

DIFFERENT PHRASAL PROMINENCE REALIZATIONS IN VO AND OV LANGUAGES

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ABSTRACT: How do infants start learning the syntax of the language they are exposed to? In this paper, we examine a plausible mechanism for the acquisition of the relative order of heads and complements. We hypothesize that the iambic-trochaic law determines the physical realization of main prominence within phonological phrases that contain more than one word: if it is realized mainly through pitch and intensity, it is in a phonological phrase that is stress-initial and has a complement-head structure, otherwise it is in a phonological phrase that is stress-final and has a head-complement structure. We show this to be the case both across languages (French and Turkish), and within a language (German, where both orders of head and complement are found). Our finding allows us to consider a psychologically plausible mechanism for the acquisition of the relative order of heads and complements, one of the basic properties of syntax. Because the mechanism is based on auditory perception, it can be utilized before any knowledge of words, thus accounting for the flawlessness in infants' first words combinations.

KEYWORDS: prosody, rhythm, perception, acquisition, iambic-trochaic law

1. INTRODUCTION

Infants appear to acquire the basic word order of their language of exposure quite early in life: when they start combining words, at about 20 months of age, they hardly make any mistakes in their relative order (Bloom, 1970; Meisel, 1992; Clahsen & Eisenbeiss, 1993). Even earlier than that, at 17 months of age – still at the one-word stage – infants appear to use knowledge about word order in a comprehension task designed to establish the identification of the

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position of subjects and objects. Hirsh-Pasek and Golinkoff (1996) found that infants looked longer at the scene that corresponded to the meaning of the spoken sentence (e.g. “Cookie Monster is tickling Big Bird”) than to one that did not (e.g. a scene showing Big Bird tickling Cookie Monster).

The speed and flawlessness with which children acquire the word order of their language appears to require that they learn this basic syntactic property before they start combining words into phrases. We propose that they do so relying on a law of grouping based on general auditory perception, the Iambic-Trochaic Law (Bolton, 1894; Woodrow, 1951, Cooper & Meyer, 1960; Allen, Hawkins & Morris, 1979; Hayes 1995) and on the Complement Law, that establishes that in a head and complement pair of words, main stress falls on the complement independently of its location, i.e. both in OV and in VO languages (Nespor & Vogel, 1982, 1986/2008; Cinque, 1993; Féry & Herbst, 2004). The Iambic-Trochaic Law, first proposed for musical perception, states that units that differ in intensity are grouped with the most prominent element first and units that differ in duration are grouped with the most prominent element last.

Our specific hypothesis concerns phonological phrase stress. We have tested whether complements are indeed realized differently and found that their prosodic realization depends on their position in the phrase – initial complements are realized mainly through higher intensity as well as higher pitch and final complements are mainly realized with increased duration. We found this pattern across languages – in Turkish (complement-head order) and in French (head-complement order) – and within a single language (German, both orders are possible). Our contribution to linguistic theory is to have established that the realization of prominence within phonological phrases is in agreement with the Iambic-Trochaic Law, with the addition of pitch, when stress is initial. While only intensity characterizes the strong elements of trochaic groups both in music (Bolton, 1894; Woodrow, 1951, Cooper & Meyer, 1960) and in secondary stress in language (Hayes, 1995), higher pitch signals initial prominence at the phonological phrase level. As a consequence, we expect children to be able to use the prosodic properties of phonological phrases to learn the head-complement order in their language.

The speed of the acquisition process and the early achievements of children in the syntax of their language would be better understood if at least the basic word order could be acquired prelexically, before infants have segmented the speech stream into words. Importantly, in order to explain why children hardly make any mistakes when they start combining words into phrases, word order must be learned before they know the meaning of words.

In order for a syntactic property to be learned prelexically, the trigger should be a clearly perceptible cue contained in the signal, since, presumably, the only language specific information available to infants is that contained in the sounds they are exposed to. It has, in fact, been proposed that the order of heads and complements – the head-complement parameter in the genera-

tive tradition (Chomsky, 1981) – could be learned on the basis of phonological properties of the speech stream. Nespor, Guasti and Christophe (1996) proposed that infants might exploit the location of prominence (stress) at the phonological phrase level, since this signals the relative order of heads and complements. Complement-head (CH) languages are stress initial and head-complement (HC) languages are stress final (Nespor & Vogel, 1986/2008).

Christophe, Nespor, Guasti, and van Ooyen (2003), used the nonnutritive sucking paradigm to show experimentally that infants of 6 to 12 weeks of age are indeed sensitive to this prosodic information: they can discriminate sentences from two languages with different orders of heads and complements, specifically, Turkish (complement-head) and French (head-complement). The material of the experiment consisted of sentences in the two languages matched for syllable type and word stress location, spoken in as natural a way as possible by native speakers. In order to preserve prosodic structure while at the same time eliminating other phonetic differences between the two languages, the sentences were resynthesized so that they were all pronounced by the same voice, and delexicalized, so that no segmental information was recoverable. The only difference between the utterances in the two languages was thus the location of prominence in the phonological phrase, leftmost in Turkish and rightmost in French (Christophe et al., 2003). The conclusion drawn from that experiment was that infants might use the location of phonological phrase stress – either at the left or at the right edge – to set the head-complement parameter.

This conclusion is based on the assumption that infants are able to segment the speech stream into phonological phrases: only then is the localization of stress within such phrases possible. In fact, if phonological phrase boundaries are not identified, the child would still not know if in a sequence of phonological phrases comprising one strong (s) and one weak (w) word, such as *s w s w s w s w s w*, the strong element is initial or final. It has, however, not been demonstrated that infants as young as 6-12 weeks are sensitive to phonological phrase boundaries.

Notice that the infant cannot rely exclusively on the prominence of utterance-initial or final syllables, because these will not necessarily correspond to branching phonological phrases (that is, phonological phrases with at least two phonological words). Since it is the relative prominence inside a phonological phrase with at least two stressed elements that is of importance to our hypothesis, utterance boundaries might not be informative without knowledge of phonological phrase constituency.

In this paper, we hypothesize that the physical manifestation of prominence within phonological phrases may aid the infant in the identification of their nature: if pitch and intensity are stronger on the same syllable, then the phonological phrase is trochaic (strong-weak); otherwise it is iambic (weak-strong). It is not necessary to detect the phonological phrase boundary itself:

the type of stress signals whether the boundary precedes or follows it. According to this hypothesis, grouping is trochaic even when pitch, intensity and duration are all stronger on the same syllable. If, instead, only intensity and duration are stronger on the same syllable, grouping is iambic. There are no cases, we hypothesize, in which longer duration and higher pitch coincide to mark the most prominent element, without a higher intensity. Prominence is, in fact, characterized as a higher degree of articulatory energy used in producing a stressed unit (e.g. Crystal, 1991).

Given the Complement Law, with the unmarked intonation typical of broad focus declarative sentences, in a complement–head pair of words, stress is always on the complement, irrespective of the order of the elements. Thus its physical manifestation indicates the relative order of head and complement.

Infants as young as 6 months are able to segment phrasal units on the basis of prosody (Soderstrom, Seidl, Kemler Nelson & Jusczyk, 2003). In addition, phonological phrase boundaries have been shown to affect lexical access by English-learning infants of 10 and 13 months of age (Gout, Christophe & Morgan, 2004). Our proposal, to be further checked experimentally, would constitute yet another cue to segmentation and, given infants' sensitivity to differences in pitch and duration (Trehub, 2003) even at the age of 4.5 months (Krumhansl & Jusczyk, 1990; Jusczyk & Krumhansl, 1993), it could allow very young infants to identify phonological phrases. Most importantly, it would signal the complement in a head-and-complement pair of words.

