during periods of nasal breathing. Therefore, I do not expect for vocal fold dehydration to result in more than 0.3 per cent extra uncertainty in pitch production over the range of realistic environments and situations in which speech is used. As the just noticeable difference of pitch in speech is in this range (0.3 Hz at 120 Hz (0.25 per cent) for level pitch, and 2.0 Hz at 120 Hz (1.67 per cent) for falling pitch, Klatt 1973) it is questionable whether such a difference would even be perceivable.

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Commentary: Culture mediates the effects of humidity on language

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Does (the presence or complexity of) tone inversely correlate with dryness of climate? The authors (Everett et al.) suggest that the absence of ambient humidity in the air negatively correlates with the presence of (complex?) lexical tone, partly because of the effect that dry air has to increase the difficulty in achieving precise articulatory targets.

There are two main problems with the argumentation used.

1. Conflating 'tone' with 'pitch' or 'fundamental frequency', and mistaking 'complexity' with a syllable domain for tone assignment;
2. conflating 'dry climate' with the absence of humidity.

The authors are not guilty in an absolute sense of these problems, acknowledging that there are complications. Their reliance on pitch contrasts as a proxy for tonal category contrasts, and the use of air humidity rather than (easily available) climate information for the ranges of different languages means that the authors are dealing with ephemeral correlations between proxy features.

In the next two sections, I will critique the use of tone primarily to refer to distinctions realised by pitch, and the use of humidity as a powerful explanatory for the existence of tone categories.

1. Tone is not simply pitch/fundamental frequency, and complexity is not brevity

The authors acknowledge that 'many non-pitch phenomena are associated with the production of tone, including ancillary laryngealization and duration

Table 1. A non-exhaustive selection of tonal contrasts in Skou

Tone	One syllable	Two syllables	Three syllables
high (H)	'bird' *tang* [˥]	'spine' *køe* [˥ ˥]	'sandfly' *lengbangbang* [˥ ˥ ˥]
Low (L)	'canoe' *tang* [˩]	'fork' *fela* [˩ ˩]	'axe' *rangwa.y* [˩ ˩ ˩]
falling (HL)	'sago' *hø* [˥˩]	'scorpion' *fungli* [˥ ˥]	'vegetable sp.' *apole* [˥ ˥ ˥]
rising (LH)	–	'chicken' *ojing* [˩ ˥]	'earthworm' *pa.a.o* [˩ ˩ ˥]

Table 2. Phonetic correlates of tonal categories in Burmese

	Tones			
	Creaky	High	Low	Stopped
Pitch	High (fall)	High (fall)	Low (rise)	High
Length	Medium	Long	Medium	Short
Phonation	Creaky	(breathy)	Modal	Modal
Vowels	Normal	Normal	Normal	Centralized
Intensity	High	Medium	Low	Very high

influences', but go on to claim that 'the heightened role of F0 (and therefore pitch) in languages with complex tone is evident in the fact that its fine-grained modulation is required on every or almost every syllable, in contrast to pitch accent languages'.

First, this claim reveals some confusion about what tone is. The authors state that 'complex tone' is a category that, following Maddieson (2013), groups languages 'with three or more tonemic contrasts', but does not categorize them according to the domain of tone assignment (e.g. Donohue 1997). If that is so, it is hard to see what it has to do with 'fine-grained modulation is required on every or almost every syllable', since many tone languages that allow three or more contrasts in tone do not contrast tone on a syllable-by-syllable basis (fully 40 per cent of word-tone languages have three or more tonal contrasts) (Hyman 2006; Donohue et al. 2013). This is illustrated with partial data from Skou, a word-tone language from northern New Guinea (Donohue 2003) Table 1. The language has more than two contrasts in tone, yet does not contrast tone 'on every or almost every syllable', any more than do so-called 'pitch-accent' languages (we can observe the restriction on the occurrence of a rising contour on a single syllable).

At the other end of the spectrum, nearly one eighth of syllable-tone languages have less than three contrastive tones (Donohue et al. 2013). It is thus hard to know what the claim is: does the absence of syllable tone correlate with the absence of humidity, or is it the elaboration of tonal contrasts that negatively correlates with the absence of humidity? Globally, syllable tone systems tend to be found in temperate climates with dry winters, rather than areas in which the climate favours high humidity.

More importantly, the claim that pitch plays a 'heightened role' when a language has complex tone is simply ill-founded. The well-known data on Burmese tone Table 2 (e.g. Bradley 1982; Tun 1982; Watkins 2001) reveal a complete intersection of different cues. There are four tones; two are both high, falling in terms of pitch, but differ in terms of phonation (one is creaky, one is breathy) and duration (one is 'normal', one is long). Another tone has the same 'normal' duration, but has modal phonation and a low rising pitch. Modal phonation is also found with a high tone that has a very short duration. Importantly, no one phonetic cue can account for all of the contrasts; there is no sense in which we can state that phonation, or length, or pitch are 'underlying' to the tone contrasts present in the language.

