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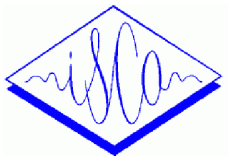

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Functional trade-off between lexical tone and intonation: typological evidence from polar-question marking

Francisco Torreira, Seán G. Roberts, Harald Hammarström

Max Planck Institute for Psycholinguistics, Nijmegen, The Netherlands
Francisco.Torreira@mpi.nl, Sean.Roberts@mpi.nl, Harald.Hammarstrom@mpi.nl

Abstract

Tone languages are often reported to make use of utterance-level intonation as well as of lexical tone. We test the alternative hypotheses that a) the coexistence of lexical tone and utterance-level intonation in tone languages results in a diminished functional load for intonation, and b) that lexical tone and intonation can coexist in tone languages without undermining each other's functional load in a substantial way. In order to do this, we collected data from two large typological databases, and performed mixed-effects and phylogenetic regression analyses controlling for genealogical and areal factors to estimate the probability of a language exhibiting grammatical devices for encoding polar questions given its status as a tonal or an intonation-only language. Our analyses indicate that, while both tone and intonational languages tend to develop grammatical devices for marking polar questions above chance level, tone languages do this at a significantly higher frequency, with estimated probabilities ranging between 0.88 and .98. This statistical bias provides cross-linguistic empirical support to the view that the use of tonal features to mark lexical contrasts leads to a diminished functional load for utterance-level intonation.

Index Terms: tone, intonation, functional load, linguistic typology.

1. Introduction

In traditional linguistic typology, the distinction between tonal and intonational languages is that the former use tonal features to mark lexical contrasts, whereas the latter use them to mark contrasts at the utterance level (i.e. speech acts, communicative attitudes, information structure) [1]. This dichotomy is somewhat misleading in that tonal languages are often reported to make use of intonation as well as of lexical tone. Given this fact, one may wonder to what extent a functional conflict arises between lexical tone and intonation in lexical tone languages. In the present article, we address this question by using typological quantitative methods that allow us to control for genealogical and areal factors.

The possibility that the expressive power of intonation is diminished in tone languages may appear trivial at first sight, given that both lexical tone and intonation employ the same phonetic medium (i.e. pitch) to a large extent. If some or all syllables or morae in an utterance are specified for lexical tone, the phonetic space left to intonational phenomena such as pitch accents and boundary tones will become necessarily constrained, and the utterance-level meanings typically encoded by intonation may require other grammatical devices in order to be expressed. Illustrating this view, for instance, [2] holds that "it is commonplace that many lexical tone languages avoid the potential conflicts between intonation and lexical tone by using a different mechanism altogether: the sentence-final particle."

However, it is also possible that both lexical tone and intonation can coexist in a language without constraining each other's functional loads in a substantial way. Several mechanisms have been reported that allow lexical tone languages to convey utterance-level meaning through intonation. These include changes in global pitch register, changes in pitch range, the suspension and reset of downstep, and the insertion of edge-tones similar to those of intonational languages at the end of utterances (e.g. see references in [2]). In principle, speakers of tone languages could make use of these mechanisms without severely compromising the realization of lexical tone, in the same way that speakers of an intonation language such as English can manipulate global pitch trends and make use of boundary tones without compromising the production of pitch accents associated to words in the utterance. Because of this, there is a possibility that the phonetic space available to intonation in tone languages is sufficient for it to be optimally expressive in everyday language use.

One way of testing whether lexical tone constrains the expression of utterance-level meaning via intonation is by comparing the frequencies with which tonal and intonational languages have developed grammatical devices for expressing utterance-level meanings typically encoded by intonation. If a functional dependency between lexical tone and intonation exists, tone languages should be more likely than intonational languages to develop grammatical devices to encode utterance-level meaning such as particles, word affixes, and changes in word order. On the other hand, if an optimal division of the phonetic space between lexical tone and intonation is often reached cross-linguistically, tonal and intonational languages should exhibit grammatical devices for encoding utterance-level meanings at a similar frequency. In the following sections, we investigate this alternative by examining the grammatical vs. intonation-only encoding of polar questions in a large number of tonal and intonational languages of the world. Polar-question marking provides a reasonable testing ground for these alternative hypotheses, since it is present in the vast majority of languages either through grammatical devices or intonation, and is well documented in typological surveys.