The iambic-trochaic law, on which our proposal is based, appears to be a general principle of the human auditory system, applying even to non-linguistic stimuli (Bolton, 1894; Woodrow, 1951; Cooper & Meyer, 1960; see also Jusczyk & Krumhansl, 1993).¹ If our proposal is on the right track, one of the basic properties of syntax can be learned through a general mechanism of perception.

The hypothesis that higher pitch induces a grouping in which the most prominent element is initial and increased duration induces a grouping in which the most prominent element is final has been empirically confirmed in a recent study. When habituated with a sequence of words that differ only in pitch, adult participants group them with the prominent element at the beginning of a phrase; if the difference is in duration, the prominent element is taken to be phrase-final instead (Bion, Peña & Nespor, submitted). Empirical confirmation has also been reached for trochaic grouping marked by intensity and for

¹ Iversen, Patel and Ohgushi (2006) found that English and Japanese speakers do not group sequences of tones in an identical way: while they both form groups beginning with higher tones, only English speakers form groups with longer final tones. They propose that linguistic rhythm influences the general perception of rhythm. Whether the iambic-trochaic law is a general human principle or is influenced by linguistic rhythm deserves further investigation. In either case, since our proposal concerns the first steps of language acquisition, a specific language cannot yet have an influence on rhythmic perception.

iambic grouping by duration and it has been shown to reflect a general auditory bias, in that it is found both with linguistic and non-linguistic stimuli (Hay & Diehl, 2007).

In order to verify our hypothesis that the realization of phonological phrase stress depends on where it occurs in the phrase, we constructed comparable phrases in Turkish (CH) and French (HC), the first containing a postposition and a word, and the second a preposition (or a prosodically equivalent item) and the same word. These languages were chosen because word primary stress, when realized, is word final (among others, Grammont, 1934; Kabak & Vogel, 2001; Kabak, 2006),² so that it is possible to find words, mainly borrowings from one language into the other, that are pronounced in much the same way, like *cognac*, borrowed in Turkish from French, or *kilim*, borrowed in French from Turkish. We measured pitch, intensity and duration for the prominent vowel of each word in both languages in order to identify their relative prominence. It will be seen that indeed prominence is marked relatively more by both pitch and intensity in Turkish³ and that it is marked mainly by duration in French.

At this point we cannot yet conclude that the specific phonetic realization of iambic and trochaic prominence at the phonological phrase level is generally associated to head–complement and complement–head languages respectively. Empirical confirmation of our hypothesis for different languages is needed. A good additional pair of languages would be formed by languages with initial word stress and opposite values for phonological phrase stress, since phonological phrase final lengthening would not add to lengthening due to prominence. In fact, though lengthening in phonological phrase final position is not universal (Cambier-Langeveld, 2000), it does exist in many languages. If such languages have word-final stress, then the lengthening on the last syllable of a phonological phrase-final word will be enhanced due to the additive contributions from word-final and phonological phrase-final stress.

We have not examined pairs of languages with initial word stress and opposing phonological phrase stress. We have, however, data from German, a language that (for different syntactic reasons) has both head-complement and complement-head surface orders in verb phrases and adpositional phrases. According to our hypothesis, prominence should be realized in different ways, reflecting the relative order of head and complement in each specific case. A general perception mechanism would thus lead the infant exposed to such a language to learn when complements precede and when they follow their head.

² The presence of some exceptions in Turkish, e.g. *Istanbul*, with penultimate stress, is not relevant to the present proposal.

³ It should be recalled that the level of stress we are considering is that assigned within phonological phrases. It is not the intonation peak, which in Turkish occupies the preverbal position (cf. Kornfilt, 1997).

In order to verify this hypothesis we constructed sentences that were identical except for the relative order of object (O) and verb (V): in some sentences the order was OV, in the others VO. In both cases, we measured the prominence of the stressed syllable of the object. Importantly, we only have objects with initial stress, so that any possible confound due to final lengthening is eliminated. In fact, in German (as in many languages), domain final lengthening is mainly realized on the final syllable (cf., among others, Kohler, 1983, who found that domain final lengthening is 87% – 176% on the final syllable but only 15% – 31% on the penultimate syllable with main lexical stress). We found that phrasal prominence on the object is indeed realized more with pitch and intensity when the object is preverbal and more with duration when it is postverbal.

We believe our German data are even stronger evidence in support of our hypothesis than an additional pair of languages could provide, since a different realization of prominence can only be due to the inversed relative prominence within phonological phrases.

How do we know that infants pay attention to phonological phrase prominence rather than to another level of prominence, for example to primary or secondary lexical (word) stress, which can also be either trochaic or iambic? First of all, phrasal prominence is much more audible than word stress. Second, it has been shown that when adults are asked to mark the prominent elements they hear in utterances of a language that they are not familiar with, this is exactly the level they mark (den Os, 1988). We assume that infants also pay attention to this most audible level of prominence.

2. FRENCH AND TURKISH MEASUREMENTS

The goal of this paper is to uncover the specific phonetic realization of the prosodic cues that signal the relative order of heads and complements. Our specific interest is motivated by the fact that infants are very sensitive to prosody and might thus exploit these cues to set the head-complement parameter at the prelexical stage. This section is dedicated to an analysis of such cues in French and Turkish.

2.1 *Material and methods*

2.1.1 Preparation of the material

In order to uncover the physical realization of phonological phrase stress in Turkish and French, we identified a set of lexical items common to both French and Turkish. These key words varied in the number of syllables (bisyllables vs trisyllables) and the type of stressed vowel (/a/ vs. /i/), as shown in Table 1. All words end in a closed stressed syllable, usually with a sonorant in the

coda and are pronounced similarly in both languages (with the exception of *machiniste* – /maʃinist/ in French and /makinist/ in Turkish).

We created a corpus of branching phonological phrases in which these target words occur as complements of a prepositional phrase (in French) and a postpositional phrase (in Turkish).⁴ For the lexical items with an /a/ stressed vowel, these were “*grâce à COMPL*” (‘thanks to COMPL’) for French, and “*COMPL kadar*” (‘as the COMPL’) for Turkish. For the lexical items with an /i/ stressed vowel, these were “*à partir du COMPL*” (‘from COMPL’) for French, and “*COMPL için*” (‘for the COMPL’) for Turkish. The adpositions are also as close as possible in the two languages with respect to number of syllables and syllabic structure. They are however not identical in these respects since, given the small repertoire of adpositions in each language, perfectly matched items do not exist.

We thus constructed additional material for French in which the prepositions are substituted with well-matched items with respect to vowel type, the number of syllables and the structure of the stressed syllable. Crucially, these items are prosodically identical to prepositions though they are not prepositions. Notice, in fact, that in head-complement languages, words that precede a lexical head within the same maximal projection are prosodically all weak nodes in a phonological phrase (Nespor & Vogel, 1986/2008). From the point of view of the prelexical infant, a preposition, a specifier, or a prenominal adjective are identical. The lexical items with an /a/ as the stressed vowel were “*pour chaque NOUN*” (‘for every NOUN’) in French, and “*NOUN kadar*” (‘as the NOUN’) in Turkish. The lexical items with an /i/ as the stressed vowel were “*antique NOUN*” (‘ancient NOUN’) in French, and “*NOUN için*” (for the NOUN) in Turkish. In both languages, the weak element of the phrase is bisyllabic, and its final syllable is stressed, closed, and has the same vowel as the stressed syllable of the noun.

Since the pattern of results for the two sets of French phonological phrases were comparable, we report the experiment only for the well-matched set of French phonological phrases.

