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The Girls, the Gays, and the Theys

Spectral Characteristics of /s/ Production in Non-Binary Speakers: An Analysis of Center of Gravity and Skewness

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Abstract:

This study investigated how non-binary speakers from the United States produce the /s/, with particular attention to whether acoustic patterns vary by assigned gender at birth. Building on prior research that linked /s/ variation to gender and sexual orientation, this study examined the center of gravity and spectral skewness in /s/ production using acoustic data from podcasts among straight cisgender men and women, and non-binary speakers. While the results were not statistically significant, meaning that these effects cannot be generalized to the broader population, the data showed that assigned male at birth (AMAB) non-binary speakers exhibited higher center of gravity (CoG) values than their cisgender AMAB counterparts, while assigned female at birth (AFAB) non-binary speakers patterned similarly to AFAB controls. Overall, AFAB speakers showed higher CoG and more negative skewness compared to AMAB speakers. With further research and a larger sample size, these patterns might suggest a sociolectal divide, with dental [s̪]—characterized by higher CoG and negative skew—potentially indexing femininity and queerness, and alveolar [s] indexing masculinity and heterosexuality.

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Introduction

The notion of "gaydar"—the ability to detect a person's sexuality based on subtle social cues such as appearance, mannerisms, or speech—has been the subject of much attention within queer communities (Barton, 2015). In fact, empirical research supports this phenomenon to some extent. For example, listeners have been found to correctly guess sexual orientation at rates above chance based on speech alone (Munson et al., 2006). But what underlies this ability? What characterizes so-called "gay speech?" More importantly for this study, how far do these stylistic patterns extend across the full spectrum of gender identities and sexual orientations represented within the lesbian, gay, bisexual, transgender, and other queer and non-normative communities (LGBT+). If certain speech features are associated with the gay identity, is it also possible for acoustic signals to reveal aspects of gender identity—particularly among gender non-conforming speakers?

The Intersection between Sexuality and Gender:

Historically, people of non-normative genders and sexualities have been grouped together in popular culture and sociolinguistics (Cameron & Kulick, 2003). Although gender identities outside of cisnormative frameworks frequently challenge heteronormative expectations (Valentine, 2007), gender identity does not always map neatly onto sexual identity in linguistic or social practices (Zimman, 2017). And while contemporary research emphasizes the importance of distinguishing these categories in order to respect individual identities (Zimman, 2013, 2017), grouping these communities together—both in society and in research—often makes sense, given their shared experiences of marginalization (Valentine, 2007) and the similar ways they may signal identity through language (Zimman, 2013, 2017). This dual reality is reflected in the use of the labels *LGBT+* and *queer* as broad umbrella terms that include all individuals whose gender identities, gender expressions, or sexual orientations fall outside cisnormative and heteronormative frameworks.

In this text, *transgender* is broadly understood as identifying with a gender different from the one assigned at birth. To reflect meaningful differences within this spectrum, a distinction is made between transgender individuals who identify within the gender binary and those who do not. This distinction was motivated by a lack of research focusing on binary non-conforming individuals. *Non-binary* is understood both as an umbrella term encompassing all identities that exist outside the hegemonic gender binary and, in many cases, as a specific gender identity label. Within this umbrella, individuals may identify with sub-labels such as *genderqueer*, *agender*, or *genderfluid*. Given that non-binary identities have only recently gained broader visibility in popular culture within the English-speaking world (Perales et al., 2025), it is likely that these definitions will continue to shift over time, and that new or more suitable labels may emerge in the future.

Speech Patterns:

1. ***Cisgender Women and Men:***

Given these complexities in gender and sexual identity, it is helpful to first consider what is already known about speech patterns among cisgender women and men. As a starting point, the voices of those assigned male at birth (AMAB) and those assigned female at birth (AFAB) often differ due to anatomical factors like vocal tract length and laryngeal size. Individuals with shorter vocal tracts and smaller larynxes (usually AFAB) tend to produce higher-pitched voices and higher-frequency vowels, while those with larger vocal tracts (usually AMAB) exhibit the opposite pattern (Schwartz, 1968; Zimman 2021). Research has documented gendered variation across a range of acoustic features—including fundamental frequency (F_0), (vowel) formant frequencies, vowel space size, segment duration, voice onset time, and voice quality—arising from both anatomical and sociocultural influences (for a review, see Zimman, 2012). However, not all of these differences can be purely anatomically-driven, as children adopt gendered speech before vocal tract differences develop, and gendered voice features vary across cultures and within genders (Zimman, 2012). This suggests that socially constructed gender roles shape learned articulatory strategies in ways that reflect gender expression (Zimman, 2012).

2. LGB Speakers:

Building on this, it is also important to consider how speech patterns vary across sexual orientation. Initial research into lesbian, gay and bisexual speech patterns theorized that these speakers may adopt vocal characteristics associated with the opposite gender, likely because in (cisgender) men[1], the more feminine a speaker is perceived to sound, the more likely they are to be perceived as gay (Munson et al., 2006). Although speech styles associated with gay (cisgender) men may share some features with those typically associated with (cisgender) women, there is no conclusive evidence that they directly mirror female speech patterns (Munson et al., 2006). For instance, studies have found no significant differences in average pitch (fundamental frequency) between gay and straight (cisgender) men (Munson et al., 2006; Rendall et al., 2008). In fact, Zimman (2013) observed the opposite trend, with gay cisgender men producing lower pitch levels than their heterosexual counterparts—contrary to what would be expected if they were aligning with female speech patterns. Nevertheless, variation in speech related to sexual orientation has been documented across a range of acoustic features. Studies

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[1]Much of the literature on "male" and "female" speech does not specify whether transgender speakers were included. In this paper, "men" and "women" include trans men and women unless noted otherwise. When the term *cisgender* appears in parentheses—e.g., (cisgender) men—it indicates an assumed but unconfirmed cisgender identity. When *cisgender* appears without parentheses, the identity is explicitly known.

have reported that gay, lesbian, and bisexual speakers differ from heterosexual speakers in their use of vowel formant frequencies (Munson et al., 2006; Rendall et al., 2008), vowel space size among women (Pierrehumbert et al., 2004), segment duration among women (Willis, 2019), voice onset time, and voice quality among men (Zimman, 2013), to name a few.

3. *Transgender Speakers:*

Transgender individuals often engage in various strategies to align their external presentation with their gender identity (Zimman, 2013). These strategies may include both physical changes (e.g., hormone therapy) and learned behaviors, such as modifications in speech (Zimman, 2013). For example, trans men who undergo testosterone therapy typically experience a lowering of vocal pitch into a range associated with cisgender men (Zimman, 2012, 2013). However, post-transition speech patterns (for intentional and unintentional reasons) do not always fully align with cisgender norms; vowel formant frequencies, for instance, often remain distinct in trans men (Zimman, 2012). Moreover, creaky voice appears significantly more frequently in the speech of trans men (and gay cisgender men) than in that of straight cisgender men (Zimman, 2013). In a related vein, transgender women differ from cisgender women in several acoustic features including fundamental frequency (F_0), (vowel) formant frequencies, voice quality (specifically, glottal noise excitation), and segment duration (Menezes et al., 2024).

These patterns appear to be shaped, in part, by sexuality (Zimman, 2017). Many transgender speakers participate in queer spaces and may feel connected to a queer identity by virtue of their trans experience, which can result in speech that reflects a blend of gendered and queer influences (Zimman, 2017). Some adopt acoustic features associated with the queer identity, while others align more closely with binary norms, whether shaped by pre-transition gender socialization or post-transition fulfillment of their gender identity. As their gender and sexuality intersect in complex ways, trans speakers may develop hybrid styles that combine gendered and queer features or intentionally resist normative patterns to express uniquely trans identities (Steele, 2019).

4. ***Non-Binary Speakers:***

Although research on speech among gender non-conforming speakers outside of the male/female binary remains limited, several exploratory studies have begun to identify meaningful patterns. Some findings suggest that non-binary speakers may acoustically distance themselves from their gender assigned at birth (GAB) (Gratton, 2016; Steele, 2019). For instance, Merritt (2023) found that non-binary speakers (analyzed without grouping by GAB) had acoustic profiles distinct from both cisgender and transgender men and women. Some measures, such as fundamental frequency (F_0) and vowel formant frequencies, tended to fall within an intermediate range between cisgender men and women, but were generally higher than those of transgender speakers. Alternatively, Papeleu et al. (2025) found no significant differences in intonation parameters between non-binary (8 AFAB; 3 AMAB) and cisgender speakers, although they did not compare non-binary speakers to cisgender speakers matched by GAB. While these studies provide valuable insights, gender non-conforming speech remains underexplored—especially regarding potential differences between AFAB and AMAB non-binary speakers, and especially in relation to /s/ production. The /s/ is among the most well-studied features linked to gender and sexuality in American English, yet it has not been systematically examined among gender non-conforming speakers.