How common is this situation? In some areas of the world, extremely common. A large body of work (e.g. Blicher et al. 1990; Shen and Lin 1991; Yu 2010; Yang 2011; Cao 2012) shows that tonal discrimination in Mandarin, the most populous tone language in the world (with four contrasts and a syllable domain) depends on phonation cues as much as it does on pitch cues. Many other Sinitic languages employ creakiness, breathiness or pharyngealization to discriminate tones, and many Hmongic languages are known to contrast some tonal categories by the use of breathiness in one, creak in another, and modal phonation in yet another (e.g. Andruski 2006).

2. Climate is not humidity

Table 3 shows the correlations between tonality and a number of geographical traits (Alexander and Millington 2000; Peel et al. 2007; Donohue et al. 2013) in different parts of the world (areas following Hammarström and Donohue 2014). The traits were selected on the basis of correlating reasonably strongly with the presence, or number, of tone(s) in languages in each of the different continent-sized regions. We can note, for instance, that a tropical climate correlates well with tonality in Africa and South America ($r = 0.25$ and 0.17, respectively), but while tone is favoured on the

Table 3. Correlations between tonal elaboration and some geographic traits (*r*)

	Africa	Eurasia	North America	Pacific	South America	World
Tropical climate	**0.25**	−0.14	−0.10	0.03	**0.17**	−0.08
Year-long precipitation	−0.09	**−0.16**	0.06	0.06	**0.17**	−0.14
Tropical rainforest	−0.07	**0.18**	−0.13	−0.02	**0.22**	−0.04
Deciduous forest	0.01	−0.07	**0.16**	0.04	−0.03	0.02
Savannah	**0.22**	−0.06	−0.09	0.08	−0.06	0.12
Dry winters	0.03	**0.22**	−0.01	−0.04	−0.06	**0.17**
Altitude	−0.01	**0.15**	0.05	**0.26**	−0.09	**0.17**
n	558	964	345	1,341	392	3,878

African savannah ($r = 0.22$), it is favoured in the tropical rainforest in South America ($r = 0.22$).

Neither of these geographic traits correlate with the use of tone elsewhere in the world, though tropical rainforests are significant in Eurasia ($r = 0.18$). A year-long supply of rainfall, and thus high humidity, favours tonality in South America ($r = 0.17$), but nowhere else is this true; indeed, it is a negative predictor of tone in Eurasia ($r = 0.16$). The best predictor of tonality in Eurasia is the existence of a dry winter ($r = 0.22$), where humidity plummets; similarly, altitude correlates with tonality in Eurasia, and in New Guinea as well ($r = 0.15$ and 0.26, respectively); but nowhere else are these significant factors.

Further continent-specific correlates of tonality include:

Africa: complexity in *contour tones* are associated with languages spoken in tropical rainforests.

Eurasia: *level tones* are associated with higher altitude, and *rising tones* are found in areas of sub-tropical forest.

Pacific: systems with high numbers of *tone contrasts* are associated with swampy environments.

World: *level tones* are associated with areas with dry winters, and negatively correlate with areas subject to year-long precipitation.

3. Society mediates geography

I do not wish to deny the possibility of geographic correlates of linguistic features. There are many such correlations, and as the authors of the article in question themselves explain, these correlations are mediated by social/historical chances. Since it is highly plausible that physical geography can influence historical social movements (and social histories are well known to influence linguistic structure), we will find many indirect correlations between different physical geography (such as location, altitude and, indeed, humidity) and different linguistic features. It is, therefore, social histories that we should be examining, rather than physical geographical ones, in the quest for non-linguistic correlates of linguistic features. The extent of the Angkor Empire in Southeast Asia is a strong predictor of 'core' features of the Southeast Asian linguistic area, and the extent of the Holy Roman Empire correlates with many unusual linguistic traits that are found in north-west Europe.

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Commentary: Considering language as expressive culture

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The Everett et al. (2016) article makes a strong and compelling case that some, if not many, aspects of language may be ecological adaptations to climate. Their argument is not just theoretical, but it is supported by many strands of evidence including careful and systematic worldwide cross-cultural research. The purpose of the present comment is not to detract from the ecological argument, but rather to suggest that linguists would do well to also consider some psychological mechanisms to explain language differences and similarities.

The 'personality integration of culture' model first put forward by John W. M. Whiting and Irvin L. Child (1953) and elaborated further in subsequent years (Whiting and Whiting 1978: 44–45) has inspired many cross-cultural studies. It proposes that some aspects of culture (referred to as 'maintenance systems') respond directly to climate and ecological conditions. Maintenance systems include culture traits such as subsistence patterns, means of production, settlement patterns, family structure, and political and social structures. But there are other aspects of culture referred to as 'projective or expressive systems' (such as religion, rituals, folklore, games, and art, and crime rates) that are probably not adaptive and might best be explained by psychological mechanisms such as generalization, projection, defense mechanisms, or identification. The model is referred to as 'personality integration of culture' because it is believed that the maintenance systems predict the expressive systems via differences in childrearing and resulting differences in modal personality. Although Whiting and Child did not specifically discuss language as part of a culture's expressive system, in my earlier work with Melvin Ember on language, two expectations about linguistic variation were derived from psychological theorizing about music. Both had empirical support in our worldwide cross-cultural tests.

The first hypothesis test was in response to Munroe et al. (1996) finding that languages with more consonant–vowel (CV) syllables are found in warmer