Indexing femininity in vowel acoustics: A comparison between speakers in eastern and western parts of Germany

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ABSTRACT

Previous research has identified cross-linguistic differences in the relation between gender identity and acoustics. This study tests whether such differences extend to different cities in the same country (in western and eastern parts of Germany, formerly BRD and GDR, with distinct historical developments). Results show that gender role concepts vary between regions, with males in the eastern city showing more egalitarian views and higher femininity than males in the west. On the group level, the difference in gender identity was not evidenced in the acoustic vowel space. On an individual level, variation in vowel productions could however be explained by femininity, especially with respect to the second formant (front-back dimension). The effect of femininity was modulated by city, with speakers in the east indexing femininity in vowel productions while speakers in the west did not. Implications for the analysis of inter-speaker variation in fine-phonetic detail is discussed.

Keywords: socio-phonetics, vowel spaces, formants, gender identity, femininity

1. INTRODUCTION

Research on phonetic differences between male and female voices has shown that perceptual, biological, and social factors explain gender-specific variation in speech [1-3]. At the same time, the conception of *gender* in western cultures is moving away from a strictly dichotomous term. Instead, gender is expressed and perceived on a more fluid scale; people may even choose to reject this categorization altogether.

Phonetic studies highlighting the significance of a speaker's *gender identity* in explaining acoustic-phonetic parameters (independent of sex) are still scarce. Several studies have investigated the impact of a speaker's sexual orientation on fine-phonetic detail: While some found differences in mean fundamental frequency (F0) between straight and gay speakers [4,5], others did not [6-8]. For German, [9] found lower mean first vowel formants (F1) in straight than in gay men. Fewer studies have investigated female voices and results are similarly inconclusive with regard to the influence of sexual orientation ([10,11] vs. [12,13]). One reason for these mixed results might be the binary distinction of sexual orientation (cf. [14]). Specifically, [14] emphasize the importance of a fine-grained analysis of psychological characteristics including gender identity in addition to sexual orientation: While there was no acoustic difference between straight and non-straight women, intra-group variability in F0 and vowel formants was related to the exclusivity of sexual orientation (intermediate score between exclusively gay/hetero) and gender-role concept. Independent of sexual orientation, [15] found that males indexed self-reported femininity scores in speech through F0 and vowel space sizes, and listeners reliably detected this information on one-word stimuli [15]. Similar results were found for females with correlations between self-ascribed and perceived femininity and hints towards the role of F2 [16]. Cross-linguistic studies have revealed that gender-specific variation is affected by cultural norms and expectations: [17] highlighted cultural aspects of differences in F0 between Dutch and Japanese women. [18] found larger differences between genders in F0 and vowel space size in German speakers than in Swedish speakers, due to lower values for Swedish females than for German females, accompanied by lower self-ascribed femininity in Swedish females.

This study tests whether such cross-linguistic differences in the relation between gender identity and acoustics also pertain to different cities within one country. We focus on two cities in Germany that differ in their historical/societal developments: Jena (eastern Germany, former GDR) and Trier (western Germany, former BRD) – both university cities of about 110.000 inhabitants. The historical difference between the two cities dates back to the division of Germany into a capitalist democracy in the West and a socialist state in the East after World War II. These differences in political systems were accompanied by varying gender roles with women working full time shortly after having children in the East while staying at home as housewives in the West. Even well after reunification, there are still economic and societal differences between the two regions: Crucially, they differ in the amount of females in leading positions (more in eastern G), gender-based salary differences (in favor of females in eastern G [19]), and in labor division (more equal in eastern G [20]). Regarding dialectal differences, the two cities are comparable in their region-specific vowel space sizes [21]. Against this background, we address three research questions:

RQ1: Do females and males differ in self-ascribed gender identity (femininity) and views on gender roles across cities (higher fem. and more egalitarian gender-role concept in males in Jena than in Trier)?