The Socially Marked ⟨s̪⟩:

Although there is individual variation among speakers, the American English /s/ is typically described as having an alveolar place of articulation and can either have a laminal or apical manner of articulation (Dart, 1998).

However, rather than examining articulatory placement, most studies investigating /s/ production have prioritized acoustic analyses—particularly spectral measures such as center of gravity (CoG) and spectral skew (Zimman, 2013). **Center of gravity** (also known as m_1 or weighted mean frequency) reflects the average frequency height in a spectrum (Stuart-Smith, 2007). It serves as an indicator of where energy is concentrated across the frequency range. A higher CoG indicates a concentration of acoustic energy in the higher frequencies (Jongman et al., 2000). **Skewness** (m_3 or spectral tilt) captures the asymmetry of the spectral energy distribution. A negative skewness value (below 0) suggests that more energy is concentrated in the higher frequencies, whereas a positive value (above 0) indicates greater energy in the lower frequencies (Zimman, 2013). Although CoG and skewness are often strongly correlated—where positive skewness indicates energy concentrated in lower frequencies and negative skewness in higher frequencies—this relationship is not always consistent (Jongman, 2000; Koenig et al., 2013).

These acoustic measures are closely linked to articulatory behavior. Research shows that more anterior tongue articulations tend to produce higher CoG values (and accordingly a more negative skewness) (Jongman et al., 2000; Gordon et al., 2002; Mack & Munson, 2012). This tendency is explained by the smaller cavity in front of the constriction for fronted sibilants, which leads to heightened resonance intensities in the front cavity (Gordon et al., 2002). However, CoG can also be influenced by other articulatory features, such as tongue shape (laminal vs. apical), lip rounding, or sublingual cavity space (the space below the tongue)

(Shadle et al., 2009; Toda et al., 2010). For example, among dental sibilants, laminal articulations exhibit higher spectral frequencies than apical ones; however, within alveolars, the opposite pattern has been observed (Dart, 1991, p. 83).

In Mack & Munson's (2012) perception experiment, a dentalized [s̪]—where the tongue tip contacts the lower incisors and the tongue lamina touches the upper incisors—was perceived as the most "gay-sounding." Additionally, a [θ] (th-like) realization was also rated as more gay-sounding, though this result did not reach statistical significance.

In popular culture, a non-standard /s/ pronunciation has often been stereotypically labeled as a "gay lisp" (Munson et al., 2006). According to the *Manual of Articulation and Phonological Disorders*, "lisping" refers to a speech pattern in which alveolar consonants are pronounced with the tongue either on or between the front teeth (Bleile, 2004, p. 71). A major challenge in studying queer speech styles is that they have historically been described in pejorative terms. Popular-culture depictions, particularly of male speech, frequently use the term "lisp," suggesting that the phenomenon is pathological, or misarticulated. According to Munson et al. (2006), this has been further compounded by research that appears to reinforce these negative stereotypes with the general public. Moreover, contemporary speech-language pathology texts have moved away from the term "lisping" due to its lack of specificity, and problematic connotations (Mack & Munson, 2012). In light of this, the current study deliberately avoids the term *lisp*, opting instead for precise acoustic descriptions based on spectral measures—specifically CoG and skewness. These measures have been key in previous research showing that gay cisgender men often (though not exclusively) produce /s/ sounds with higher spectral frequencies and more negatively skewed spectra than straight (cisgender) men (Munson et al., 2006; Zimman, 2013; Hazenberg, 2016). Therefore, what has been referred to as a "gay lisp" is more accurately described as a socially marked, high-frequency, negatively skewed, dental (or more anterior) ⟨s̪⟩. In this study, ⟨s̪⟩ denotes the socially marked variation, while /s/ represents the broader phonemic category of the voiceless alveolar sibilant in American English (which includes all recognizable /s/ variants). Bracketed notation [s̪] was deliberately avoided to emphasize that this articulation is not primarily motivated by phonetic or lexical context, but rather by social factors. Spectral skew is suggested to be the more reliable indicator of the ⟨s̪⟩ because gay-sounding (cisgender) men do not necessarily produce /s/ sounds with higher mean spectral frequencies; rather, their productions tend to exhibit a concentration of acoustic energy in the frequencies above the mean (Munson et al., 2006).

Interestingly, no significant difference in /s/ production was observed between gay and straight cisgender women (Munson et al., 2006; Hazenberg, 2016). However, evidence suggests that this high-frequency ⟨s̪⟩ is not limited to gay cisgender men. Research consistently shows that *overall,* cisgender women tend to produce /s/ with higher center of gravities and more negatively skewed spectra than cisgender men (for a review, see Flipsen et al., 1999; Fuchs & Toda, 2010; Zimman 2013; Hazenberg, 2016). Although evidence suggests that anatomical factors do play a role in this, these differences likely reflect social learning rather than anatomy alone (Fuchs & Toda, 2010). This is supported by findings that differences in /s/ frequency appear in childhood, before puberty-related vocal tract changes occur (Flipsen et al., 1999), and that these differences vary across languages (Gordon et al., 2002). Supporting this view, Zimman (2017) reported that a bilingual speaker produced different /s/ CoG values in each of their two languages.

Additionally, transgender speakers have been shown to use a higher-frequency ⟨s̪⟩ as a tool for modulating perceived femininity (Zimman, 2017). Trans men were found to generally pattern with cisgender men, producing lower-frequency /s/, while trans women patterned with cisgender women in CoG and skewness (Zimman, 2013; Hazenberg, 2016). However, Zimman (2017) found notable variation within this group: trans men who identified as queer tended to produce higher CoG values than those who identified as straight. Some trans men also adopted a higher-frequency ⟨s̺⟩ to position themselves in contrast to normative masculinity. While a high-frequency ⟨s̺⟩ typically indexed femininity when speakers were perceived as women, these trans men—once recognized as men, particularly post-transition—felt more comfortable using this feature to construct a masculinity that challenged hegemonic norms. This suggests that /s/ production is shaped by intersecting and sometimes competing influences of gender identity and sexual orientation.

The Present Study:

Building on prior research identifying acoustic correlates of sexual orientation and gender, this study investigates whether non-binary speakers produce a socially marked ⟨s̺⟩, and whether these patterns differ by assigned gender at birth (AFAB vs. AMAB). The central hypothesis is that gender non-conforming speakers will show differences in /s/ production—measured through center of gravity (CoG) and spectral skewness—compared to cisgender heterosexual speakers. Specifically, it is hypothesized that non-binary AMAB speakers will produce /s/ with higher CoG values and more negative skewness than their cisgender heterosexual AMAB counterparts, reflecting use of a socially marked high-frequency ⟨s̺⟩. For non-binary AFAB speakers, no directional hypothesis is proposed given competing possibilities: they may either pattern with cisgender heterosexual men (using a lower-frequency /s/ to distance themselves from femininity) or exhibit higher-frequency /s/ productions, reflecting alignment with broader queer speech styles.

Methods

Overview:

This study presents an acoustic analysis of center of gravity (CoG) and spectral skewness in American English /s/ productions by gender non-conforming speakers. Given the significant social—and sometimes biological—influences on /s/ production, non-binary speakers were compared to cisgender counterparts with the same gender assigned at birth (AFAB or AMAB). The analysis is based on publicly available podcast recordings (see *Podcast Selection* for details). Although this approach introduces variability in audio quality due to differing recording setups, methodological controls were applied to minimize these effects. Additionally, using existing data avoids the labor-intensive challenge of traditional speaker recruitment. All research procedures were reviewed and approved by the Ethics Review Board of the University of Amsterdam (Ethics Application No. FGW-6299). Appropriate public notice was issued in accordance with ethical guidelines for research using publicly accessible data (see *1.1 Public Notice* in Appendix). This notice provided information on the nature of the study, data handling practices, and options for opting out.

