Neutralisation and the perception of close-mid and open-mid vowels: The gradient between phonological categories

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20th International Congress of Phonetic Sciences (ICPhS)

20th International Congress of Phonetic Sciences
7-11 August 2023 | Prague | Czech Republic

Introduction

The way we decode speech signals into phonemic categories is still unclear, but some studies (Eerola et al. 2012; Iverson and Kuhl 2000; Lively and Pisoni 1997) have shown that prototypes play an important role in structuring the categories of speech sounds.

This study was based on two theoretical assumptions:

1 The perception of speech sounds is influenced by the relationships they have within their language system (Boomershine et al. 2008; Hume and Johnson 2003; Troubetzkoy 1939);

2 The categories of speech sounds, especially vowels, have an internal structure (Kuhl 1991; Kuhl et al. 1992).

A prototype theoretical framework was the basis of the present study on the impact of neutralisation on the perception of Portuguese close-mid and open-mid vowels and the gradient between phonological categories.
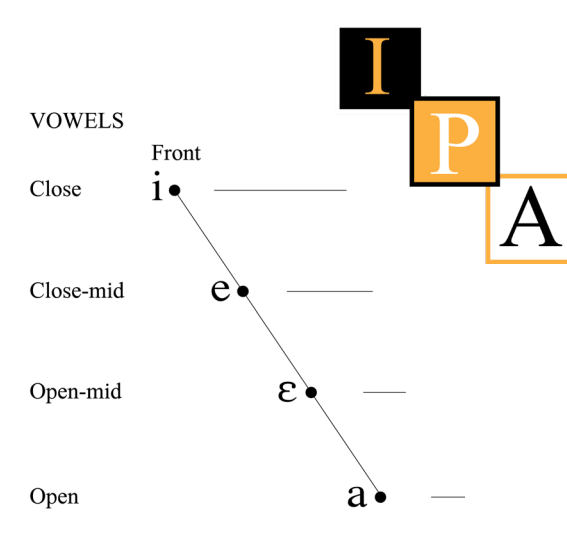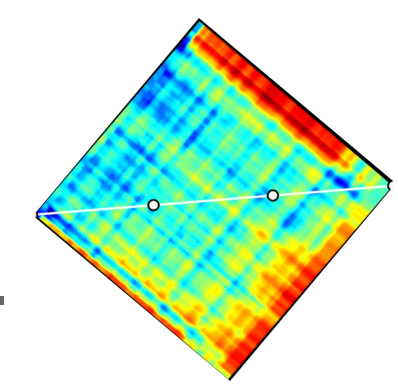
Method

Recording of the target-vowels: One male speaker from Lisbon produced [i, e, ɛ, a].

Creation of stimuli: [i, e, ɛ, a] were used as anchors to generate 31 stimuli with a TANDEM-STRAIGHT morphing procedure.

Perception test: 15 (females = 9) European Portuguese speakers from Lisbon, listened to 20 repetitions of each stimulus (620 stimuli in total) randomly presented.

The experiment included two tasks:

1 To choose one of the words presented on the screen containing the tonic vowel they heard (**identification task**);

2 To classify the quality of the sound heard on a scale of 1 to 5 according to the vowel chosen in the task (**goodness rating task**).