These branching phonological phrases were embedded in a comparable frame sentence in each language (*Türkçe’de denir*, ‘In Turkish. . . is said’; *En français se dit*, ‘In French. . . is said’), as in the following examples:

- (1) Türkçe’de **kilim için** denir (Turkish)
 ‘In Turkish **for the kilim** is said’
- (2) En français **antique kilim** se dit (French)
 ‘In French **ancient kilim** is said’

⁴ Ideally, the material should consist of verb-object and object-verb pairs of words, for French and Turkish, respectively. Duration would in fact be more reliable, since verbs, unlike adpositions are not reduced. It was however impossible to construct such material for language specific lexical reasons.

In both languages, the sentence frames are very similar; in particular, they have the same number of syllables and the same stress pattern.

	Bisyllabic		Trisyllabic	
	/i/ in target	/a/ in target	/i/ in target	/a/ in target
French	kilim, civil	moral, cognac	crocodile, machin- iste, magazine	radical, capitale
Turkish	kilim, sivil	moral, konyak	krokodil, makinist, magazin	radikal, kapital

TABLE 1: The set of words used in the two languages. Despite differences in orthography, the words are pronounced in a similar manner in the two languages.

We obtained a total of 9 sentences in French and 9 in Turkish (refer to the Appendix for the complete list of sentences).

2.1.2 Recordings

The sentences were presented in randomized order to four French and four Turkish speakers naïve as to the purpose of the experiment (two males and two females for each language), who were recorded with professional equipment in a quiet room in Trieste and in Istanbul, respectively. We instructed the speakers to read the sentences in a natural way at their normal speech tempo and to repeat each sentence three times (for Turkish) and twice (for French). All the test phrases were pronounced as exhaustive well-formed phonological phrases.

2.1.3 Analysis

All sentences were stored as separate audio files. After discarding several files due to recording or pronunciation errors, we obtained a final corpus of 93 files for French and 205 files for Turkish. The difference is largely due to the greater number of repetitions of each sentence in Turkish.

PRAAT (Boersma, 2001) was used for the segmentation and analysis. For all the files, the entire sentence, the stressed syllables, and the vowels of the stressed syllables were marked on separate TextGrid tiers. The stressed syllables were the last syllable of the adposition and of the noun in both languages. A PRAAT script extracted the following variables for all sentences:

- The duration of the entire sentence and the duration of both vowels.
- The mean pitch for the entire sentence and for both vowels.
- The pitch peak inside both stressed syllables.
- The intensity of the entire sentence and of both vowels.

The values of all four variables for the two vowels – the duration, mean pitch, pitch peak and mean intensity – were normalized by the corresponding

values for the entire sentence. This allows us to better compare these values across speakers and languages.

All statistical analyses were carried out using Data Desk 6.2 for Mac OS X (Data Description, Inc.). Preliminary analyses indicated that most of the variance in the data for the four variables was accounted for by the factors Language (French or Turkish) and Position (first or second vowel). Note that the variable 'Position' implicitly codes for HC or CH structures. Thus, while in French the first position corresponds to the head and the second to the complement, the opposite is the case for Turkish.

Thus, for each variable, the data was divided into four (Language X Position) groups. For each group, values equal to or greater than the mean + 3 S.D. and values equal to or smaller than the mean - 3 S.D. were removed. In all cases, no more than 2% of the data were removed. Finally, values for the four measurements were collapsed across repetitions, and across the word categories, corresponding to the eight (Language X Vowel X Number of Syllables) cells in Table 1.

The resulting data was analyzed in a full factorial MANOVA, using the Wilks Lambda Criterion for multivariate tests. The dependent variables in the MANOVA were the normalized values for Intensity, Duration, Pitch Peak and Mean Pitch. The independent factors were Language (French or Turkish), Position (first or second), Vowel (/i/ or /a/) and Number of Syllables (bi or tri). The speakers were entered as a random factor.

Results for the four dependent variables of interest were computed in separate univariate ANOVAs nested inside the MANOVA. For clarity, results are presented for the main factors and the interaction of primary interest, that between Language and Position. Effect sizes, where relevant, are presented as the partial η^2 . The Scheffe test was used for relevant post-hoc comparisons.

We also compared the absolute differences between the vowel in the first and the second position for the four measurements using univariate ANOVAs nested in a MANOVA. Thus, the dependent variables were the absolute differences between the first and the second vowel in the phrase for the four measurements - the normalized values for Intensity, Duration, Pitch Peak and Mean Pitch. The independent factors were Language, Vowel and Number of Syllables. Only results from main factors and two-way interactions were considered.

2.2 Results

Overall, the MANOVA for the values for the two syllables (in head and complement position) considered separately showed significant effects for all the main factors, Language ($\Lambda=0.051$, approximate $F(4,3)=14.0$, $p=0.028$), Position ($\Lambda=0.017$, approximate $F(4,3)=42.5$, $p=0.006$), Vowel ($\Lambda=0.013$, approximate $F(4,3)=58.1$, $p=0.004$) and Number of Syllables ($\Lambda=0.074$, approximate

$F(4,3)=9.43$, $p=0.048$). Below, we report the analysis separately for the four measurements from the univariate ANOVAs.

The MANOVA for the absolute difference between the first and second syllables in each phonological phrase showed no significant effect for all three variables, although there was a trend towards significance for the factor Vowel ($\Lambda=0.093$, approximate $F(4,3)=7.36$, $p=0.066$) and Language ($\Lambda=0.115$, approximate $F(4,3)=5.76$, $p=0.091$). The results from the univariate ANOVAs of interest are described below.

2.2.1 Intensity

Figure 1 shows the normalized intensity values for the vowel in the first and the second stressed syllable in the phonological phrase in French and in Turkish. Note that in this and all subsequent figures, the box represents the 95% confidence limits of the mean; the central horizontal line represents the mean. The whiskers indicate ± 1 S.D. of the data.

There was no main effect of Language, $F(1,354) = 0.69$, $p = 0.44$ or of Number of Syllables, $F(1,354) = 0.037$, $p = 0.85$. However, there was a significant effect of both Position, $F(1, 354) = 8.32$, $p = 0.028$, partial $\eta^2 = 0.113$ and Vowel, $F(1, 354) = 82.53$, $p \leq 0.0001$, partial $\eta^2 = 0.379$.

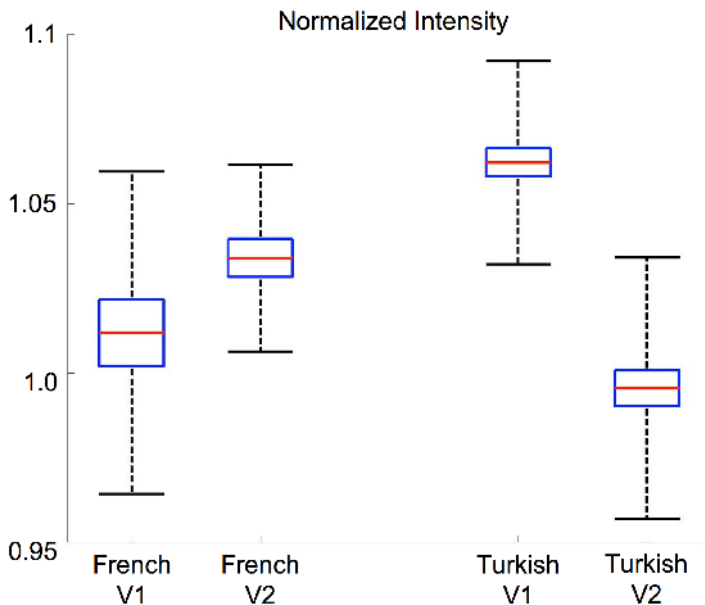


FIGURE 1: Normalized intensity values for the first (V1) and second (V2) stressed vowel in French and Turkish. Boxes: 95% limits of the mean (horizontal line), whiskers: ± 1 S.D.