Audio Selection:

Several methodological considerations were accounted for when considering the choice of the source audio. Acoustic measures can be impacted by many factors such as recording device quality, microphone type, background noise, and individual speaker differences (Deliyski et al., 2005). Given that acoustic analysis has been shown to be relatively unreliable when using audio from video conferencing platforms such as Zoom (Zhang et al., 2021), and Skype (Bulgin et al., 2010), podcasts were selected as the primary data source. While recordings uploaded to YouTube were considered, the platform's audio processing remains unclear. Research suggests that compressed audio can significantly differ from lossless recordings, potentially making it unreliable for detailed phonetic analysis (Bulgin et al., 2010). De Decker & Nycz (2011) found that uploading already-compressed files to YouTube didn't noticeably degrade quality further, but noted that YouTube likely applies its own compression during upload—meaning the impact depends on the original file's quality.

The podcasts selected for this study were commercially produced and assumed to be recorded using professional equipment in controlled environments designed for production-quality audio. While specific details about the microphones or recording setups were not available, a baseline level of audio quality was assumed given the commercial nature of the material, though this cannot be confirmed. All audio was manually screened to ensure that audio samples were recorded with a sampling rate of at least 44.1 kHz (corresponding to a Nyquist frequency of 22.05 kHz) following practices described by Munson et al. (2006), Fuchs and Toda (2010), and Steele (2019). Since CoG is limited to a maximum of half of the sampling rate, comparing CoG values across studies with inconsistent sampling rates is challenging (Koenig et al., 2013). Only tokens judged to have clear audio quality—those free from substantial background noise or music—were included in the analysis.

Podcast Selection:

The majority of the data for this study was sourced from the podcast *Gender Reveal*, based in Portland, Oregon. This podcast was chosen specifically because it features interviews with a diverse range of trans and gender non-conforming speakers across the United States, focusing primarily on their experiences of gender identity and expression. According to the hosts, guests are recruited through personal networks, social media, listener suggestions, PR contacts, and grant applications, with a deliberate emphasis on including Black, Indigenous, Latine (or Latinx), and other people of color, as well as a range of gender identities, including trans women, trans men, and non-binary speakers. Since *Gender Reveal* included few cisgender speakers, additional data was sourced from two other podcasts that were chosen because they regularly featured couples as guests. The first source, *Where Should We Begin?*, is a New York City–based podcast hosted by Esther Perel. This relationship-centered series presents anonymized couples' therapy sessions involving both same-sex and heterosexual partners. All identifying information was removed prior to publication and was not accessible to the researcher. The second source, *Let's Talk Love*, hosted by Robin Ducharme, features interviews with couples and relationship experts, exploring the complexities of love, communication, and partnership.

Speaker Selection:

All speakers (N = 42) self-identified as either cisgender (n = 22) or non-cisgender (n = 20). Speakers who did not identify as cisgender used a wide range of gender identity labels, and often described themselves using multiple terms. For example, some speakers identified as both transgender and non-binary, while others solely identified as non-binary (See *3.1 Raw Data - Speaker Information* in Appendix). Pronoun usage informed categorization: speakers who used or accepted gender-neutral pronouns (they/them) to describe themselves were categorized as NON-BINARY, following a broad usage of the term. This categorization does not assume that the speakers individually identified with the label *non-binary* (and in some cases not). Those who exclusively used binary pronouns (he/him or she/her) were categorized as either CISGENDER (if pronoun use aligned with GAB) or as TRANSGENDER (if pronoun use differed from their GAB). Only CISGENDER and NON-BINARY speakers were considered for analysis. Cisgender speakers who did not identify as heterosexual were excluded from the analysis. Sexual orientation was not considered for non-cisgender speakers. Since this study was group matched by GAB, normalization of CoG and skewness values was deemed unnecessary.

In cases where the speakers' gender (both gender identity and GAB) was not explicitly stated, inferences were made based on available indicators. For gender identity this included pronoun usage, and for AMAB/AFAB status this included (but was not limited to), references to conception/giving birth, references to genitalia, and reflections on childhood gender experiences (see *3.2 Raw Data – Phrases Used to Identify GAB* in Appendix). Speakers whose gender identity or GAB could not be inferred were excluded from the analysis.

Cisgender speakers often did not explicitly disclose their sexual orientation. In these cases, heterosexuality was assumed based on two main criteria: (1) past or present participation in a heterosexual relationship, and (2) references to romantic or sexual involvement with a member of the opposite gender identity. Even with these criteria, some speakers may have identified as queer or bisexual, so some degree of misclassification cannot be ruled out.

To minimize dialectal effects, only /s/ tokens bordered by vowels from the General American English vowel inventory—or with no adjacent sound—were included (see *Table 1* under Token Selection). Tokens bordering vowel productions characteristic of other varieties (e.g., dialect-specific vowels from North-Central American & Canadian English, Southern & African American Vernacular English, or Chicano English) were excluded from analysis. Speakers were sourced from across the U.S. and were evaluated by the researcher (a U.S.-raised L1 speaker of English with experience coaching American accent performance for L2 English speakers) as producing L1 pronunciations of American English. When explicit information about speakers' regional background was unavailable, birthplace or formative linguistic environment was inferred based on dialectal features or publicly accessible biographical sources (when available). Additional language background was not considered. Only those who did not exhibit speech or language disorders based on their recorded speech were included. While exact ages were generally unknown, speakers were presumed to be adults between the ages of 20 and 50 (see *3.1 Raw Data - Speaker Information* in Appendix). No speakers who identified as minors (under 18) were included in the analysis. While some speakers disclosed indicators of socioeconomic status, these were not recorded or incorporated into the analysis.

Token Selection:

To account for intra-speaker variability, each speaker provided minimally two tokens, with no fixed upper limit. Consequently, the total number of tokens varied across speakers. Since the spectral shape of a sibilant is influenced by neighboring vowels, consonants (Niebuhr et al. 2011), and syllable position (Chodroff & Wilson, 2022), only instances of the word "so" were selected for analysis to ensure a relatively consistent articulatory environment. The choice of "so" was motivated by its high frequency in conversational speech, ensuring that enough tokens could be sourced. Both conjunction and adverbial uses of "so" were considered. Tokens were found using transcripts provided by the podcast creators. However, because "so" often functions as a filler word, it is possible that some instances were omitted during transcription and therefore not captured in the dataset. Special attention was paid to the word immediately preceding "so", and only tokens that started a turn of speech or came after vowels were included in the analysis. Since vowels are often sustained sounds with clear formant patterns, they were chosen because it is easier to label their boundaries accurately. When analyzing six vowels (/i, e, æ, ɑ, o, u/), Jongman at al. (2000) found that the center of gravity for /s/ was significantly lower in the context of the back rounded vowels /o/ and /u/. Based on this, vowel contexts in the current study were grouped into four categories: FRONT (/i, ɪ, eɪ, ɛ, æ/), CENTRAL (/ə/), and BACK (/u, ʊ, ʌ, oʊ/), and NONE (∅). Tokens of "so" before diphthongs of multiple articulatory classes (/aɪ/, /ɔɪ/, /aʊ/) were excluded from the analysis. Additionally, /ɑ/ and /ɔ/ were excluded due to the potential effects of the cot–caught merger. If /ɔ/ is present in a speaker's vowel inventory, it could cause /ɑ/ to be produced more centrally.

Table 1: *General American Vowel Inventory. Vowels in light grey were not included for analysis.*

	FRONT		CENTRAL	BACK	
Close	ɪ	i		ʊ	u
Mid	ɛ	eɪ	ə	ʌ	oʊ
Open	æ		ɑ (ɔ)		
Diphthongs			aɪ ɔɪ aʊ		

Spectral Frequency Measuring:

The word preceding the /s/ token and the word containing the token (which was always "so") were extracted using the speech analysis software Praat (Boersma & Weenink, 2025), and subsequently aligned with the Montreal Forced Aligner using a pre-trained American English model (`english_us_arpa`) (McAuliffe et al., 2017). Onset and offset boundaries were determined using the aligner and manually verified. Since spectral moments vary across a sibilant's duration—likely due to phonetic context (Flipsen et al., 1999)—the analysis focused on a window between 10% before and after the midpoint to minimize coarticulatory effects (20% of the total sibilant duration). Acoustic measures for CoG and skewness were found automatically with a script (see *2.1 Praat Script for CoG and Skewness Extraction* in Appendix) developed by Vet (2025) and used in Praat (Boersma & Weenink, 2025). Each token was analyzed within a band-pass frequency range of 1000 Hz to 22,050 Hz, following practices in Steele (2019), Cuddy (2019), and Podesva & Van Hofwegen (2016). Spectral energy in adult-produced sibilants have been reported up to 15,000 Hz (Toda et al., 2010), and this frequency window effectively captures the frequencies that distinguish dental and alveolar sibilants (Mack & Munson, 2012). Additionally, excluding lower frequencies reduces the influence of voicing—specifically F_0 and its associated low-frequency harmonics—which might otherwise lower the CoG artificially (Niebuhr et al., 2011).