2. Data

Our data come from three sources. First, we identified 307 languages that are coded for both polar-question marking and tone in the World Atlas of Linguistic Structures (WALS) [3]. Polar-question marking in WALS [4] can take one among several values, including question particle (n = 195), interrogative verb morphology (n = 48), mixture of the previous two types (n = 8), interrogative word order (n = 4), absence of declarative morphemes (n = 2), interrogative intonation only (n = 49), and no interrogative-declarative distinction (n=1). As explained in [4], languages assigned a grammatical marking value may or may not use intonation as

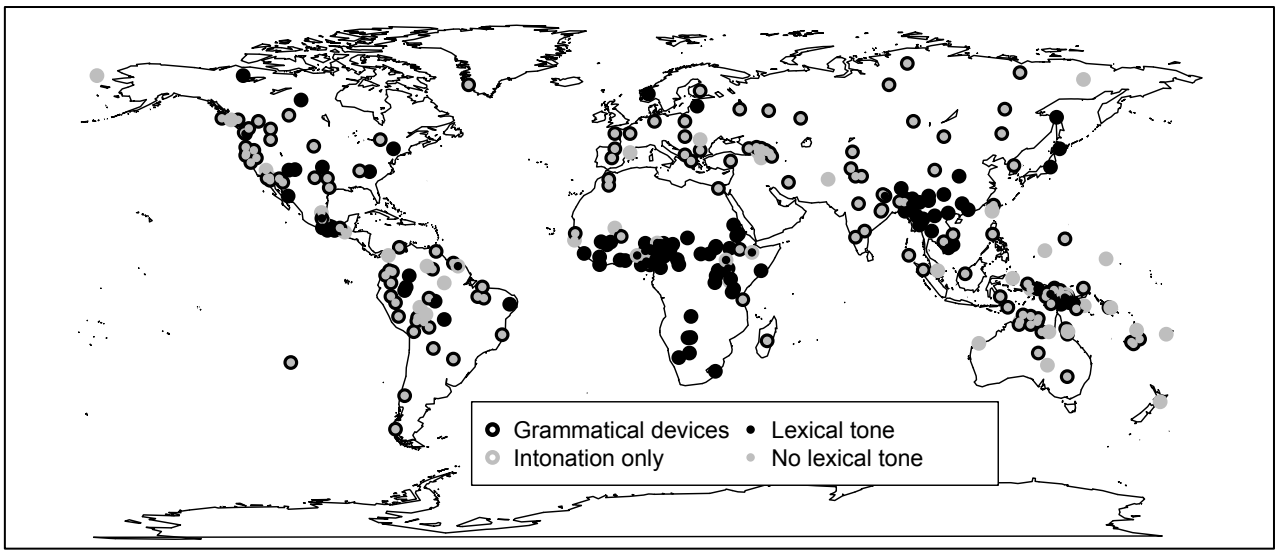

Figure 1: A map of the typological data collected from WALS. Each language is represented by a circle. The inner color denotes whether the language has lexical tone or not. The outer color denotes whether the language uses at least one grammatical device (question particle, variable morphology or word order) or only intonation for marking polar questions. Therefore, tonal languages with grammatical devices for marking polar questions are indicated by an entirely black circle.

well to mark polar questions. These levels were regrouped into two: interrogative intonation only, and grammatical devices. Chalcatongo Mixtec, the only language in the WALS that does not appear to have an interrogative-declarative distinction, was excluded from the dataset. The tone feature in WALS [1] consists of three levels: no tones (n = 184 in our dataset), simple tone system (with two lexical tones; n = 76), and complex tone system (with more than two lexical tones; n = 47).

In order to ensure that our findings are not biased by the specific coding in WALS, we also collected information from the ANU World Phonotactics Database [5], which contains detailed information on the phonemic inventory (including tonemic contrasts) of over 2,000 languages. Matching this database with the languages in WALS coded for polar-question marking provided us with a second dataset of 540 languages.

Assessing statistical patterns in datasets containing related languages may run into Galton's problem. Languages often inherit features from a common ancestor or borrow them from neighboring languages. For this reason, they do not provide independent observations from a statistical point of view, and this may lead to inflated p values and inadequate conclusions. To control for this, we collected information about the linguistic family and genus of each language as recorded in WALS, and about its geographic area according to [6] (i.e. Africa, Eurasia, North America, South America, Papua, and Australia).