Coming to the interaction of interest, there was a significant Language X Position interaction, $F(1,354) = 53.25$, $p = 0.0003$, partial $\eta^2 = 0.449$. Post-hoc tests revealed the following pattern: for Turkish, the first vowel (V1) had a significantly greater intensity than the second, $p = 0.00015$, while for French, the second vowel (V2) had a significantly greater intensity than the first, $p = 0.033$. Thus, the stressed vowel of the noun, i.e. the complement position, shows a greater intensity than the stressed vowel of the head position, or the prosodically equivalent weak element in both languages.

Comparing across languages, we find that the Turkish vowel in the complement position (Turkish V1) has a significantly higher intensity than the French vowel in the complement position (French V2), $p = 0.034$.

In Figure 2, the absolute differences in intensity of the two stressed vowels in each phonological phrase are shown separately for French and Turkish.

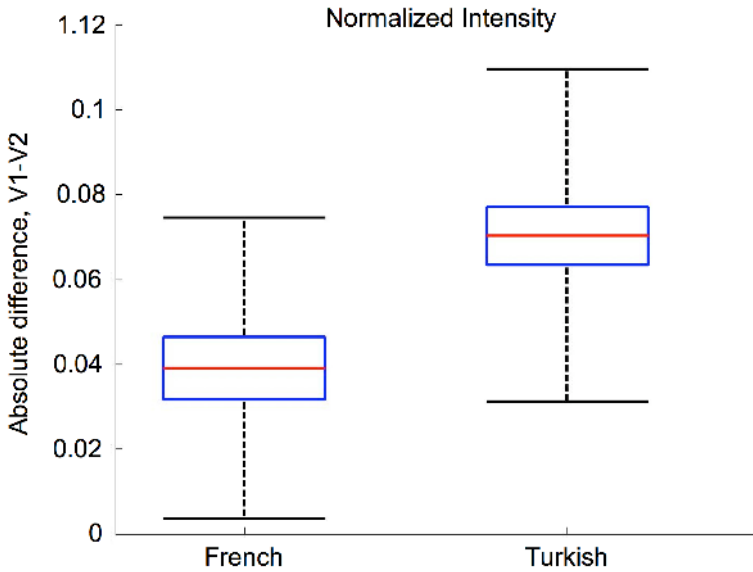


FIGURE 2: Absolute difference in normalized intensity between the two stressed vowels in French and Turkish. Boxes: 95% limits of the mean (horizontal line), whiskers: ± 1 S.D.

From Figure 2, it can be seen that the difference in intensity between the two stressed vowels in each phonological phrase is greater in Turkish than in French. However, this difference is not significant overall, $F(1,249) = 2.32$, $p = 0.18$, partial $\eta^2 = 0.097$; but (in a post-hoc test) is significant for the vowel /a/ alone, $p = .025$.

2.2.2 Duration

Figure 3 shows the normalized durations of the first and the second stressed vowel in French and in Turkish.

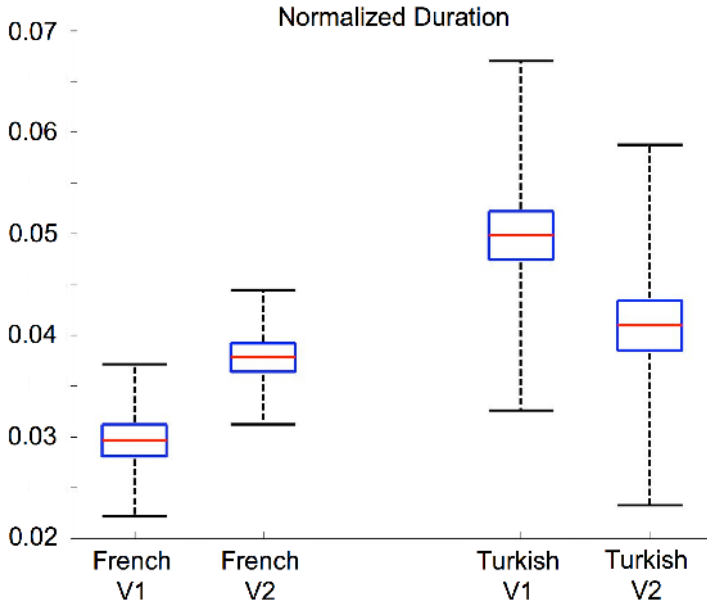


FIGURE 3: Normalized values for the duration of the first (V1) and the second (V2) stressed vowels in French and Turkish. Boxes: 95% limits of the mean (horizontal line), whiskers: ± 1 S.D.

The univariate ANOVA for the two syllables separately showed a significant main effect of Language, $F(1,354) = 29.49$, $p = 0.002$, partial $\eta^2 = 0.436$, Vowel, $F(1,354) = 51.597$, $p = 0.0004$, partial $\eta^2 = 0.55$, and Number of Syllables, $F(1,354) = 15.3$, $p = 0.008$, partial $\eta^2 = 0.067$. The factor Position was not significant ($p > 0.8$). Thus, overall, Turkish vowels were longer than French vowels, the vowel /a/ was longer than /i/, and the vowel in bisyllables was longer than the vowel in trisyllables.

Turning to the interaction of interest, there was a significant Language X Position interaction, $F(1,354) = 25.31$, $p = 0.0024$, partial $\eta^2 = 0.204$. Post-hoc analyses indicated that for French, the second vowel (V2) was longer than the first, $p = 0.024$, while for Turkish the first vowel (V1) was longer than the second, $p = 0.005$. Thus, in both languages, the vowel in the stressed syllable in the complement position was longer than its counterpart in the head position. Comparing across languages, the Turkish vowel in the complement position (V1) was significantly longer than the French vowel in the complement position (V2), $p < 0.001$.

Figure 4 shows the absolute normalized difference in duration between the two target vowels in each phonological phrase in French and in Turkish.

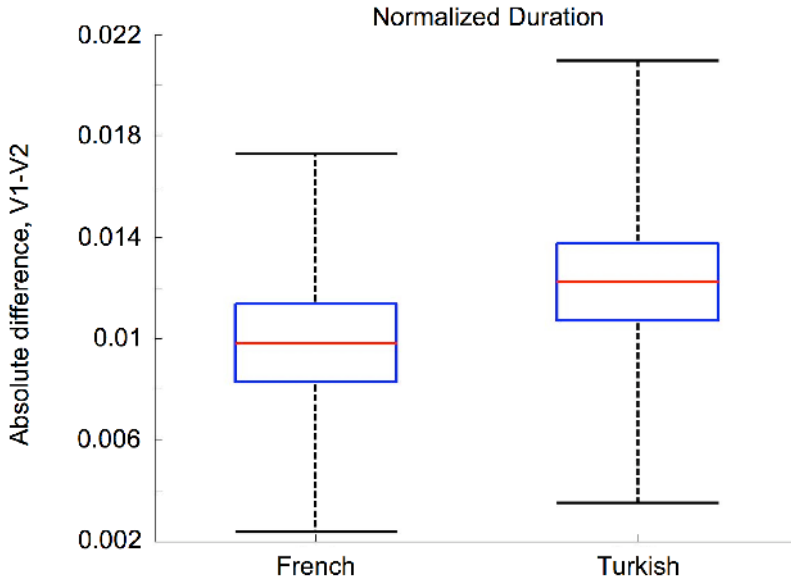


FIGURE 4: Absolute differences in normalized duration for the two target stressed vowels in French and Turkish. Boxes: 95% limits of the mean (horizontal line), whiskers: ± 1 S.D.

An ANOVA revealed that the slightly greater difference in duration between head and complement in Turkish phonological phrases as compared to French is not significant ($p = 0.19$).

2.2.3 Pitch Peak

Figure 5 shows the normalized value for the pitch peak in the first and the second stressed syllable in French and in Turkish.