Stimuli presented via Praat version 6.0.37, using Sennheiser HD 380 Pro headphones connected to the internal sound card of a laptop.
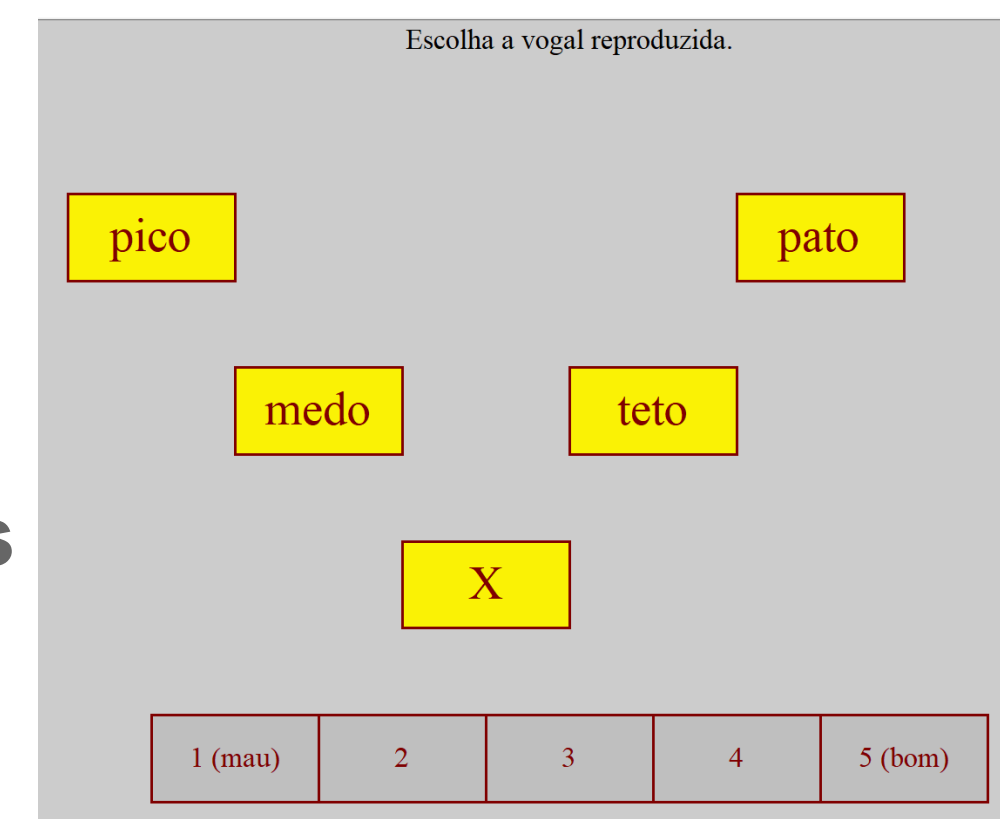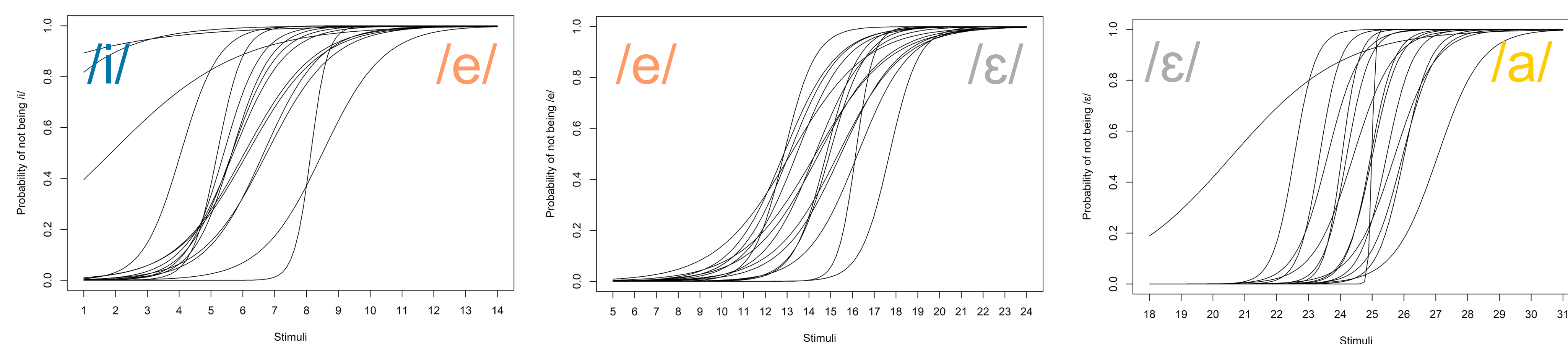
Results

