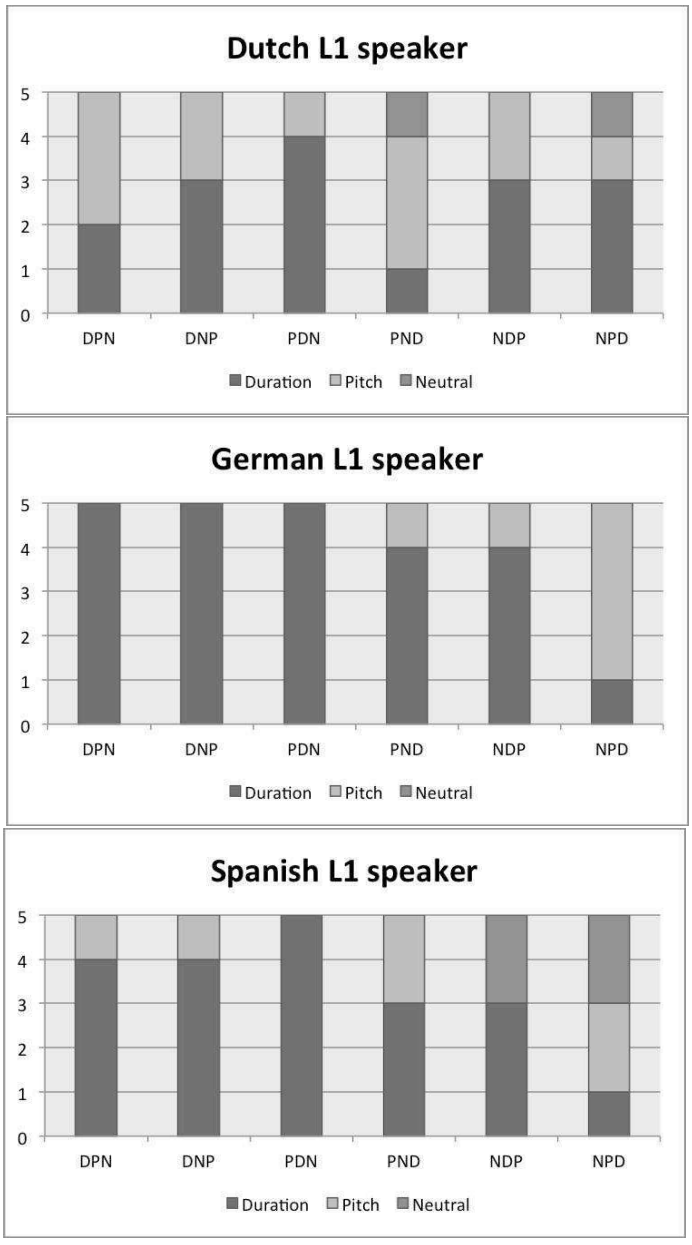


Figure 1: (Continued on page 40.)

our speaker perceived the higher pitched σ2 in NPD (and only there, cf. the first bar) as stressed in four out of five cases.