There was a main effect of Language, $F(1,354) = 19.97$, $p = .0042$, partial $\eta^2 = 0.113$ and Position, $F(1,354) = 94.84$, $p \leq 0.0001$, partial $\eta^2 = 0.435$. The factors Vowels and Number of Syllables were not significant (both $p > 0.6$). It was seen that, collapsing head and complement positions, the overall pitch peak on the vowel was higher in French than in Turkish, and, considering the two languages together, the peak in the first syllable was higher than the peak in the second. Notice that in French, this high pitch does not correspond to phrasal stress, but is a language specific initial rising pitch movement, usually called *accent initial* (Pasdeloup, 1990; Jun & Fougeron, 2002). Such

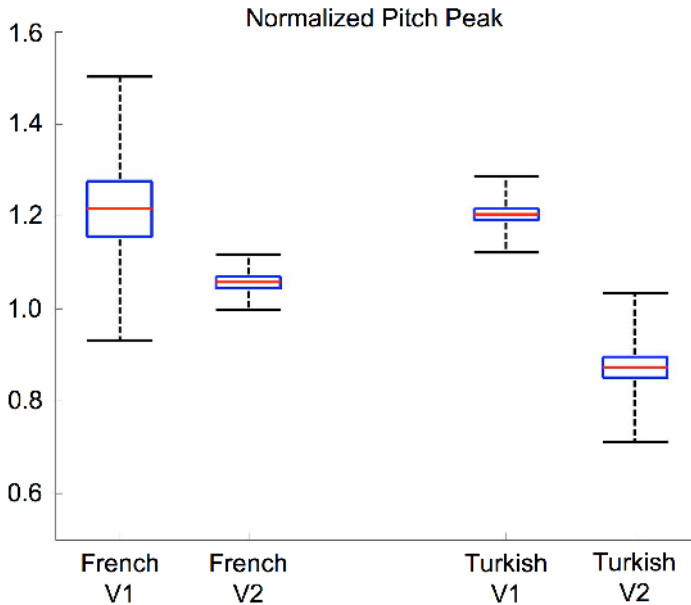


FIGURE 5: Normalized pitch peak in the first (V1) or second (V2) stressed syllable in French and Turkish. Boxes: 95% limits of the mean (horizontal line), whiskers: ± 1 S.D.

an *accent initial* is not associated with higher intensity in our data and this is crucial for our hypothesis.

The Language X Position factor was significant, $F(1,354) = 20.29$, $p = 0.004$, partial $\eta^2 = 0.141$. Post-hoc tests showed that the first vowel had a significantly higher pitch peak than the second both in Turkish, $p < 0.0001$, and in French, $p = 0.017$. Considering only the complement positions, the Turkish vowel (V1) had a higher pitch peak than the French counterpart (V2), $p < 0.01$.

Figure 6 shows the absolute difference in pitch peak and mean pitch of the vowel for the two languages.

The univariate ANOVA for the difference in pitch revealed a significant effect of Language, $F(1,249) = 18.13$, $p = 0.005$, partial $\eta^2 = 0.24$, with the difference for Turkish being significantly larger than that for French, as we would expect given the interaction between Language and Position described above.

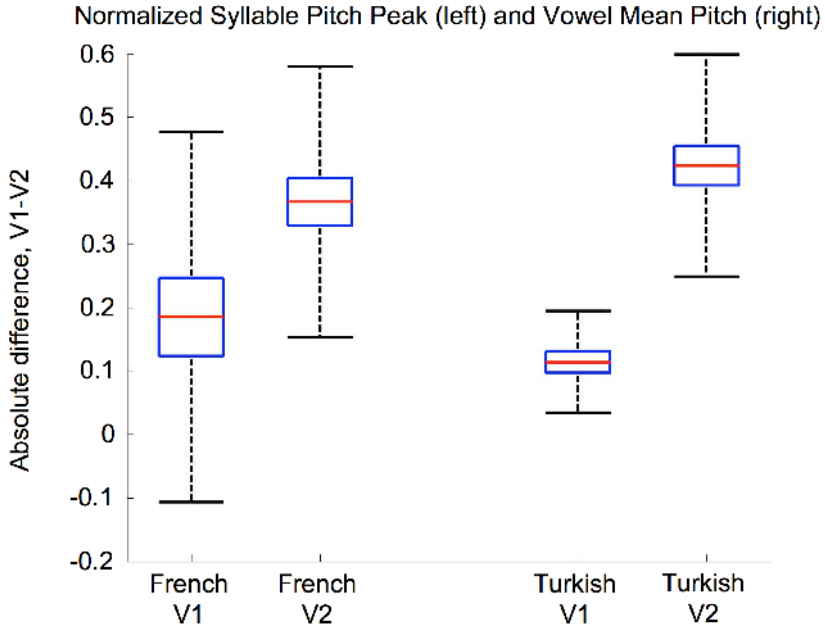


FIGURE 6: Absolute difference in normalized values for the pitch peak in the syllable (left) and the mean pitch in the vowel (right) between the first and the second stressed syllables for French and Turkish. Boxes: 95% limits of the mean (horizontal line), whiskers: ± 1 S.D.

2.2.4 Mean Pitch

Figure 7 shows the normalized value for the mean pitch in the vowel of the first and the second stressed syllable in French and in Turkish.

The mean pitch of the vowel shows a main effect only for Language, $F(1,354) = 13.67$, $p = 0.01$, partial $\eta^2 = 0.336$, and a trend for Vowel, $F(1,354) = 4.82$, $p = 0.071$, partial $\eta^2 = 0.014$. Again, as before, French shows higher overall values than Turkish, and the vowel in the first stressed syllable has a larger mean pitch than the second.

There was a significant Language X Position interaction, $F(1,354) = 22.73$, $p = 0.003$, partial $\eta^2 = 0.331$. Post-hoc tests showed the similar pattern as with the syllabic pitch peaks: within both languages, the vowel of the first stressed syllable had a greater mean pitch than the second ($p = 0.048$ for French and $p < 0.0001$ for Turkish). Comparing just the complements in the two languages, the vowel in the complement in Turkish (V1) has a higher mean pitch than the vowel in the complement in French (V2), $p = 0.033$.

From Figure 6, it can be seen that the absolute difference in mean pitch of the target vowels is different for the two languages. This difference is significant, $F(1,249) = 22.83$, $p = 0.003$, partial $\eta^2 = 0.498$.

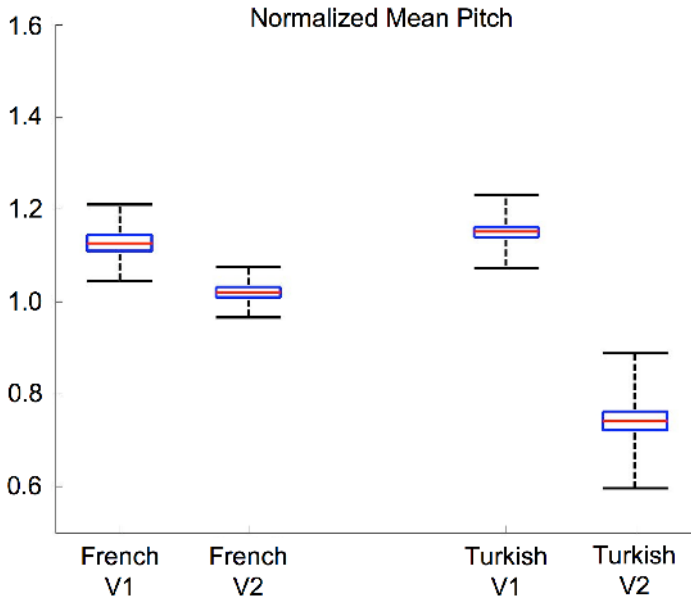


FIGURE 7: Normalized mean pitch in the vowel of the first (V1) and the second (V2) stressed syllable in French and Turkish. Boxes: 95% limits of the mean (horizontal line), whiskers: ± 1 S.D.