Statistical Analysis:

After CoG and skewness were measured for each token, a series of linear mixed-effects regression analyses were conducted in RStudio using the lme4 package (RStudio Team, 2025). All statistical tests were evaluated using an alpha level of $\alpha = 0.05$ and p-values were calculated using Satterthwaite approximations via the lmerTest package (Kuznetsova et al., 2017). Results with p-values between 0.05 and 0.10 are reported as marginally significant and interpreted as potential trends, but are **not** conclusive effects. The primary between-speaker factors were gender identity, CISGENDER vs. NON-BINARY; and GAB, AFAB vs. AMAB. To account for potential influencing variables, the analyses controlled for preceding vowel type, and the grammatical function of "so" (adverbial or conjunctional) as within-speaker factors.

To interpret model coefficients in line with the study's hypotheses, custom contrast coding was applied to several categorical variables.

Vowel type was initially modeled as a four-level factor (FRONT, CENTRAL, BACK, NONE) with FRONT vowels as the reference level (see *4.1 Trial Model – Vowel Type* in Appendix). However, this model produced a singularity, and CENTRAL vowels showed the least statistical influence ($p = 0.576$). As a result, CENTRAL vowels were grouped with FRONT vowels to simplify the model. While back vowels were expected to lower CoG values, it was unknown if tokens without any preceding words (∅) would show higher or lower values. Contrast coding was set such that back vowels were assigned positive values. Vowel categories were coded as follows: *Front*, *Back*, and *None (∅)*, with *Front* as the reference level.

```
[-1/3, 1/3] (Front); [2/3, 1/3] (Back); [-1/3, -2/3] (None (∅)).
```

For "so" type, no directional hypothesis was made regarding its effect on CoG or skewness. Contrast coding was applied with *conjunctions* as the reference category.

```
[-0.5] (Adverb); [+0.5] (Conjunction)
```

Regarding speaker variables, gender assigned at birth was coded to reflect the expectation that AFAB speakers would show higher CoG and more negative skewness values; AFAB was coded positively.

```
[-0.5] (AMAB); [+0.5] (AFAB)
```

Similarly, gender identity was contrast coded so that non-binary speakers were compared against cisgender speakers, with the expectation that non-binary speakers—particularly AMAB non-binary speakers—might show higher CoG values.

```
[-0.5] (Cisgender); [+0.5] (Non-binary)
```

The model included random intercepts for Speaker to account for individual variability in /s/ production. An initial model with random slopes for vowel type and "so" type by Speaker was tested, but the model was simplified by removing the intercept for vowel type due to convergence issues.

```
model <- lmer(CoG/Skewness ~ Gender_ID * GAB + So_Type + Vowel_Type + (1 +
So_Type | Speaker), data = data)
```

While an interaction model formally tests whether the effect of gender identity depends on GAB (in other words, it questions whether the *AMAB difference* is bigger or smaller than the *AFAB difference*)—it might not capture patterns where groups align along a more linear continuum. To address this, a single model was implemented using sliding difference contrasts, applied with the *MASS* package (Venables & Ripley, 2002). Groups were coded to reflect a hypothesized progression in /s/ production (from lowest CoG and most positive skewness to highest CoG and most negative skewness): AMAB cisgender < AMAB non-binary < AFAB non-binary < AFAB cisgender. Each group was compared to its immediate neighbor using the following contrasts:

```
[-1, +1, 0, 0] (AMAB non-binary vs. AMAB cisgender)
[0, -1, +1, 0] (AFAB non-binary vs. AMAB non-binary)
[0, 0, -1, +1] (AFAB cisgender vs. AFAB non-binary)
```

This coding provides a clearer assessment of trends across the gender identity and GAB spectrum—patterns that might otherwise be obscured in a standard interaction framework. Following this additional model, post-hoc analyses were performed to explore additional group comparisons.

```
model <- lmer(CoG ~ Group + (1 | Speaker), data = data)
summary(model)
```

Results

Overview:

The purpose of this experiment was to examine whether non-binary speakers (split by gender assigned at birth) would produce /s/ with higher center of gravity (CoG) values and more negative skewness than their cisgender heterosexual counterparts, reflecting the use of a socially marked ⟨s̺⟩.

Data Summary:

1. ***Speakers, Tokens, and Podcasts:***

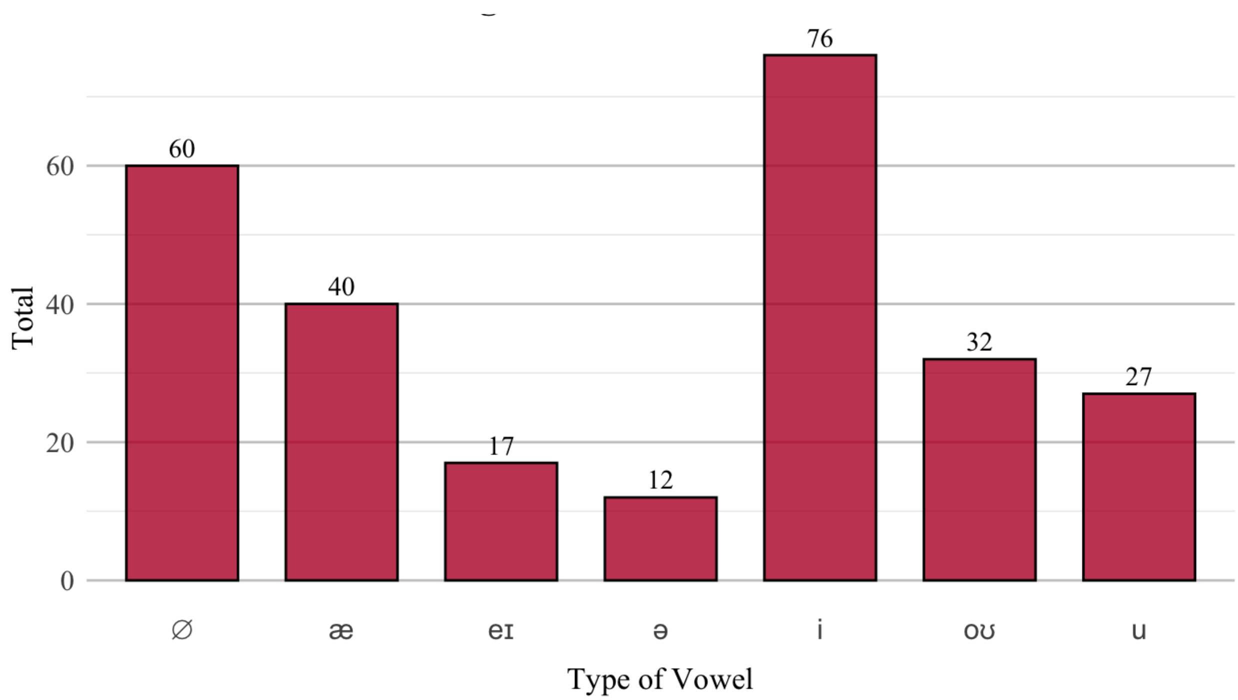
In total, 42 speakers and 264 speech tokens were included for analysis. The number of tokens per speaker ranged from 2 to 20, with an average of 6.28 tokens. 20 tokens were excluded due to crosstalk or extraneous background noise. All CoG values fell within the typical range as defined by the interquartile range method (IQR), with no tokens below 3,553 Hz or above 11,652 Hz (calculated as Q1 – 1.5×IQR and Q3 + 1.5×IQR, respectively). In contrast, 11 tokens had skewness values outside the corresponding IQR bounds (below –1.575 or above 2.545). These tokens were retained in the analysis, as their extreme values may reflect meaningful sociophonetic variation rather than measurement error.

Table 2: *Data broken down by speaker and podcast.*

Speaker Data		**Speakers**	**Tokens**
Cisgender (Heterosexual)	AMAB	10	48
	AFAB	12	48
Non-Binary	AMAB	9	67
	AFAB	11	101
Podcast Data			
Podcast A – *Gender Reveal*		20	169
Podcast B – *Where Should We Begin?*		19	69
Podcast C – *Let's Talk Love*		3	26
Total Data			
		42	264

The most frequently occurring vowel in the dataset was /i/. No tokens were found following the vowels /ʊ, ɪ, ɛ, ʌ, ɔ, ɔɪ/. Disqualified tokens were relatively rare, with only 2 instances of /ɑ/, 7 of /aɪ/, and 4 of /aʊ/ occurring before "so."