Figure 1: The logistic regression curves of all participants for the /i/-/e/ (left), /e/-/ɛ/ (middle) and /ɛ/-/a/ (right) transitions
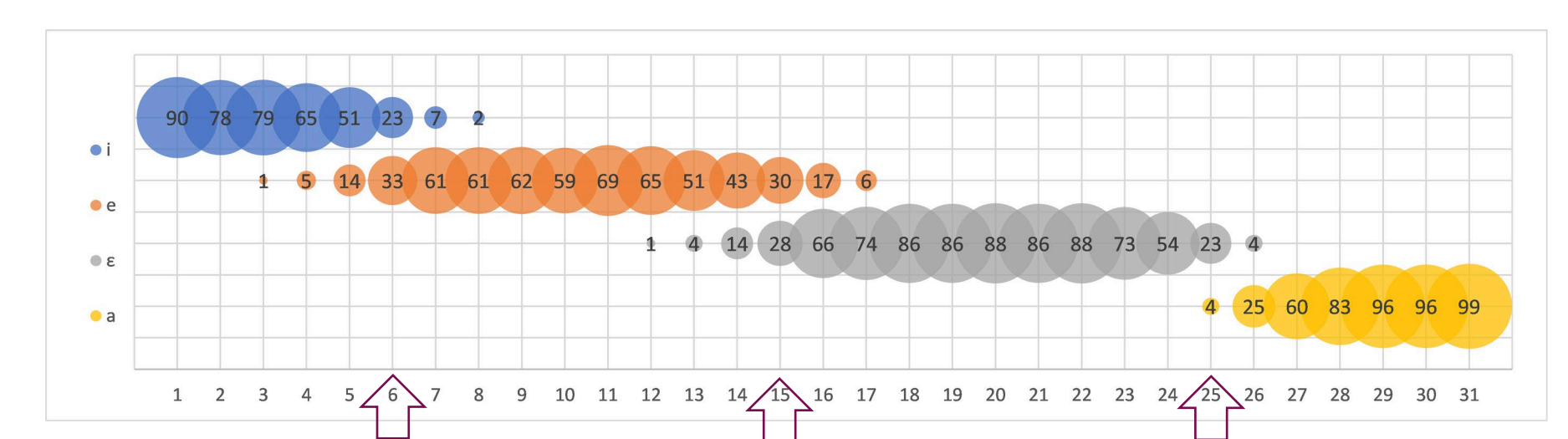

Figure 2: Median goodness rating of all participants, for each of the 31 stimuli (horizontal axis). Scores are represented by the sizes of the circles. The number inside each circle is the median score for each stimulus, considering all participants, which may range from 1 (worst) to 100 (best).

- Estimates (median / mean ± standard deviation) for the 3 boundaries were obtained from the logistic regression curves adjusted for all participants (shown in Fig.1).
- Significant distance between the samples of the 3 boundaries for each participant (ANOVA/ Tukey's HSD tests).
- Fig. 2 shows that as the stimulus moves away from the centroid, the goodness score decreases.
- The gradient of the boundaries was also analysed empirically, by calculating the ratio between the median goodness scores at the boundaries between categories (see Fig. 2). Results revealed the /e/-/ɛ/ boundary as the least steep of the three.

Conclusions

- Most listeners used **4 categories** with **3 boundaries**, exhibiting an internal structure that included their prototype
- The boundaries between /i/ and /e/, and /e/ and /ɛ/ were less steep than the boundary between /ɛ/ and /a/, the latter being non-neutralizable.
- The gradient of the /e/-/ɛ/ boundary could be due to the complex phonological relations that these sounds establish in the vowel system of European Portuguese.
- Stimuli beyond /i/ and /a/ would have covered the entire categories of these two vowels.
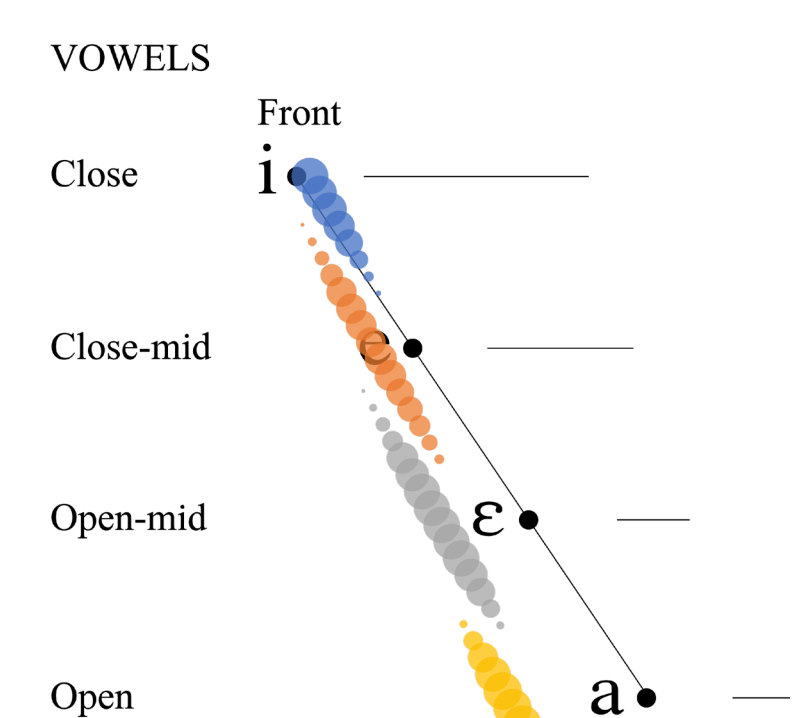
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