2.3 Discussion

The results can be summarized as follows:

For intensity and duration. The vowel in the stressed syllable of the complement, or the strong position in the phonological phrase, is longer and more intense than the vowel in the stressed syllable of the head, or the prosodically equivalent weak element. Additionally, the vowel in the complement position in Turkish is longer and more intense than its French counterpart.

For pitch. The first stressed syllable of the phonological phrase has a higher pitch than the second, as measured by the pitch peak in the syllable or the mean pitch of the vowel. In Turkish, this phrase-initial pitch reinforces the pitch on the stressed syllable of the complement, while in French it does not. Consequently, in Turkish, the absolute difference in pitch between the two stressed syllables is larger than in French. This is significant for the mean pitch in the vowel, and also for the pitch peak in the syllable. As we noted earlier, the high pitch of the initial weak element of the phonological phrase in French is due to a language specific intonational property (Jun & Fougeron, 2002). It is not relevant to our hypothesis since it is not accompanied by higher intensity.

In summary, for Turkish, the vowel of the first stressed syllable in a branching phonological phrase has a higher intensity, a higher pitch and is longer than the vowel of the second word. In contrast, in French, the vowel of the second stressed syllable has a higher intensity and is longer than the first one. That is, the more intense syllable coincides with the complement in both languages, but is accompanied by a different acoustic cue: pitch in Turkish and duration in French.

In order to confirm our hypothesis, we still need evidence from languages with word-initial stress to exclude the possibility that the observed duration effect observed in French is caused by constituent final lengthening, rather than phonological phrase stress. In French, in fact, the stressed syllable (the final syllable of the word) is also the last syllable of the phrase. Therefore, the observed increase in duration might be due to a combination of phrase final lengthening of the last syllable and lengthening associated with ‘lexical stress’. In addition, our hypothesis suggests that, in languages with mixed word order, phrases with different orders of heads and complements are signaled in different ways. We examine data from German in order to address these questions.

3. GERMAN MEASUREMENTS

In order to confirm our hypothesis a) in a language with non final word stress, and b) in a language with mixed word order, we measured the stressed syllable of direct objects (complements) in pre- and postverbal positions in German, a language with variable, though mainly initial word stress (Wiese, 1996).

According to our hypothesis, the stressed syllable in the complement of an OV configuration should have a higher intensity and pitch as compared to its head. Similarly, the stressed syllable of the complement in a VO configuration should have a longer duration and higher intensity as compared to its head. Thus, we predict that (a) the stressed syllable in the complement of an OV configuration will have a higher pitch than in a VO configuration, (b) the stressed syllable in the complement of a VO configuration will have a longer duration than its OV counterpart.

However, we expect that the intensity would be larger for *both*, relative to their heads (which we do not measure). Nevertheless, from the iambic-trochaic law, we expect that the intensity of the complement (O) in an OV structure would be larger than that in a VO structure. Indeed, from the cross-linguistic French and Turkish data, we observe that the normalized intensity for the (vowel of the) complement in Turkish is significantly higher than its French counterpart (compare Turkish V1 and French V2 in Figure 1). Therefore, we predict that intensity should pattern like pitch. That is, the intensity should be higher for the stressed syllable in the complement of an OV configuration as

compared to the stressed syllable in the complement of a VO configuration. In German we measured the whole stressed syllable and not just the stressed vowel, as in Turkish and French, since the words in the two conditions are identical, while in Turkish and French they were not.

We believe that finding different realizations of prominence in the two cases within a language is a particularly good test case and adds more credibility to our hypothesis than would additional pairs of languages.

3.1 *Material and methods*

3.1.1 Preparation of the material

In order to uncover the physical realization of phonological phrase stress in pre- and postverbal objects in German, we constructed 10 pairs of sentences. The two sentences of each pair were identical in all respects except for the relative order of object and verb (the crucial words are emphasized) sentence finally, as exemplified below.

- (3) Der Abend wird gut werden, weil ich *Papa sehe*.
Der Abend wird gut werden, denn ich *sehe Papa*.
'The evening will be pleasant, because I (will) see Papa.'

The two different orders are made possible by two complementizers of which one, *weil*, requires the order OV, and the other, *denn*, requires the order VO. All object nouns were bisyllables and had initial stress. In addition, in order to keep the material as homogeneous as possible, they all consisted of two identical CV syllables (refer to the Appendix for the complete list of sentences).

3.1.2 Recordings

Each of the sentences was presented three times (resulting in a total of 60 sentences) in randomized order to seven females, who were native speakers of German. They were recorded with professional equipment in a quiet room at the university of Potsdam. We instructed the speakers to read the sentences in a natural way at their normal speech tempo.

3.1.3 Analysis

All sentences and the target syllables were marked separately. A PRAAT script extracted all the phrases as well as the target syllables within each phrase, and computed the following variables of interest:

- The duration of each phrase and target syllable.
- The intensity of each phrase and target syllable.
- The mean pitch for the phrase and target syllable

- The pitch peak inside the target syllable in each phrase.

The values of all four variables for the target syllables were normalized by the corresponding values for the entire phrase. Measurements for the four variables were separated depending on whether the target syllable was in the object from the OV or the VO configuration, and values equal to or greater than the mean + 3 S.D. and values equal to or smaller than the mean – 3 S.D. were removed. In doing so, at most 1 data point was removed for all measurements, except for the pitch peak within the syllable, for which between 2.4% and 3% of the data was removed.

As before, statistical analyses were carried out using Data Desk 6.2 for Mac OS X (Data Description, Inc.).

The resulting data was analyzed in a series of separate univariate ANOVAs for the four factors, i.e. the normalized values for Intensity, Duration, Pitch Peak and Mean Pitch. Effect sizes, are presented as the partial η^2 . In each ANOVA, the ten syllables and seven speakers were entered simultaneously as random factors, and we considered only the effect of the main variable of interest. This was done to improve the estimation of the relevant effects, across both speakers and items. Note that traditional analyses revealed significant F1 and F2 values for all variables that are significant, as reported below, except for the pitch peak in the target syllables.

3.2 Results

The results are presented separately for the four variables of interest.

3.2.1 Syllable duration

Figure 8 shows the normalized value for the duration of the stressed syllable when it occurred in the object position in an OV or a VO configuration.

As is clear from the figure, the duration of the stressed syllable of the object when it is in the final position is greater than when it is in the initial position, and this is significant, $F(1,391) = 157.64$, $p \leq 0.0001$, partial $\eta^2 = 0.287$.

3.2.2 Syllable intensity

Figure 9 shows the normalized value for the intensity of the stressed syllable when it occurred in the object position in an OV or a VO configuration.

The ANOVA confirmed that the intensity of the stressed syllable of the object when it is in the initial position is greater than when it is in the final position, $F(1,392) = 82.2$, $p \leq 0.0001$, partial $\eta^2 = 0.173$.

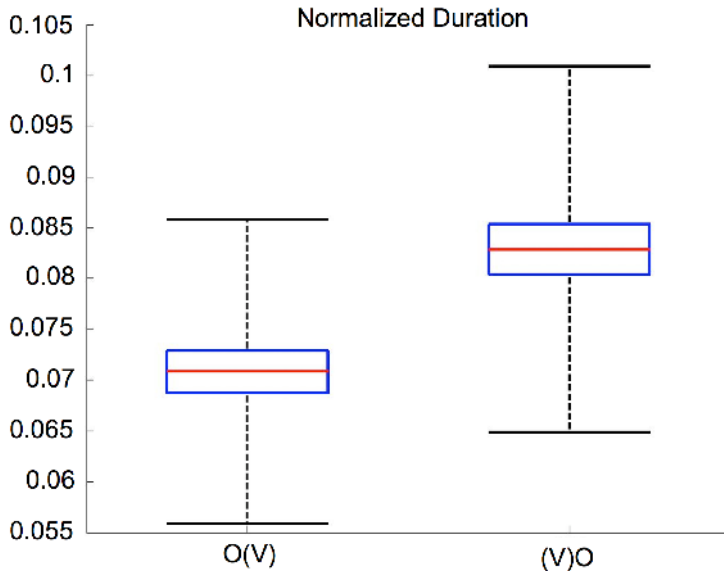


FIGURE 8: Normalized mean duration of the stressed syllable of the object of the verb in the OV or the VO configurations. Boxes: 96% limits of the mean (horizontal line), whiskers: ± 1 S.D.