RQ2: Are these potential regional differences reflected in gender-specific variation in vowel spaces (larger diff. between sexes in Trier than in Jena)?

RQ3: Does the self-ascribed gender identity explain inter-speaker variability **within the sexes** in vowel formants (F1, F2) and if yes, does this differ between regions?

2. METHOD

The study was approved by the Ethics Committee of the Friedrich Schiller University, Jena (2019-1389-BO); all speakers gave their written consent.

2.1. Participants

We recruited speakers between 30 and 50 years who were born and raised in Jena (eastern Germany) or Trier (western Germany). In total, 37 speakers from Jena and 25 from Trier participated for a small payment, see Table 1. The groups (per gender) did not differ in age, height, schooling, sexual orientation, as well as how much they liked their city (all p>0.12).

	Jena		Trier	
	f	m	f	m
N	15	22	15	10
Mean age in years (SD)	36.53 (7.19)	38.59 (4.44)	38.10 (6.64)	38.40 (5.38)

Table 1: *Number of participants per city and sex.*

2.1.1. Socio-psychological parameters

GEPAQ_Fem: Self-ascribed gender identity was assessed via the positive femininity scale of GEPAQ (*German Extended Personality Attributes Questionnaire* [22]) which was constructed to determine the personality-based gender-role self-concept. The scale consists of eight adjective pairs describing positively evaluated personality traits traditionally attributed to women (e.g., kind, gentle). Participants were asked to rate themselves on these adjective pairs on a scale from 1 to 7 (e.g., 1=very unkind, 7=very kind). Mean values were calculated for each speaker, with higher scores reflecting higher femininity.

NGRO: The Normative Gender Role Orientation Questionnaire [23] measures explicit stereotypes towards women and men. Here, we selected nine items to measure participants' view on gender roles. Participants indicated the extent to which they agree with these statements on a 7-point scale (1=I strongly disagree; 7=I strongly agree). Higher means indicate a more egalitarian view on gender roles.

SO: Sexual orientation was measured using a Kinsey-like scale ranging from 1 (exclusively heterosexual) to 7 (exclusively gay/lesbian).

2.2. Speech material

A picture-description task was used to elicit semi-spontaneous speech data (cf. [15], [18], [24]). Participants were asked to describe 15 different pictures that showed several objects and animals, see Table 2. Pictures were designed to contain several carrier words with the target vowels in stressed position, e.g., *Tiger* (tiger), *Biene* (bee) for /iː/; *Äpfel* (apples) for /ɛ/; *Katze* (cat), *Tasse* (cup) for /a/; and *Kuh* (cow), *Buch* (book) for /uː/. Table 2 shows a summary of the number of vowels in the dataset, split by *city* and *sex*.

	Jena		Trier	
	f	m	f	m
iː	217	314	246	132
ɛ	61	94	85	46
a	202	320	246	139
uː	185	293	214	126

Table 2: *Observations included per group (left) and example picture showing target words (right).*

2.3. Phonetic analyses: Vowel acoustics

The first two formants (F1, F2) in the vowels (/iː a ɛ uː/) of the carrier words were measured at the vowel midpoint using Praat's [25] linear predictive coding formant measurement algorithm. Analysis parameters included a time step of 0.01s, a maximum number of 5 formants, a window length of 0.025s, and a pre-emphasis from 50 Hz. The maximum formant value was set to 5500 Hz for females and 5000 Hz for males. For /uː/, the maximum number of formants was set to 2 and the maximum formant value to 1200 for males and 1500 for females. Erroneous measurements were checked and corrected manually. To get an estimation of vowel dispersion, the polygon size spanned by F1 and F2 of the corner vowels (/iː a ɛ uː/) was calculated for each speaker.