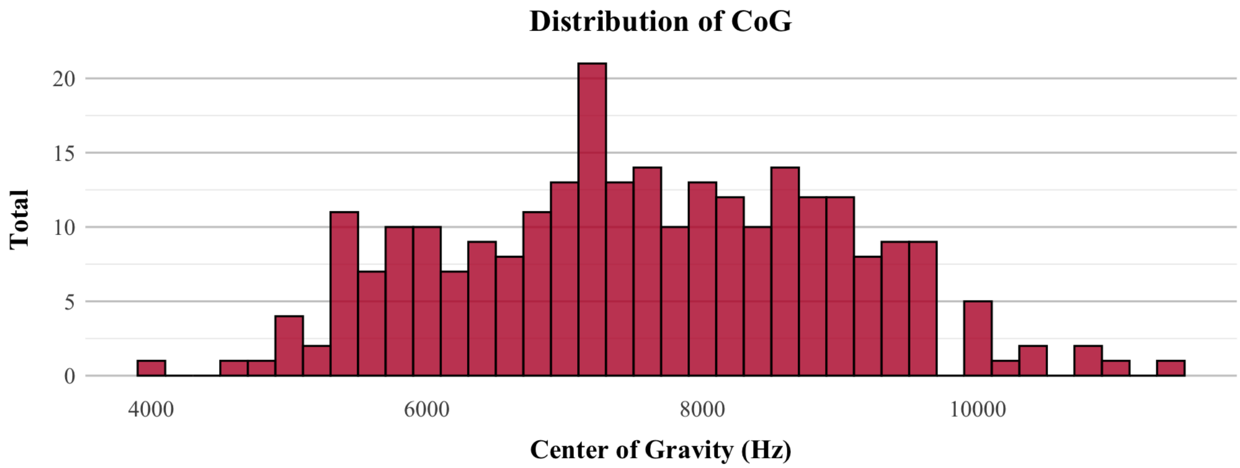
Figure 1: *Frequency of qualifying vowels before "so."*



2. CoG and Skewness:

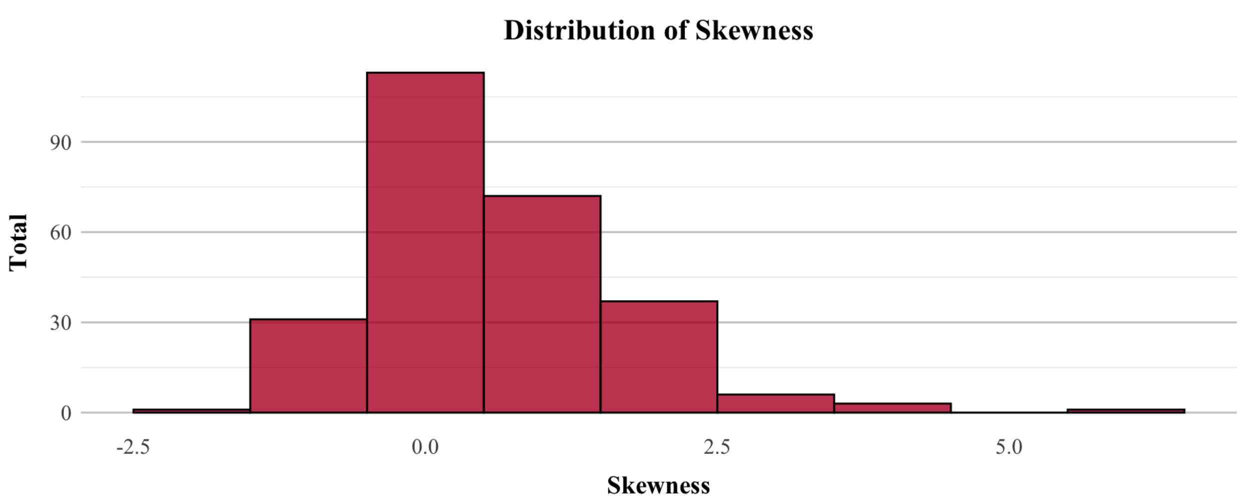
The overall distribution of CoG values (*Figure 2*) aligns with previously reported acoustic measurements of American English /s/. While spectral energy in adult-produced sibilants can extend up to 15,000 Hz (Toda et al., 2010), they generally fall between 4500 and 9000 Hz (Fuchs & Toda, 2010). In the present dataset, CoG values ranged from 4,053 Hz to 11,416 Hz, broadly consistent with these prior findings.

Figure 2: *Total distribution of CoG per token (bounded by Nyquist frequency limit of 22.05 kHz).*



The overall distribution of skewness (*Figure 3*) shows more positive values than typically expected. For example, Fuchs and Toda (2010) report skewness values for AMAB speakers ranging from –0.47 to 0.06 (average –0.25) and for AFAB speakers from –1.23 to –0.47 (average –0.85). In this study, AMAB speakers ranged from –2 to 6 (average 0.89) and AFAB speakers from –1 to 4 (average 0.46).

Figure 3: *Total distribution of skewness per token. Note that skewness values outside the range of -1 to +1 were rounded to the nearest whole number during data processing.*



The distribution of CoG (*Figure 4*) is reported across four gender groups defined by the combination of GAB and gender identity. As expected, AFAB speakers produced a higher average CoG (+1448.5 Hz) than AMAB speakers. Within the AFAB group, cisgender speakers exhibited the highest CoG values, followed closely by non-binary AFAB speakers. Among AMAB speakers, cisgender speakers showed the lowest CoG values, while AMAB non-binary speakers fell between the AMAB cisgender group and both AFAB groups.

Figure 4: *Density distribution of CoG by Gender ID and GAB*

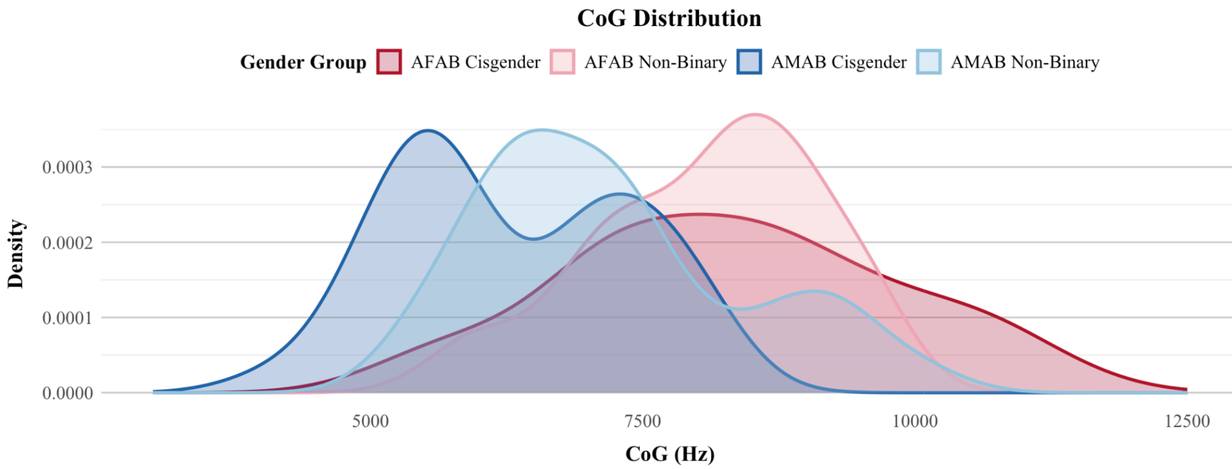


Table 3: *Summary data of **CoG** per group (For each column, **darker shades** indicate higher values and **bold** indicates the highest value).*

Group		Mean	SD	Median	Min.	Max.
AFAB	NON-BINARY	8087	1042	**8260**	**5480**	9980
	CISGENDER	**8316**	**1504**	8229	5392	**11416**
AMAB	NON-BINARY	7211	1225	7078	5279	10081
	CISGENDER	6295	1093	5914	4053	8215
All Speakers		7581	1393	7551	4053	11416

The distribution of skewness (*Figure 5*) is also reported across these four gender groups. As expected, AFAB speakers produced a more negative skew (–0.43) than AMAB speakers.

Unexpectedly, the cisgender group (both AFAB and AMAB) showed more positive skewness values than the non-binary group.