3.2.3 Syllabic pitch: mean and peak values

Figure 10 shows the normalized value for the mean pitch and the pitch peak of the stressed syllable when it occurred in the object position in an OV or in a VO configuration.

The stressed syllable of the object in the OV configuration had a higher pitch than the stressed syllable of the object in the VO configuration, for both the mean pitch in the syllable, $F(1,367) = 72.92$, $p \leq 0.0001$, partial $\eta^2 = 0.166$, and the pitch peak in the syllable, $F(1,378) = 9.47$, $p = 0.0022$, partial $\eta^2 = 0.024$.

3.3 Discussion

The results can be summarized as follows: when the complement of the head (the direct object of the verb in these examples) is in the initial position (OV), its stressed syllable has a higher pitch and is more intense than when it follows the verb (VO). The reverse is true for the duration of the stressed syllable: it is longer in the VO configuration than in the OV configuration.

On the basis of these results we can conclude that the iambic-trochaic law, on which we base our proposal, signals whether the complement is initial or

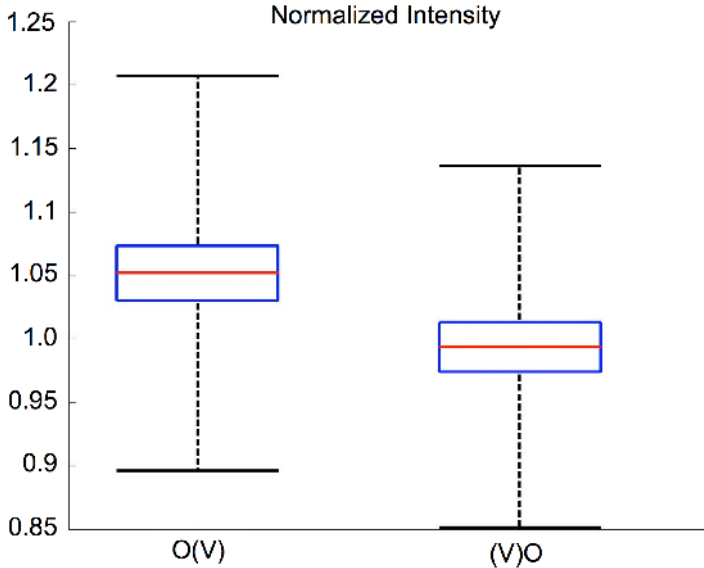


FIGURE 9: Normalized mean duration of the stressed syllable of the object of the verb in the OV or the VO configurations. Boxes: 96% limits of the mean (horizontal line), whiskers: ± 1 S.D.

final even within a single language. In German, a language with predominantly word-initial stress (among others, Wiese, 1996), OV and VO phrases are signaled by distinct acoustic-phonetic patterns. These results corroborate our hypothesis in that (a) they exclude the possibility that the difference in (normalized) duration found in Turkish and French is due to the enhancement of duration due to final position, rather than to phonological phrase stress, (b) they show that Turkish and French are not isolated cases, and (c) they show that our hypothesis is not only valid across linguistic systems, but also within a language. We consider the latter the best possible corroboration of our hypothesis. The German results thus add feasibility to our hypothesis that infants could determine the relative order of heads and complements, even in languages with a mixed order, especially given the child's uncanny ability to make use of such cues (among others, Jusczyk, 1997).

One aspect that requires further study in order to completely parallel the results we obtained for Turkish and French (but which will not affect the validity of our hypothesis) is the following: we should contrast the object complement with its verbal head in the two conditions in German: object first and object last. We can assume that the stressed syllable of the object, with phonological phrase stress, is always more intense than the stressed syllable of the

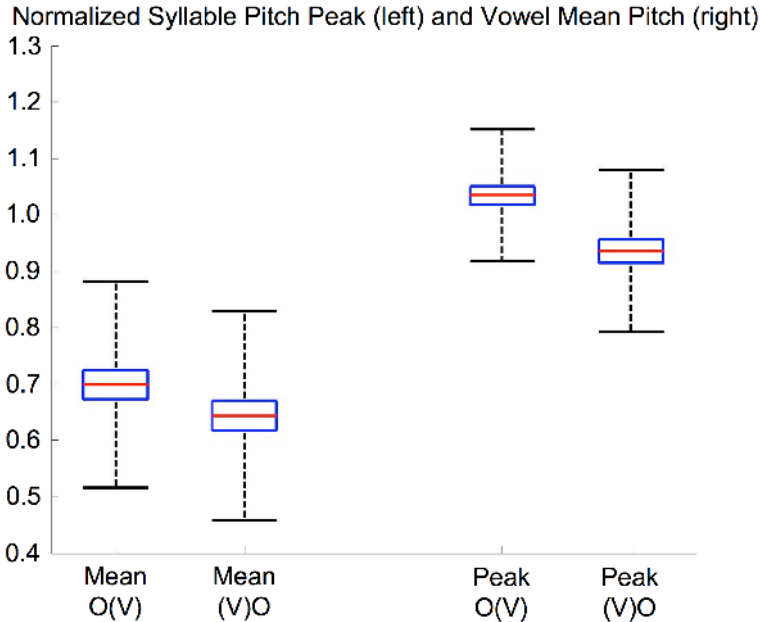


FIGURE 10: Normalized mean duration of the stressed syllable of the object of the verb in the OV or the VO configurations. Boxes: 96% limits of the mean (horizontal line), whiskers: ± 1 S.D.

verb, because of the Complement Law. We can also assume that in broad focus declaratives, pitch is higher on the first stressed word of a phonological phrase than on the second unstressed word, among other reasons, because of declination and because of a final low tone (among others, Féry, 1993; Kügler, Féry & van de Vijver, 2003), but whether, in OV structures, duration is relatively greater on the first than on the second stressed syllable, as is the case for our Turkish complement-head structures remains an open question. Only after comparing O with V, would we know whether the stressed vowel of the preverbal complement is indeed *relatively* longer than the stressed vowel of its head, as is the case for Turkish. That is, up till now, for German, two possibilities remain open: in complement-head structures, phonological phrase stress makes the stressed vowel of the complement more prominent than the stressed vowel of the final head (a) in all respects, (b) in pitch and intensity, but not in duration. Some crosslinguistic and even intralinguistic variation is predicted in this respect: for example, if in such complement-head structures, the phrase-final word has primary stress on the last syllable, the duration due to word stress adds to the duration due to final position and might very well overcome duration due to phonological phrase stress in the initial (complement) position. Independently of which one of the two options mentioned above will turn out

to be the case, our German data confirm our hypothesis: if the more intense stressed syllable also has a higher pitch, grouping is trochaic; otherwise it is iambic.

4. GENERAL DISCUSSION AND CONCLUSIONS

We have presented a hypothesis concerning the physical realization of phonological phrase prominence in complement-head and head-complement structures. It is realized through a combination of higher pitch and intensity (and possibly also duration) in the first case, and through a combination of increased duration and intensity in the second case. We tested this hypothesis in two languages – Turkish and French – with opposite order of heads and complements, as well as in a language with both orders, German.