3. RESULTS

3.1. Femininity and gender role in Jena and Trier

Figure 1 shows the self-ascribed femininity scores (GEPAQ_Fem; Cronbach's α=0.82) and gender-role orientation (NGRO, Cronbach's α=0.53), separated by city and gender. Fig. 1 suggests that the difference in the scales between sexes is smaller in Jena (similar values across sex) than in Trier (lower values in males than in females). Compared to males in Jena, males in Trier showed a less egalitarian view on gender roles (NGRO, t=2.6, df=14.5, p=0.02) and a tendenc

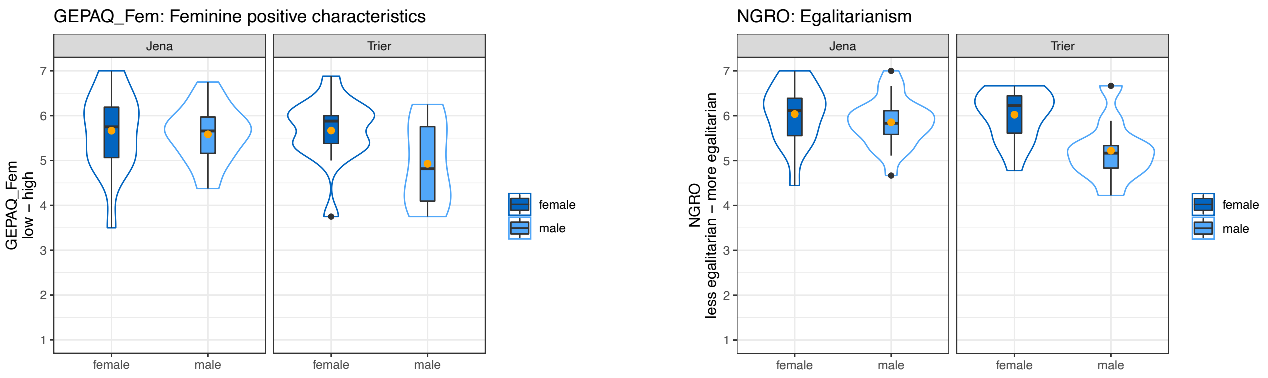

Figure 1: Self-ascribed gender identity in Jena (east) and Trier (west); GEPAQ_Fem left and NGRO (egalitarianism) right.

for lower femininity (GEPAQ_Fem, t=2.05, df=12.96, p=0.06, **RQ1).** Females in Trier vs. Jena did not differ in femininity or egalitarianism (both p>0.94). Responses for both scales were significantly correlated (r=0.4, p=0.001). To analyse the relation between gender identity and vowel acoustics, we use GEPAQ_Fem, which had a higher scale reliability.

3.2. Variability in vowel acoustics and femininity

Figure 2 shows the acoustic vowel spaces in Jena and Trier **(RQ2).** The female polygon spanned by F1 and F2 of the four corner vowels (/i: a ɛ u:/)) was 0.45 kHz^2 (SD=0.09) in Jena and 0.42 kHz^2 (SD=0.07) in Trier. The male polygon was 0.25 kHz^2 (SD=0.05) in Jena, and 0.26 kHz^2 (SD=0.05) in Trier. Not surprisingly, females had a significantly larger vowel space than males (ß=0.18, SE=0.02, t=10.86, p<0.001). There was, however, no interaction between *sex* and *city* (p=0.35), indicating that the difference in vowel space between males and females was not different in the two cities. Hence, the difference in self-ascribed gender identity between Jena and Trier (Figure 1) was not indexed in the acoustic vowel space on the group level **(RQ2)**, see Figure 2.

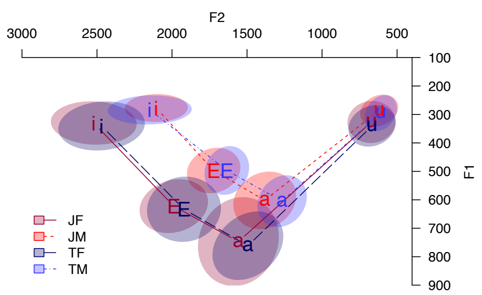

Figure 2: Acoustic vowel space for speakers in Jena (red) and Trier (blue); females in dark, males in light.

