Quantifying variability

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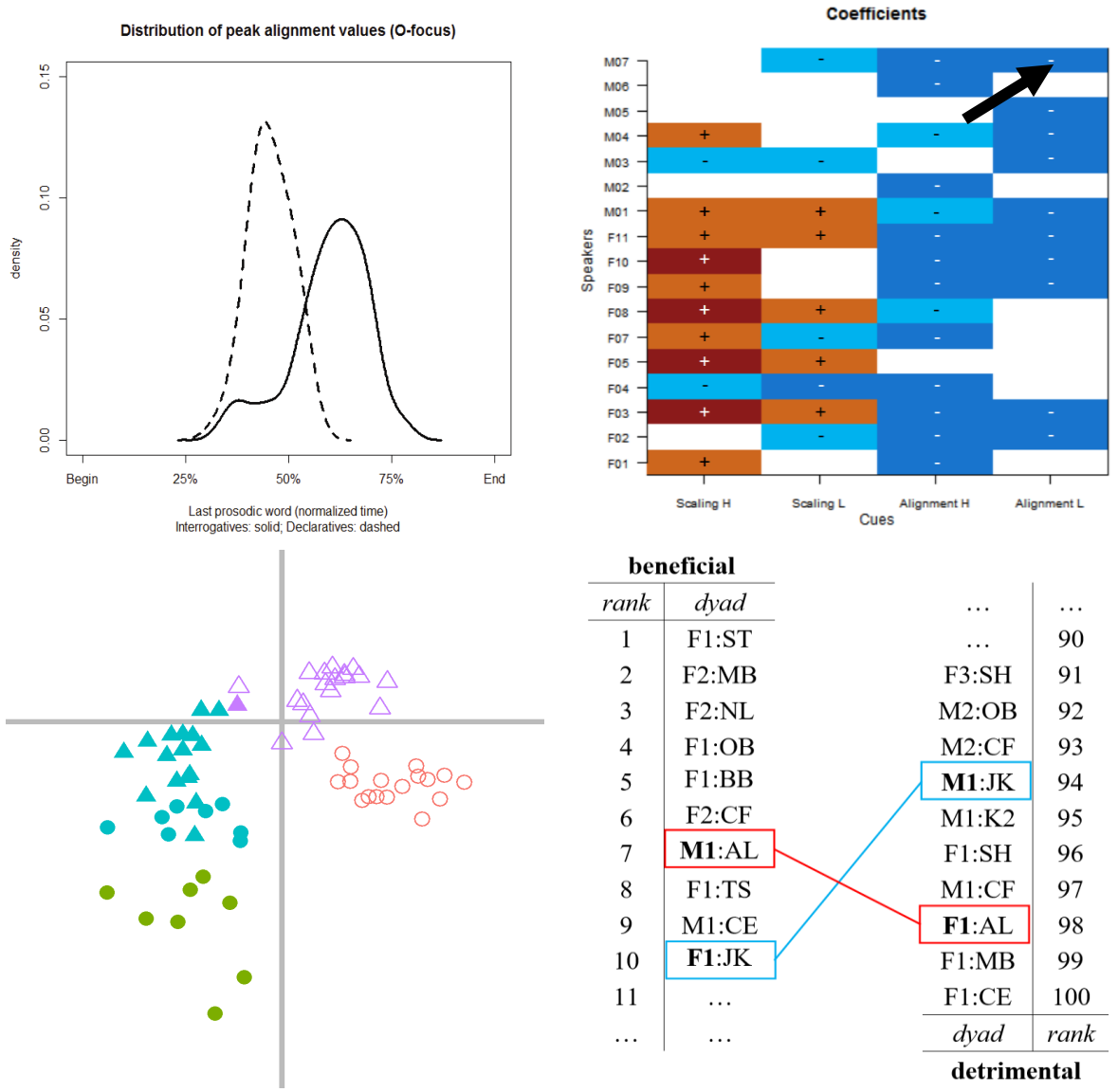
In the last decade, phonetic research in perception and production has increasingly focussed on the notions of variability in the behaviour of individual language-users. Developments in theory (e.g. refined models of categoriality), in data collection practices (e.g. software for stimulus presentation) and in quantitative analysis (e.g. mixed-effects modelling) have fostered an interest in closely examining i) dispersion measures as a complement of central tendencies (e.g. variance, in addition to averages) and ii) patterns of individual-specific behaviour (e.g. speaker- or listener-specific strategies in the encoding and decoding of linguistic units). As a result, targeted explorations of variability have informed several areas of linguistic research. We illustrate this development with a selection of experimental studies on prosody carried out in our lab, all focussing on the theoretical insights and the methodological challenges raised by the study of variability.