The fact that the predicted different realization of prominence has been found not only in French and Turkish, but also within one single language, German, shows that this is not an arbitrary, language-specific difference in prominence realization, but is a cue to the type of rhythmic alternation that signals the relative order of heads and complements. Since in a head-complement pair of words, in a broad focus intonation, stress is on the complement, its specific realization signals whether it is initial or final. It is thus a more powerful cue than the location of prominence, which requires a prior identification of the boundaries of a branching phonological phrase.

It should be noted that the different types of prominence in a phonological phrase – stress is initial or final – is predicted to not only affect heads and complements, but any items contained in branching phonological phrases. Thus the different cues, pervasive throughout a speech stream, will signal to the prelexical infant whether a language is head-complement or complement-head; and in mixed languages, such as German, that both orders are found (cf. also Nespor et al., 1996).

It is so far not clear how infants acquire the syntax of their target language, especially those properties that must be acquired at the prelexical stage. There have been very few concrete proposals about how the basic properties of syntax can be acquired. One primary problem is to understand what are the cues in the signal that are both immediately apparent to an infant, as well as robust with respect to the property they represent.

If indeed our hypothesis is correct, it represents a way out of the conundrum of how the relative order of heads and complements, a fundamental property of the organization of language (Baker, 2001) is acquired. Indeed, our proposal relies on capacities that are attested in prelexical infants. The first is the capacity to discriminate relative pitch levels, and to memorize the pitch and temporal organization of auditory material (Trehub, 2003, amongst others). In fact, Krumhansl and Jusczyk (1990) and Jusczyk and Krumhansl (1993) showed that 4.5-month-old infants can use pitch and duration cues to

group musical phrases, the phrases being defined by a relatively high initial note and a relatively long final note.

Second, several authors have proposed that syllables represent basic units in infants' speech perception (e.g., Bertoncini & Mehler, 1981; Bertoncini, Floccia, Nazzi & Mehler, 1995, amongst others), and stressed syllables might be more apparent to infants, given their perceptual prominence (e.g. Echols & Newport, 1992; Echols, 1993). Taken together, the available psycholinguistic evidence suggests that infants are able to represent an utterance as a series of weak syllables, punctuated by perceptually salient stressed syllables. According to our hypothesis, if infants find that the stress is implemented mainly through variation in pitch and intensity, they will prefer a trochaic grouping, while if stress is implemented mainly through lengthening and intensity, they will be biased towards an iambic grouping. Such a strategy might further aid in discovering the boundaries of phonological phrases.

Indeed, as discussed in the introduction, recent evidence suggests that prelinguistic infants are sensitive to phonological phrase boundaries (Soderstrom et al., 2003; Gout et al., 2004).

In addition, the very organization of the phrases provides a robust cue to the relative order of heads and complements. That is, a trochaic grouping implies a complement-head order while an iambic grouping implies a head-complement order.

Of course it remains to be shown that, within phonological phrases, iambic patterns are more realized through lengthening and trochaic patterns through pitch and intensity cross-linguistically. If our results hold up, our proposal would provide a psychologically plausible mechanism for the acquisition of word order, accounting for the fact that this is one of the first achievements in language acquisition in the domain of syntax (Brown, 1973).

By this we do not imply that cues of a different nature cannot also contribute to signaling the order of heads and complements. For example, it has been shown that 7-month-old Japanese and Italian infants have opposite order preferences in an artificial grammar experiment, in which frequent items alternate with infrequent ones. The word order of their native language determines the preferred grouping (Gervain, Nespor, Mazuka, Horie & Mehler, in press).

Thus different kinds of signals might indicate important properties of the syntax of a language. And infants at the prelexical stage may have at their disposal different learning mechanisms that aid them into the acquisition of a single grammatical property. According to the present proposal, prosodic grouping as determined by the modified iambic-trochaic law leads the infant to segment speech into phonological phrases and thus to the identification of word order not only in languages that are regular as to word order, but also in languages in which the relative order of heads and complements changes according to the structure in which the phrases are embedded.

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APPENDIX

French sentences

- (i) En français antique kilim se dit.
'In French, ancient carpet, is said.'
- (ii) En français antique civil se dit.
'In French, ancient civilian, is said.'
- (iii) En français antique crocodile se dit.
'In French, ancient crocodile, is said.'
- (iv) En français antique magazine se dit.
'In French, ancient magazine, is said.'
- (v) En français antique machiniste se dit.
'In French, ancient machinist, is said.'
- (vi) En français pour chaque morale se dit.
'In French, for every morale, is said.'
- (vii) En français pour chaque cognac se dit.
'In French, for every cognac, is said.'
- (viii) En français pour chaque capitale se dit.
'In French, for every capital, is said.'
- (ix) En français pour chaque radical se dit.
'In French, for every radical, is said.'

Turkish sentences

- (i) Türkçe'de kilim için denir.
'In Turkish, for the carpet, is said.'
- (ii) Türkçe'de sivil için denir.
'In Turkish, for the civilian, is said.'
- (iii) Türkçe'de krokodil için denir.
'In Turkish, for the crocodile, is said.'
- (iv) Türkçe'de magazin için denir.
'In Turkish, for the magazine, is said.'
- (v) Türkçe'de makinist için denir.
'In Turkish, for the machinist, is said.'
- (vi) Türkçe'de moral kadar denir.
'In Turkish, as the morale, is said.'
- (vii) Türkçe'de konyak kadar denir.
'In Turkish, as the cognac, is said.'

- (viii) Türkçe'de kapital kadar denir.
'In Turkish, as the capital, is said.'
- (ix) Türkçe'de radikal kadar denir.
'In Turkish, as the radical, is said.'

German sentences

- (i) OV: Meine Schwestern werden nicht hingehen, weil sie Lili verabscheuen.
VO: Meine Schwestern werden nicht hingehen, denn sie verabscheuen Lili.
'My sisters won't go, because they hate Lili.'
- (ii) OV: Seine Mutter hat das gesagt, weil sie Pepe braucht.
VO: Seine Mutter hat das gesagt, denn sie braucht Pepe.
'His mother did say that, because she needs Pepe.'
- (iii) OV: Meine Freunde wollen meine Hilfe, weil ich Sissi kenne.
VO: Meine Freunde wollen meine Hilfe, denn ich kenne Sissi.
'My friends want me to help, because I know Sissi.'
- (iv) OV: Mein Bruder wird gehen, weil er Coco trifft.
VO: Mein Bruder wird gehen, denn er trifft Coco.
'My brother will go there, because he knows Coco.'
- (v) OV: Ich weiß bescheid, weil ich Mimi kenne.
VO: Ich weiß bescheid, denn ich kenne Mimi.
'I know it about it, because I know Mimi.'
- (vi) OV: Das brauchen wir nicht, weil sie Mama fragt.
VO: Das brauchen wir nicht, denn sie fragt Mama.
'We don't need that, because she will ask Mama.'
- (vii) OV: Der Abend wird gut werden, weil ich Papa sehe.
VO: Der Abend wird gut werden, denn ich sehe Papa.
'The evening will be pleasant, because I (will) see Papa.'
- (viii) OV: Deine Schwester kommt nicht, weil sie Lolo hasst.
VO: Deine Schwester kommt nicht, denn sie hasst Lolo.
'Your sister won't come, because she hates Lolo.'
- (ix) OV: Ihre Eltern haben angerufen, weil sie Kiki suchen.
VO: Ihre Eltern haben angerufen, denn sie suchen Kiki.
'Her parents rang, because they are looking for Kiki.'
- (x) OV: Ich weiß schon lange, dass er nichts von dir will, weil er Sasa liebt.
VO: Ich weiß schon lange, dass er nichts von dir will, denn er liebt Sasa.
'I have known it for a long time that he doesn't fancy you, because he loves Sasa.'