We further controlled for genealogical relatedness in a more fine-grained way by using a phylogenetic tree linking all languages in our data based on the linguistic classifications in [6]. Language families were connected by assuming that all language families were 6,000 years old and had a single common ancestor 60,000 years ago. Branch lengths were scaled according to Grafen's method and the model used of the Pagel's lambda correlation structure [7]. Although these are unrealistic assumptions for the history of languages, we believe that this procedure provides a reasonable way of preserving the assumption that each language family is effectively independent while specifying more fine-grained relationships within language families.

3. Results

3.1. Lexical tone and polar questions in WALS

Table 1 below shows the raw number of languages using interrogative intonation only vs. grammatical devices (e.g. question particles, verbal morphology, syntactic inversion) for marking polar questions separated into groups of tonal complexity in our first dataset entirely extracted from WALS. Interestingly, the data is significantly skewed (Fisher's exact test p = 0.0007) towards tone systems using other methods of marking polar questions than interrogative intonation in comparison to non-tonal systems.

As mentioned above, the languages in our dataset do not provide independent observations from a statistical point of view. In order to control for this lack of independence, we fitted a mixed-effects logistic regression model with polar-marking as the response, tonal complexity as a fixed effect, and language family, language genus, and geographical area as random effects using the R package *lme4* [8]. Comparing this full model to a reduced model with an intercept as only fixed effect plus the above-mentioned random effects revealed a statistically significant improvement in fit ($\chi^2(2) = 593.6$, $p < 0.00001$). Adding random slopes for tonal complexity by area did not result in a better fit ($\chi^2(5) = 0.8$, $p = 0.98$), indicating that the relationship between tonal complexity and the grammatical marking of polar questions does not differ among areas in a statistically significant way.

	No tones	*Simple tone system*	*Complex tone system*
Interrogative intonation only	41	6	2
Grammatical devices	143	70	45

Table 1 Number of languages in WALS exhibiting interrogative intonation only vs. grammatical devices for marking polar questions, separated into three groups according to their tonal complexity.

The effect of tone on the probability of having grammatical marking of polar questions was derived from the regression coefficients of the full model. The predicted chance of a language without lexical tone having some grammatical marking of polar questions was 85%, compared to 96% for languages with simple tone systems (z = 2.3, p = 0.02) and 98% for languages with complex tone systems (z = 2.0, p = 0.04). There was no significant difference between the estimates for simple and complex tones (z = -0.7, p = 0.6). In other words, whereas the probability of intonational languages having intonation as their only polar-question marker is fairly low (15%), our model predicts that this even less frequent in lexical tone languages (2-4%).

The previous analysis revealed a statistical correlation between lexical tone and the grammatical marking of polar questions in the world's languages. In this respect, it should be noted that our initial hypotheses about the relationship between lexical tone and the grammaticalmarking of polar questions were theoretically motivated –not informed by a search through all WALS variables. However, spurious correlations between culturally transmitted variables can occur due to the dynamics of cultural evolution [9], making it difficult to assess what the critical level of chance is for our dataset. In order to assess the risk of having found a spurious correlation between lexical tone and the grammatical marking of polar questions in our previous tests, we compared this correlation with the distribution of correlations between interrogative intonation and all other variables in WALS.

We first binarised all the linguistic features in WALS so that every possible contrast between the levels of a feature could be included separately in the test. We then fitted mixed-effects logistic regression models predicting the grammatical vs. intonation only marking of polar questions using each of the binarised features and language family, genus, and area as random factors. Models converged for 922 binary contrasts, providing a distribution of p values. Among these 922 models, the one with lexical tone as the predictor outperformed 97.6% of the other models, indicating that the correlation between the grammatical marking of polar questions and lexical tone is significantly stronger than the vast majority of other possible correlations. Similarly, replacing the dependent variable of grammatical marking of polar questions in the model with other WALS variables resulted in a less significant effect in 97% of the cases (664 comparisons). These results suggest that the correlation between lexical tone and the grammatical marking of polar questions found in our initial analyses is not likely to be spurious.