Speaker-specific behaviour has proven to be crucial in sketching the phonological inventory of Egyptian Arabic intonation (Cangemi, El Zarka et al. 2016), showing that individual speakers might use a different set of phonetic cues to phonological categories in order to encode the same pragmatic contrast. Crucially, analyses that do not take into account speaker-specific behaviour fail at recognising the existence of different prosodic patterns for the analysed focus types. Extensive (but structured) variation at the level of the individual has been found in the non-grammaticalised use of intonation of Northern Vietnamese (Brunelle et al. 2012, Cangemi, Weitz et al. 2016). Vietnamese is a tone language that makes large use of sentence particles, and thus encodes sentence-level meaning redundantly, which allows for more specificity in individual behaviour. This contrasts with languages which encode sentence-level meaning in a less redundant way (e.g. in Italian, which mainly uses intonation), and are thus expected to exhibit a lesser degree of individual specificity. Through the notions of redundancy and grammaticalisation, variability and specificity can thus also contribute to the study of sound change, suggesting pathways for the development (or the loss) of prosodic marking of sentence-level meaning. Work on intonation in German (Cangemi et al. 2015) has shown that individual-specific behaviour in production and perception of prosodic categories (i.e. in the encoding and decoding of focus type contrasts) can refine our understanding of broader theoretical constructs, such as the notion of intelligibility: Individual specificity in prosodic encoding (i.e. the patterns of use of individual acoustic cues) is shown to interact with individual specificity in prosodic decoding (i.e. identification of prosodic categories), in the sense that some listeners find it easier to decode prosodic categories as encoded by particular speakers. As a result, the notion of intelligibility is shown to be intrinsically dyadic in nature, and not a property of an individual speaker (as customarily assumed to be the case). Finally, work on intonation in Neapolitan Italian (Cangemi & Grice 2016) suggests that the degree of variability in speakers' productions can be different across categories. Specifically, pitch accents in statements are produced with phonetic realisations that are much narrower in range than those of pitch accents in questions. Such "differential variability" can be explained by invoking the relatively more redundant prosodic encoding of questions (e.g. through the additional use of boundary tones), but it also raises the question of whether some prosodic categories need to be considered as intrinsically more variable than others. The latter claim is compatible with models that take into account the diatopically, diastratically and diaphasically stratified competence of language users, since question intonation is much more variable than statement intonation in Italian regional varieties. In conclusion, the study of variability and specificity can contribute important insights to the exploration of phonological inventories, of sound change, of intelligibility and of stratified language competence.

Crucially, studies of this kind require the development of statistical techniques that can fully unveil the explanatory potential of phonetic variability and of individual-specific behaviour. With this submission we present several such techniques, as employed both in the literature and in our own work. The different degree of variability in the phonetic encoding of two prosodic categories is represented with density plots in the top-left figure (from Cangemi & Grice 2016). The figure shows that Declaratives (dashed line) have a compact realisation, with unimodal distribution and small kurtosis; Interrogatives, on the other hand, are much more variable, showing a bimodal distribution and larger kurtosis in the main peak. Quantification of these effects is achieved through Levene's and F-tests. Individual-specific use of the available cues is represented graphically in the top-right figure (from Cangemi, El Zarka et al. 2016) through a heat-map featuring cues as columns, speakers as rows, effect size as saturation, and effect direction as hue. Such profiling is based on the value of coefficients for the relevant cue in full models after Likelihood Ratio Tests. For example, the dark blue cell in the top right hand corner (see arrow) indicates that in the productions of speaker M07 (top row) the alignment of the low turning point (rightmost column) is significantly earlier (dark blue) in one of the two prosodic conditions. Top-down analyses such as this can be complemented by bottom-up approaches, as in the clustering results in the bottom-left figure (adapted from Cangemi, Weitz et al. 2016). Here we plot in a feature space (i.e. normalised duration on the x-axis and f0 slope on the y-axis) individual data points from a speaker's productions, using different symbols for the experimental

categories and different colours for the different clusters identified by the algorithm. Various degrees of match between colours and symbols are attested for each speaker, and indicate how well the two selected features characterise the speakers' encoding strategies (in this example, very adequately). The interaction between speaker-specific behaviour and listener-specific behaviour is represented in the bottom-right figure (from Cangemi et al. 2015). Here the random intercepts for speaker-listener dyads are listed from most beneficial to most detrimental (to performance in an identification task). The figure shows that one listener (AL) might find the productions of a given speaker (M1) highly intelligible but the productions of another speaker (F1) least intelligible (see red boxes); the converse pattern (F1 more intelligible than M1) is attested for another listener (JK; see blue boxes), thus providing quantitative evidence in support of the interactional nature of the concept of intelligibility.



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