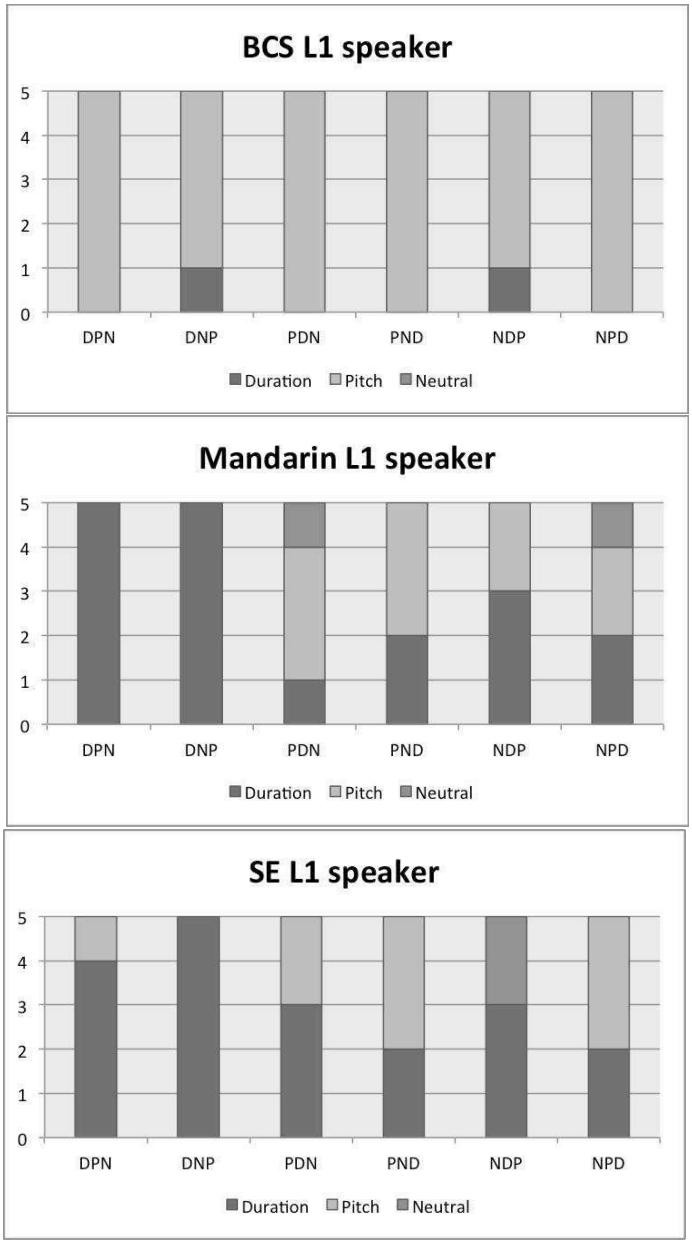


Figure 1: (Continued from page 39.) Perceived stress as a function of syllable types and position.

For the Spanish speaker (bottom on page 39), position shows an effect on the general preference for duration over pitch: lengthened syllables in first position (bars 1 and 2) and second position (bars 3 and 5) are perceived as stressed in 80% of the cases, as against only 40% in final position (bars 4 and 6). Again, NPD (bar 6) differs from the rest in that all three syllable types are perceived as stressed at least once. Finally, the Spanish speaker shows the largest share of neutral syllables (see Table 3); but rather than being randomly distributed between the different items, they only occur with N in word initial position (bars 5 and 6).

The BCS speaker (top on page 40) shows a very strong preference for pitch. If anything, we might infer a very slight effect of position from bars 2 and 5, where our speaker identifies the lengthened syllable as stressed (though only once per category), presumably due to a bias against final stress.

Apart from a solid preference for duration over pitch, our Mandarin speaker (mid on page 40) shows a marked preference for word-initial stress. Thus, lengthened syllables are perceived as stressed to 100% if word-initially (bars 1 and 2), but only to 40% in non-initial positions. Similarly, higher pitched syllables are perceived as stressed to 60% in initial position (bars 3 and 4), but only to 20% non-initially. Notice that position (σ1) and acoustic cue (duration or pitch) have to coincide in order to achieve high scores, in other words: word-initial *neutral* syllables (bars 5 and 6) are barely perceived as stressed.

Finally, the SE speaker (bottom on page 40) shows a pattern similar to the Mandarin speaker: a preference for duration over pitch, and another favoring initial stress ('σ1 > 'σ2 > 'σ3). Compared to Mandarin, duration seems to be a slightly stronger cue in SE, in the sense that lengthened second syllables are still perceived as stressed in 60% of the cases (bars 3 and 5). Pitch scores of 60% are only found with duration in final position (bars 4 and 6).