We will now turn to the third research question **(RQ3)** on whether inter-speaker variation within the sexes can be accounted for by individual gender identity. We report on a potential relationship between vowel acoustics (in terms of F1 or F2) and GEPAQ_Fem (femininity). We will investigate the first two formants instead of vowel space to base our analysis on more data points, and to be able to test effects of gender identity for individual vowels. In addition to *vowel*, we include *city* and *sexual orientation* as potentially interacting factors with the effect of *gender identity*. In response to **RQ3**, we run separate linear mixed effects regression models [26] for each sex for both F1 and F2, testing for an effect of GEPAQ_Fem and its interaction with the factors *vowel*, *city*, and *sexual orientation*. Categorical fixed factors were dummy coded (*vowel*=/a/ and *city*=Jena as reference levels). For convergence reasons, *sexual orientation* was grouped into straight (Kinsey-Scale=1: n=36 speakers) and non-straight persons (Kinsey-Scale=2-7, n=26 speakers). *Speaker* and *word* were included as random effects (by intercept adjustments). Model comparisons based on LogLikelihood (using anova()) indicated the final model.

F1. The model for **females** revealed an interaction beween GEPAQ_Fem**vowel* ($\chi^2(6)$=131.2, p<0.001) such that for the vowels /a/ and /ɛ/ the relation was slightly negative (F1 decreases with higher femininity), while /u:/ and /i:/ showed no relation. The effect of femininity is, however, small (ß =-17.3 for the reference /a/) and in an unexpected direction. There was no interaction with city or sexual orientation. The model for F1 for **males** did not reveal an effect of femininity (neither as main effect nor in interaction with the other factors), only the expected main effect of vowel type ($\chi^2(3)$=134.7, p<0.001).

F2. The final model for **females** revealed a significant interaction between GEPAQ_Fem**vowel* ($\chi^2(6)$ =126.2, p<0.001) and a marginally significant interaction between GEPAQ_Fem**city* ($\chi^2(2)$=4.9, p=0.08), see Figure 3 (left panel) for predicted values for F2. In particular, for the vowel /a/ in females from Jena (reference level), F2 significantly increased with higher femininity (ß=85.4), i.e., the vowel is more fronted. This relation was also observed for the three other vowels, but to a smaller extent (for /i:/: ß=-26.11; for /ɛ/: ß=-47.48, for /u:/: ß=-62.12).

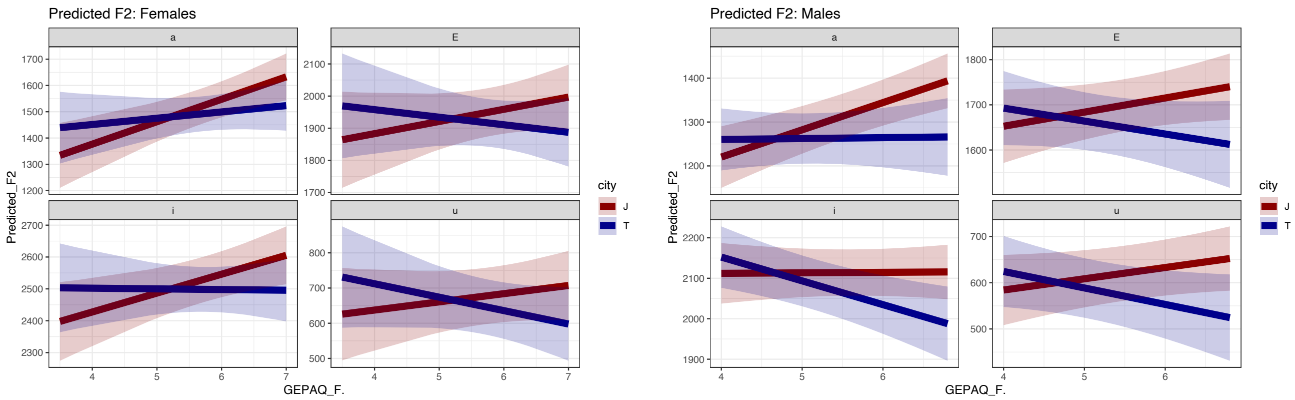

Figure 3: Predicted values for F2 for female (left) and male speakers (right) for individual vowels; speakers from Jena are coded in red, speakers from Trier in blue. Note that y-axes scaling is different for individual vowels.