3.2. Lexical tone in the ANU Phonotactics Database

To ensure that the effects reported above are not due to the precise coding of lexical tone WALS, we also considered the number of contrastive tones in a language as reported in the ANU World Phonotactics Database. A mixed effects model was fit to the data, predicting the presence or absence of grammatical marking of polar questions by the number of tones. The model included random intercepts for language family, genus and geographic region. Including the number of tones significantly improved the fit of the model (log likelihood difference = 5.1, $\chi 2(1) = 13.2$, p = 0.002). For a model with a fixed effect of number of tones and random slopes for number of tones by language families and language genera, greater number of tones correlated with a lower chance of interrogative intonation (z = -2.5, p = 0.01).

We also tested whether the complexity of the tonal system affected the correlation. Compressing the tone range quadratically did not change the qualitative results. Allowing different slopes for simple and complex tone languages did not improve the fit of the model (log likelihood difference = 0, $p \approx 1$). Additionally, the number of tones was not a significant predictor of grammatical marking of polar questions when excluding languages with no tones from the analysis (z = 0.4, p = 0.66). This suggests, as above, that the complexity of the tonal system is not a major factor in this correlation.

3.3. Fine-grained control of phylogeny

In all previous tests, we controlled for the relatedness of languages using classifications of language family and genus. In this subsection we perform a more fine-grained control using phylogenetic generalised least squares regression (PGLS) [10]. This method weights each observation by how closely it is related to others in a phylogenetic tree. As explained in section 2, we used the linguistic classifications from [6] to create phylogenetic trees linking the languages in our two datasets. We then ran two separate PGLS regression models using each of the two datasets. For the first dataset, which consisted entirely of WALS data for 306 languages, the model estimated the probability of intonation-only languages having some grammatical marking of polar questions as 73% ($t(241,241) = 6.32$, $p < 0.001$; model $\lambda = 0.04$, residual standard error = 0.37). This rises to 89% for languages with simple tone systems (t = 2.9, p = 0.004) and 92% for languages with complex tone systems (t = 2.8, p = 0.007). As in our previous analyses, there was no significant difference between simple and complex tone languages (t = 0.34, p = 0.73). For the second dataset, which included ANU tonal codings and WALS polar-question codings for 540 languages, the number of tones in a language significantly predicted the grammatical marking of polar questions ($t(593,591) = -3.95$, p = 0.0004; model $\lambda = 0.16$, residual standard error = 0.38,). As in our previous analysis, the effect disappeared after excluding languages with no lexical tones, indicating that tonal complexity within tone languages does not affect the probability of having grammatical marking polar questions. The estimated probability for intonational languages to exhibit grammatical marking of polar questions was 75% vs. 88% for tonal languages. Our analyses with more fine-grained phylogenetic control therefore confirm our previous findings from mixed-effects regression.

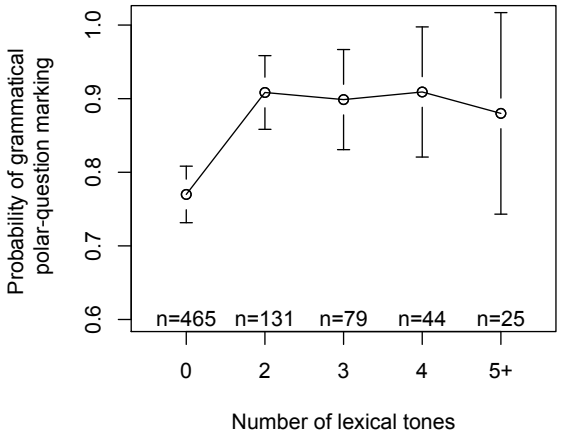

Figure 2: The probability of grammatical polar-question marking as a function of number of lexical tones in our second dataset combining ANU codings of lexical tone with WALS codings of polar question marking (see text for details). Error bars indicate 95% confidence intervals.

	WALS mixed-effects	WALS PGLS	ANU PGLS
Intonational languages	.85	.73	.75
Lexical tone languages	.96-.98	.89-.92	.88

Table 2: Estimated probabilities of exhibiting grammatical polar-question marking for intonational and lexical tone languages according to our three regression analyses (see text for details).