# 5 Discussion

We expected speakers of stress-timed languages to perceive stress primarily by means of duration, and speakers of syllable-timed languages to rely mainly on pitch differences (because stressed and unstressed syllables should not differ much in duration). German and BCS seem to confirm this hypothesis, but stressed-timed Dutch does not, and neither do syllable-timed Spanish, Mandarin, and SE. As a matter of fact, our brief discussion of some phonetic work in Section 3 has already unmasked the traditional isochrony of stress-timed and syllable-timed languages as an oversimplification; and the same holds for the classification of languages into those with dynamic stress and those with melodic stress.

As regards the actual phonetic properties of stress in our participants' L1, our results confirm reports from the literature on the prominent role of duration for stress in German (Dogil & Williams 1999), Spanish (Ortega-Llebaria 2006), Mandarin (Shen 1993), and SE (Tan 2002). The relatively even distribution between duration and pitch of the Dutch speaker is less in line with the literature (Sluijter & van Heuven 1996), but matches well with the variable reactions to the stress pattern of the word *Pluto*

in "is er leven op Pluto?", mentioned in the introduction. Finally, the BCS speakers' strong preference for pitch goes directly against (Lehiste & Ivić 1986), who found duration to be the most reliable phonetic correlate of stress. We have no explanation for this mismatch. Notice that the equation of higher pitch with stress on the second and third syllable is particularly surprising, given that in BCS higher pitch on a non-initial syllable does *not* coincide with stress, but rather indicates stress on the *preceding* syllable.

The strength of a particular phonetic cue (duration, pitch) for the perception of stress can also be seen in the way it competes with positional preferences. To start with the two extremes, duration in German and pitch in BCS, these cues overrule position by far: words in BCS, for instance, are never stressed on their final syllable, and yet our BCS speaker perceives final syllables with higher pitch as stressed to 80%. The effect of position on phonetic cues is moderate for our Dutch and Spanish participants, and strong for the Mandarin and the SE speaker.

Finally, stress judgments on NNN words (Table 4) show similarities between Dutch and Spanish on the one hand, and German and Mandarin on the other. The marked difference between Dutch and German might come as a surprise; after all, the two languages are closely related and their stress systems are typically analyzed as very similar. Yet, both languages allow (in principle) stress on all three light syllables in a trisyllabic word (Dutch: *Cánada*, *pyjáma*, *chocolá*; German: *Kánada*, *Bikíni*, *Melodié*), and it is thus possible that the Dutch speaker prefers a foot structure with one final syllabic trochee L(ĹL) while the German speaker parses [tatata] into two trochees (LL)(L), with either the first or the second carrying main stress: (L̀L)(Ĺ) or (ĹL)(L̀). It is also possible that the Dutch speaker interprets [a] as a long vowel /a:/ (because short /a/ has a back quality [ɑ] in Dutch), which would increase the likeliness of stress on the penultimate syllable (Gilbers & Jansen 1996).

## 6 Conclusion

We conducted a pilot study to examine how speakers from typologically different languages (Dutch, German, Spanish, Bosnian-Croatian-Serbian, Mandarin Chinese and Singapore English) perceive word stress by means of pitch and duration. Our German speaker relied mainly on duration, the speaker of Bosnian-Croatian-Serbian used pitch almost exclusively. The other participants showed a slight or moderate preference for duration. Our results are (mostly) in line with the phonetic properties of stress in our participants' L1, but *not* with traditional classifications into stressed-timed and syllable-timed languages, thereby confirming earlier criticism of such clear-cut typological categories (Roach 1982; Cauldwell 2002; among many others). Notice, however, that not all our results can be ascribed to the native language of our participants. Since we tested only one speaker of each language, we cannot rule out from the outset that (some of) the differences are a result of *individual* (and thus L1-independent) preferences for one cue over the other. In other words: if speakers of Dutch can be divided between duration and pitch if they receive conflicting cues (as in *Pluto* above), so can speakers of other languages. Future research with more

speakers from each language will help to detangle systematic (i.e. L1-related) effects from possible individual preferences.

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