The effect of femininity on F2 was smaller in females in Trier than in females in Jena (ß=-61.41 with respect to the reference /a/). For other vowels, there is no or a (slight) negative relation in females in Trier.

The final model for **F2 in males** revealed significant interactions between GEPAQ_Fem**vowel* ($\chi^2(6)=150.9$, $p<0.001$) and GEPAQ_Fem*city ($\chi^2(2)=9.2$, $p<0.01$), see Figure 3 (right panel) for predicted values for F2. Similar to females in Jena, F2 for male speakers from Jena significantly increased with higher femininity for the vowel /a/ (reference level, ß=62.0; i.e., more fronted); this relation was present but smaller for /ɛ/ and /u:/ (ß=-30.7 and -7.7), but lacking for /i:/ (ß=-60.8). Also, the effect of femininity on F2 was different in male speakers from Trier than in males from Jena (ß=-60.00, with respect to the reference level), see also Figure 3 (no other or even negative relationships). Sexual orientation did not play a role (as main effect or interaction) in the models for F1 or F2 (all p>0.5).

4. DISCUSSION

Extending previous socio-phonetic studies on cross-linguistic differences in gender-related phonetic variability [18], the present study assessed the self-ascribed gender identity in two cities in Germany, which differ in their historical background and societal development. As expected, gender identity – captured via the Femininity Scale of the GEPAQ [22] and the NGRO [23] – differed between the sexes to varying degrees in the two cities Jena (eastern Germany) and Trier (western Germany). While female speakers' gender role orientations did not differ across cities, male speakers in Jena showed a more egalitarian view on gender roles and ascribed themselves higher femininity (RQ1). However, on a group level, these differences in ascribed gender identity were not directly evidenced in the vowel space sizes (RQ2).

Importantly, inter-speaker variation in vowel productions could be explained by individual scores for self-ascribed femininity, especially with respect to the second formant (F2, RQ3); sexual orientation did not play a role. The effect of femininity was shaped by vowel category and city. While higher femininity values clearly go along with higher F2 (more fronted vowels) in male and female speakers from Jena, this relation is absent or even negative in speakers in Trier (especially in men, but given the small sample size in this group, interpretation needs to remain cautious). Hence, while speakers who consider themselves more feminine front vowels in Jena, speakers in Trier do not. With regards to vowel quality, our results point to a strong effect of femininity on /a/, followed by /ɛ/ for males and /i:/ for females.

Earlier studies have shown the relevance of F2 regarding the indexicality of gender identity in fine phonetic detail ([14, 16]). However, in light of the differences between the cities found in the present study, generalization on the social meaning of F2 regarding femininity should be made with caution (see [14] for similar regional differences). Our results clearly point to a regionally influenced phonetic encoding of gender identity in speech – within one language, potentially affected by differences in historical developments – which, in turn, might have influenced people's normative gender-role concepts.

Along with other socio-phonetic studies that point to locally constructed social meaning of phonetic variation [27], our study emphasizes that the analysis and explanation of inter-speaker or inter-group variation in fine phonetic detail needs to incorporate a number of social factors, and to consider ideologies, norms and expectations of both speakers and listeners, which are shaped by the local environment, society, and history. The reasons underlying the regional differences in indexing femininity in speech yet remain to be detected. A possible reasoning is that it might be more important for speakers from Jena to index their femininity in speech since differences between the genders in many aspects of life have become smaller. Using fine phonetic detail is hence one source of variation to express one's female identity.

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