Figure 5: *Density distribution of skewness by Gender ID and GAB. Note that skewness values outside the range of -1 to +1 were rounded to the nearest whole number during data processing.*

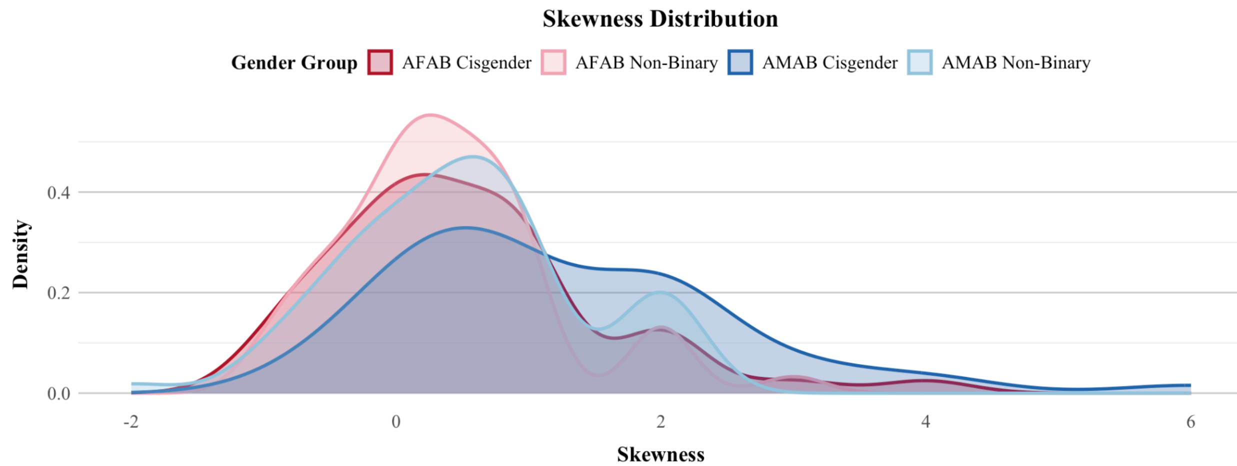


Table 4: *Summary data of **skewness** per group (For each column, **darker shades** indicate higher values and **bold** indicates the highest value).*

Group		Mean	SD	Median	Min.	Max.
AFAB	NON-BINARY	0.39	0.81	0.3	-1	3
	CISGENDER	0.53	1.02	0.35	-1	4
AMAB	NON-BINARY	0.51	0.89	0.5	-2	2
	CISGENDER	**1.27**	**1.32**	**1**	**-0.7**	**6**
All Speakers		0.6	1.02	0.5	-2	6

Statistical Results:

1. Relationship Between CoG and Skewness:

A negative relationship between CoG and skewness was observed. A Pearson's product-moment correlation was used to test this relationship, and the correlation was found to be statistically significant (*Table 5*). The same pattern was observed and tested for the AFAB group, with similarly significant results.

Table 5: *Pearson correlation statistics between CoG and skewness.*

GAB	Correlation	CI 95% (Lower)	CI 95% (Upper)	*t*-value	*p*-value	Significance
AMAB	-0.704	-0.76	-0.64	-16.06	< 0.001	***
AFAB	-0.624	-0.71	-0.51	-9.68	< 0.001	***

2. CoG:

For CoG (*Table 6*), the model revealed a significant main effect of GAB ($p < 0.001$). AFAB speakers produced higher CoG values approximately +1,312 Hz higher than AMAB speakers. There was no significant main effect of gender identity: non-binary speakers produced CoG values +407 Hz higher on average than cisgender speakers, but this difference was not statistically significant ($p = 0.170$). The interaction between gender identity and GAB showed a trend toward significance ($p = 0.084$; $0.05 < p < 0.10$). The difference between non-binary and cisgender speakers in CoG was smaller by approximately +1,034 Hz among AFAB speakers compared to AMAB speakers. No significant effects were observed for the grammatical function of "so" ($p = 0.885$), or for vowel type comparisons: back vs. front vowels ($p = 0.815$), and front vowels vs. no preceding vowel ($p = 0.951$).

Table 6: *Linear mixed effects regression model results of **CoG** (in Hertz).*

Predictor	Estimate	Std. Error	CI 95% (Lower)	CI 95% (Upper)	*t*-value	*p*-value	Significance
(Intercept)	7345	160.73	7032.05	7651.92	45.70	< 0.001	***
Gender ID (+NB -CIS)	407	291.56	-148.63	963.92	1.40	0.170	
GAB (+AFAB -AMAB)	1312	291.69	756.78	1871.22	4.50	< 0.001	***
So Type (+CONJ -ADV)	-24	165.22	-363.51	332.68	-0.15	0.885	
Vowel Type (+BACK -FRONT)	32	136.48	-240.46	296.27	0.23	0.815	
Vowel Type (+FRONT -NONE)	09	148.41	-284.62	296.27	0.06	0.951	
Gender ID*GAB (+NB -CIS) (+AFAB -AMAB)	-1034	583.51	-2167.52	88.06	-1.77	0.084	. (trend)

3. Skewness:

For skewness (*Table 7*), the model revealed that both gender identity and GAB showed trends toward significance ($0.05 < p < 0.10$) for predicting skewness. Non-binary speakers produced skewness values that were, on average, –0.428 lower than cisgender speakers ($p = 0.062$). Similarly, AFAB speakers produced skewness values that were –0.442 lower than AMAB speakers ($p = 0.054$). No significant effects were found for grammatical function of “so” ($p = 0.558$) or vowel type comparisons: back vs. front vowels ($p = 0.827$) and front vowels vs. no preceding vowel ($p = 0.469$). The difference between non-binary and cisgender speakers appeared larger among AFAB speakers than among AMAB speakers (by +0.447). Though this interaction between gender identity and GAB was not significant ($p = 0.321$).

Table 7: *Linear mixed effects regression model results of* ***skewness***.

Predictor	Estimate	Std. Error	CI 95% (Lower)	CI 95% (Upper)	*t*-value	*p*-value	Significance
(Intercept)	0.677	0.126	0.435	0.921	5.37	< 0.001	***
Gender ID (+NB -CIS)	-0.428	0.222	-0.851	-0.006	-1.93	0.062	. (trend)
GAB (+AFAB -AMAB)	-0.442	0.222	-0.876	-0.013	-1.99	0.054	. (trend)
So Type (+CONJ -ADV)	0.103	0.174	0.237	0.459	0.59	0.558	
Vowel Type (+BACK -FRONT)	-0.029	0.133	-0.287	0.237	-0.22	0.827	
Vowel Type (+FRONT -NONE)	-0.103	0.142	-0.377	0.179	-0.73	0.469	
Gender ID*GAB (+NB -CIS) (+AFAB -AMAB)	0.447	0.444	-0.405	1.31	1.01	0.321	

4. Post-Hoc Ordered Group Comparisons:

For CoG (*Table* 8), the post-hoc model revealed a significant effect of gender identity within AMAB speakers and a trend-level effect among non-binary speakers. AMAB non-binary speakers produced CoG values that were, on average, +909 Hz higher than AMAB cisgender speakers ($p < 0.05$). AFAB non-binary speakers, in turn, produced CoG values that were +818 Hz higher than AMAB non-binary speakers, showing a trend toward significance ($p = 0.056$). The difference between AFAB cisgender and AFAB non-binary speakers was small (+105 Hz) and not significant ($p = 0.791$).

Table 8: *Sliding contrast estimates for **CoG**.*

Term	Estimate	Std. Error	CI 95% (Lower)	CI 95% (Upper)	*t*-value	*p*-value	Significance
(Intercept)	7334	146.29	7054.5	7613.77	50.13	< 0.001	***
AMAB NB vs AMAB CIS	909	433.73	80.40	1737.26	2.10	< 0.05	*
AFAB NB vs AMAB NB	818	414.92	25.69	1610.44	1.97	0.056	. (trend)
AFAB CIS vs AFAB NB	105	392.78	-645.19	855.53	0.27	0.791	

For skewness (*Table 9*), the post-hoc model revealed a significant difference between AMAB non-binary and AMAB cisgender speakers. AMAB non-binary speakers produced skewness values that were, on average, –0.674 lower than AMAB cisgender speakers ($p < 0.05$). No significant differences were found between AFAB non-binary and AMAB non-binary speakers ($p = 0.433$), nor between AFAB cisgender and AFAB non-binary speakers ($p = 0.535$).