4. Discussion and conclusions

The goal of the present paper was to investigate whether the often reported coexistence of lexical tone and utterance-level intonation in many languages leads to a diminished functional load for intonation. In order to address this question, we collected data from two large typological databases, the World Atlas of Linguistic Structures, and the ANU World Phonotactics Database, and examined whether the probability of a language exhibiting any form of grammatical marking of polar questions (i.e. question particle, verbal morphology, word order) differed between lexical tone and intonational languages. Our rationale was that if lexical tone and utterance-level intonation can coexist within a language without undermining each other's functional loads in a substantial way, the probability of exhibiting grammatical markings for functions typically encoded by intonation, such as polar question marking, should not differ between these two kinds of languages.

The results of all of our tests, which controlled for genealogical and geographic factors, indicate that, while both intonational and lexical tone languages tend to exhibit grammatical markings of polar questions over chance level, lexical tone languages do this at a significantly higher frequency. The estimated probabilities of exhibiting a grammatical marking of polar questions ranged between .73 and .85 for intonational languages, and between .88 and .98 for lexical tone languages (see Table 2 above for a more detailed summary). Our results therefore support the view that lexical tone and phrase-level intonation are in functional dependency.

Another interesting finding arising from our analyses is that tonal complexity (i.e. the quantity of contrastive tones) does not appear to be related to the probability of exhibiting a grammatical marking for polar questions. Tone languages clearly differed in this respect from intonational languages, but tone languages with simple tone systems (i.e. only two tones) did not differ from other tone languages with more complex systems (e.g. three or more tones). One possibility why this is the case is that the number of lexical tonal contrasts available within a language does not necessarily correlate with the amount of phonetic space needed to realize such contrasts in running speech (i.e. at the utterance level). Other tonal properties of languages such as tonal density (i.e. the proportion of tonal bearing units that are tonally specified in running speech) [11] or the positional distribution of tones at the utterance level might be more closely related to the functional load of intonation. Typological surveys including other tonal properties of languages such as these would be needed to investigate this issue in more detail.

In conclusion, our findings support the view that lexical tone languages tend to avoid potential conflicts with utterance-level intonation by making use of grammatical devices encoded with segments. While this view is in no way new in the literature, our study is the first one to lend it cross-linguistic empirical support. Further research taking into account tonal properties of languages other than the number of lexical tones is needed to better understand the functional trade-off between lexical tone and utterance-level intonation.

5. Acknowledgements

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6. References

[1] Maddieson, I., "Tone", in *The World Atlas of Language Structures Online*, ed. M. S. Dryer & M. Haspelmath, Leipzig: Max Planck Institute for Evolutionary Anthropology. (Available online at http://wals.info, Accessed on 2014-02-12.)

[2] Yip, M., *Tone*, Cambridge University Press, 2002.

[3] Dryer, M. S. & Haspelmath, M. (ed.), *The World Atlas of Language Structures Online*. Leipzig: Max Planck Institute for Evolutionary Anthropology. (Available online at http://wals.info, Accessed on 2014-02-12.)

[4] Dryer, M. S., "Polar Questions", in *The World Atlas of Language Structures Online*, ed. M. S. Dryer & M. Haspelmath, Leipzig: Max Planck Institute for Evolutionary Anthropology. (Available online at http://wals.info, Accessed on 2014-02-12.)

[5] Donohue, Mark, Rebecca Hetherington, James McElvenny and Virginia Dawson. World phonotactics database. Department of Linguistics, The Australian National University. http://phonotactics.anu.edu.au. Accessed (accessed 10/02/2014)

[6] Nordhoff, S., Hammarström, H., Forkel, R. & Haspelmath, M. Glottolog 2.2. Leipzig: Max Planck Institute for Evolutionary Anthropology. Available at http://glottolog.org. Accessed on 2013-11-02.

[7] Pagel, M. Inferring the historical patterns of biological evolution. *Nature*, 401,877–884. 1999.

[8] Bates, D., Maechler, M., Bolker, B. and Walker, S. (2013). lme4: Linear mixed-effects models using Eigen and S4. R package version 1.1-0. https://github.com/lme4/lme4/

[9] Roberts, S. G. and Winters, J. Linguistic diversity and traffic accidents: Lessons from statistical studies of cultural traits. *PLoS One*, 8(8):e70902. 2013.

[10] Butler, M. A. and King, A. A. Phylogenetic comparative analysis: a modeling approach for adaptive evolution. *The American Naturalist*, 164(6):683–695. 2004.

[11] Gussenhoven, C. *The phonology of tone and intonation*. Cambridge University Press. 2004.