Table 9: *Sliding contrast estimates for **skewness**.*

Term	Estimate	Std. Error	CI 95% (Lower)	CI 95% (Upper)	*t*-value	*p*-value	Significance
(Intercept)	0.714	0.111	0.502	0.926	6.43	< 0.001	***
AMAB NB vs AMAB CIS	-0.674	0.329	-1.302	-0.046	-2.05	< 0.05	*
AFAB NB vs AMAB NB	-0.247	0.31	-0.839	0.346	-0.79	0.433	
AFAB CIS vs AFAB NB	0.187	0.298	-0.382	0.755	0.63	0.535	

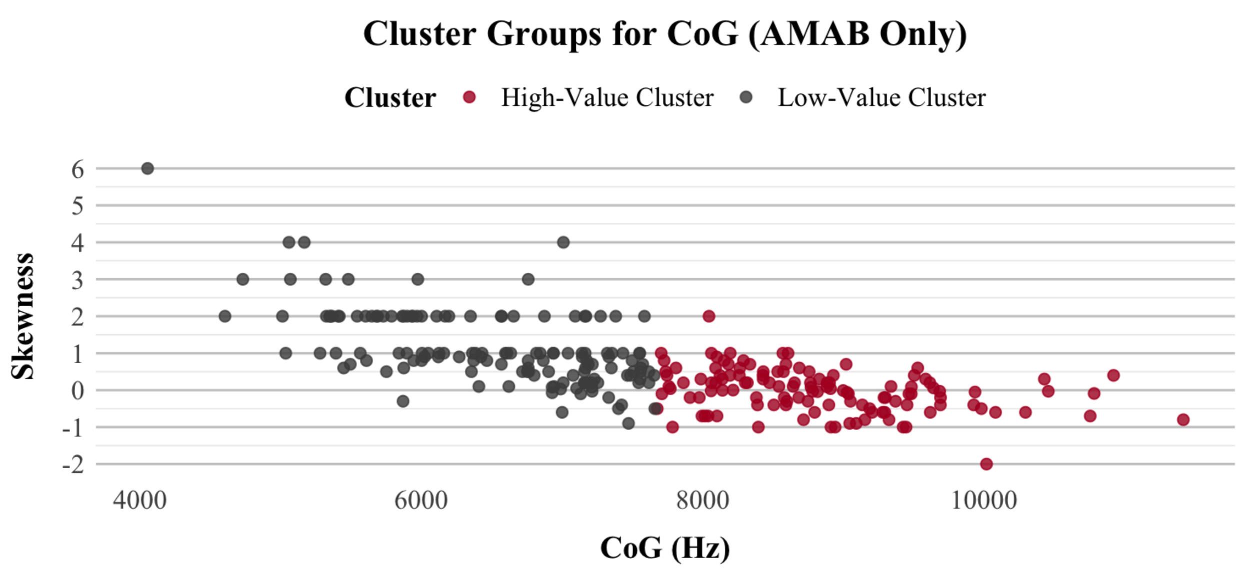
Exploratory Post-Hoc Analysis of Bimodal Patterns:

Interestingly, an unexpected bimodal pattern emerged in both CoG and skewness, with the effect most pronounced in AMAB speakers for CoG. Among cisgender AMAB speakers, two distinct peaks appeared in CoG values: one between 5000–6000 Hz and another between 7000–8000 Hz.

AMAB non-binary speakers showed a similar pattern, though shifted slightly higher, with peaks between 6000–7000 Hz and 8000–9000 Hz. While a minimal "shoulder" was visible among AFAB speakers, this effect was far less pronounced compared to the AMAB group.

To explore this unexpected pattern further, a post-hoc K-means clustering analysis was conducted on the AMAB speakers (since they were the most pronounced), dividing the data into higher and lower CoG value groups (*Figure 6*).

Figure 6: *CoG Cluster groups for AMAB speakers. Note that skewness values outside the range of -1 to +1 were rounded to the nearest whole number during data processing.*



When broken down by vowel and "so" type, these factors did not appear to account for the bimodal pattern observed in CoG distributions. *Table 10* displays the frequency of tokens by cluster membership across "so" and vowel type. Both clusters contained a mix of adverbial and conjunctional tokens, as well as a range of vowel types, with no obvious pattern that would explain the emergence of two peaks.

Table 10: *Counts of "So" Type and Vowel Type tokens by cluster membership (low- and high-value CoG groups).*

Cluster	Adverb		Conjunction	
Low-Value	11		43	
High-Value	6		55	
	Back	**Central**	**Front**	**None (∅)**
Low-Value	7	3	29	15
High-Value	11	3	28	19

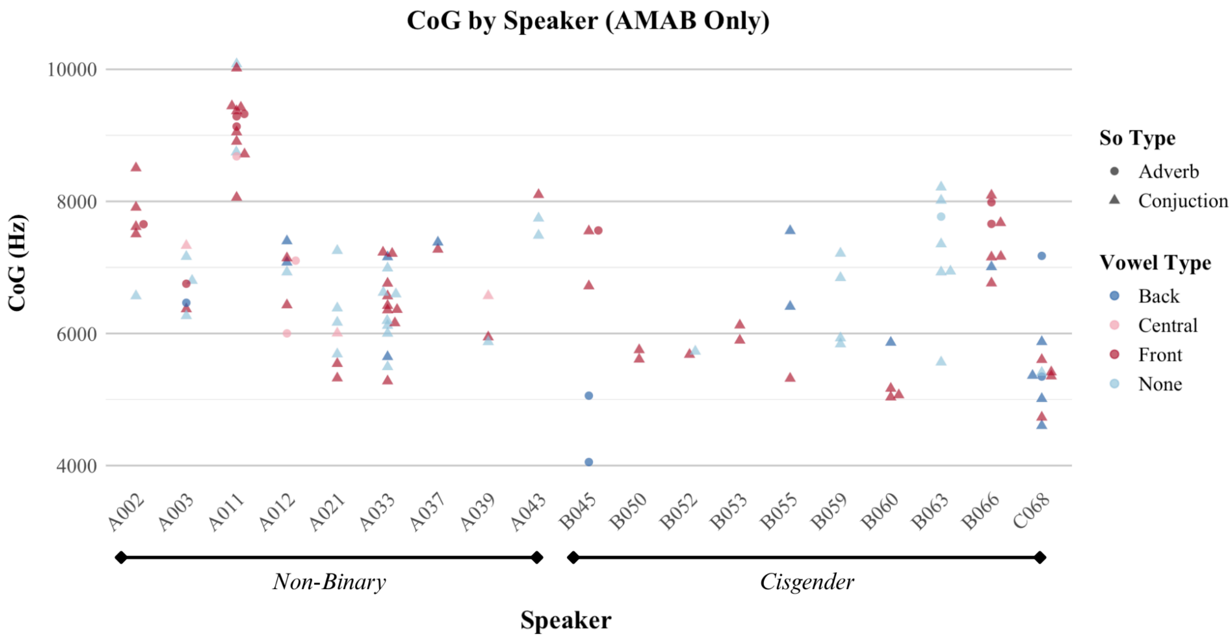
This impression was supported by statistical tests (*Table 11*). A chi-square test of independence showed no significant association between cluster membership and "so" type (p = 0.19), nor between cluster membership and vowel type (p = 0.81).

Table 11: *Results of Chi-square test statistics for CoG cluster membership.*

Comparison	Chi²	*p*-value	df	Significance
Vowel Type vs. Cluster	0.95	0.81	3	
So Type vs. Cluster	1.76	0.19	1	

In order to determine whether this effect was driven by variation within speakers or between speakers, individual CoG tokens were plotted by speaker (*Figure 7*). Most speakers exhibited a relatively wide range of CoG values without clear concentrations. One non-binary speaker (A011) exhibited higher values than other speakers, but did not meet criteria for being classified as an outlier.

Figure 7: *Individual CoG values plotted by speaker for AMAB speakers.*



Discussion

This study aimed to investigate whether gender non-conforming speakers produce a socially marked ⟨s̺⟩ by analyzing CoG and skewness.

Effects of Linguistic Controls:

As part of this analysis, vowel type and "so" type were examined to assess its potential influence on these spectral characteristics. While vowel type did influence spectral characteristics to some extent, the effects were relatively small and likely do not indicate substantial acoustic differences. Tokens without preceding vowels exhibited the lowest CoG and most positive skewness values, suggesting that vowel coarticulation tends to decrease CoG and increase skewness. Among vowel contexts, tokens following back vowels showed slightly elevated CoG (+32 Hz) and more negatively skewed spectra (–0.029). In contrast, front vowels were associated with lower CoG and more positively skewed spectra. These patterns differ from Jongman et al.'s

(2000) findings, which reported a lower CoG in the context of back rounded vowels. However, since the effects observed in the present study were not statistically significant, they should be interpreted with caution.

The grammatical function of “so” (conjunction or adverb) was not found to significantly affect CoG or skewness. While adverbial uses showed a slight increase in CoG (+24 Hz) and a small decrease in skewness (–0.103), these effects were not statistically significant, and any potential articulatory differences across grammatical contexts remain uncertain.

Evidence of a Socially Marked ⟨s̪⟩:

In this study, as anticipated, AFAB speakers exhibited significantly higher CoG values than their AMAB counterparts, as well as a tendency toward a more negative skew. These findings are broadly consistent with prior research reporting similar patterns comparing speakers based on gender assigned at birth (GAB) (Flipsen et al., 1999; Fuchs & Toda, 2010; Zimman, 2013; Hazenburg, 2016). Although the difference in skewness was only marginally significant (not generalizable to the entire population), it suggests a potential effect that warrants further investigation with a larger sample, as it may reflect a meaningful pattern in the acoustic realization of /s/.

When analyzing the interaction between gender identity and GAB (rather than GAB alone), a gradient in CoG values emerged: cisgender AFAB speakers produced the highest CoG values, followed by AFAB non-binary speakers, AMAB non-binary speakers, and finally cisgender AMAB speakers. The difference between non-binary and cisgender speakers was smaller by about –1034 Hz among AFAB speakers compared to AMAB speakers—a trend that approached, but did not reach significance.

The pattern for skewness differed slightly: while cisgender AMAB speakers had the most positive skewness values, cisgender AFAB speakers also showed more positive values than AMAB non-binary speakers, with AFAB non-binary speakers exhibiting the lowest skewness overall. This result is noteworthy given that skewness is generally found to correlate with CoG (Jongman et al., 2000; Koenig et al., 2013), which would lead us to expect AFAB cisgender speakers to exhibit the lowest (most negative) skewness values. When analyzing the interaction for skewness between gender identity and GAB, the difference between non-binary and cisgender speakers appeared larger among AFAB speakers than among AMAB speakers (by approximately +0.447). However, this effect did not reach statistical significance, and cannot be generalized to the broader population without further research.

These results seem to tentatively suggest that non-binary people are producing a socially marked ⟨s̪⟩ that is acoustically similar to the ⟨s̪⟩ that cisgender women and gay cisgender men were found to produce (Munson et al., 2006; Zimman, 2013, 2017). AMAB non-binary speakers might be employing similar articulatory strategies—whether intentionally or unintentionally—as a form of alignment with broader non-straight and non-male speech norms. Additionally, since no evidence was found to suggest substantial differences in AFAB /s/ productions, this may indicate that, for AFAB non-binary speakers, distancing from straight male-associated norms is prioritized over dealignment with female ⟨s̪⟩ production. This finding is also consistent with post-hoc analyses, which revealed no evidence of acoustic differences in /s/ production between the AFAB groups or between the non-binary groups. In contrast, a significant difference (+909 Hz for CoG and –0.674 for skewness) emerged between non-binary AMAB speakers compared to their cisgender, heterosexual AMAB counterparts. Both of these patterns may indicate an emerging shared sociolect between females, queer people, and non-binary people. However, given the limited sample size, this interpretation remains provisional, and further research with a larger, more representative sample would be necessary to confirm the robustness of this effect.

If this finding is substantiated, it is likely that the lower-frequency ⟨s⟩ observed in some trans men and heterosexual cisgender men (Zimman, 2013) functions as a gender-affirming signal that aligns with dominant masculine norms. This perspective helps explain why, in this study, cisgender men exhibited an average CoG that was –1576 Hz lower than the combined average of the other three groups, along with a skewness value that was +0.79 more positive. It would also help explain the absence of /s/ frequency differences between gay and cisgender women in other studies (Munson et al., 2006; Hazenberg, 2016); a lower-frequency ⟨s⟩ may inadvertently signal masculinity, and further fronting (leading to even higher frequencies) may not provide a salient (or even articulatory feasible) social contrast against heterosexual women.

One possible explanation for the existence of this potential sociolect lies in accommodation theory, which posits that people often adjust to the speech patterns of their communities (Giles et al., 1991). If someone spends more time in queer spaces, they might pick up stylistic features common in that community—even if those features originated in other groups. This dynamic is possible given evidence that many cisgender women report feeling more at ease in queer spaces because they feel less threatened by queer men, and they share experiences of marginalization (Grigoriou, 2004).

Evidence of Bimodal Distribution:

Returning to the acoustic data, the /s/ center of gravity values (and skewness to a lesser extent) did not appear unimodal; rather, the figures suggested a degree of bimodality. Neither the grammatical function of “so” nor vowel context appeared to explain the bimodality in CoG observed in the AMAB group based on the cluster analysis. However, because the cluster groups seem to be unevenly distributed, but were treated as if they were evenly split (50/50), these effects may have been obscured. Further analysis is needed to determine whether this influenced the results. When each AMAB speaker was plotted individually, the figures suggested that the variation came from *within* speakers rather than just *between* speakers. Nearly all speakers showed a wide range of CoG values, and few consistently produced higher values that would easily explain the bimodal pattern. This suggests that the bimodality is likely driven by other untested variables (e.g., prosody, speech rate, social factors). It is unlikely that recording effects explain this split, as such effects would likely have impacted both AMAB and AFAB speakers similarly. While one might speculate that recording artifacts could have selectively impacted lower CoG values (and thus disproportionately affected AMAB speakers), the overlap between AMAB non-binary CoG values and those of AFAB cisgender speakers makes this explanation improbable. Further research is needed to investigate these patterns, as the presence of bimodality may contribute to linguistic theories such as exemplar-based models of phonology, in which speech categories emerge from clusters of stored tokens shaped by both linguistic and social factors (Pierrehumbert, 2001).

Limitations:

There are a number of limitations that might limit the generalizability of these findings.

1. ***Audio:***

One important limitation concerns the audio data, as the accuracy of acoustic measurements may have been affected by unknown variability in recording quality, equipment, or environment. Since acoustic measurements are sensitive to recording conditions (Deliyski et al., 2005), it is difficult to determine the extent to which differences in microphone type, setup, or post-processing may have influenced the CoG and skewness values for each podcast. This uncertainty complicates interpretation, as any such differences are not readily quantifiable in the present analysis.

Additionally, the majority of speakers in the non-binary group were recorded under a single podcast setup. While this consistency may have reduced within-group variability, it raises the possibility that the near-significant CoG interaction trend (whether it facilitated or constrained significant findings) could partly reflect podcast setup differences rather than gender identity. Encouragingly, Ge et al. (2021) found minimal effects of recording environment on spectral moments, reporting only a 40 Hz difference in /s/ CoG's between a lab and a conference room. They also found differences based on the recording device used, but the authors presumed this to result from varying sampling frequencies. In the present study, each audio sample was manually inspected to ensure a consistent sampling rate of 44.1 kHz across podcasts.

Additionally, if recording artifacts played a role in shaping the present study's measures, they do not appear to have fully overshadowed the observed CoG differences across GAB groups—an effect broadly consistent with prior research on spectral variation and gender (Flipsen et al., 1999; Fuchs & Toda, 2010; Zimman, 2013, 2017; Hazenburg, 2016). CoG values fell within the typical range reported for adult-produced sibilants (4500–9000 Hz; Fuchs & Toda, 2010), which provides some reassurance regarding the validity of these measurements, however, their impact on skewness remains uncertain. The overall distribution of skewness in this dataset shows more positive values than typically expected, as most studies have reported predominantly negative averages for American English /s/ (Jongman et al., 2000; Munson et al., 2006; Fuchs & Toda, 2010). While positive skewness values have been documented (e.g., Zimman, 2013), no established standard range exists for /s/ skewness in American English. The unexpectedly positive averages are unlikely to be driven solely by outliers, as the median skewness across all tokens was also positive (0.5), and only 11 tokens were identified outside of the interquartile range. However, the observed negative correlation between CoG and skewness—consistent with prior findings (Munson et al., 2006; Hazenberg, 2016)—supports the conclusion that spectral patterns were not entirely overshadowed by recording effects. Future studies would benefit from using standardized recording protocols.

2. Nature of the Podcast:

In addition to technical factors, the nature of the podcasts themselves may have influenced the results. The speech data for this study was drawn from three podcasts with varying conversational formats and interpersonal dynamics. These contextual differences are important to consider, as speakers draw on linguistic features as stylistic tools to convey social meaning (Eckert, 2012), and it is unlikely that a queer sociolect—including the indexical use of ⟨s̺⟩—would be employed uniformly across all contexts. Previous work in sociolinguistics suggests that speakers adjust their linguistic performances based on the identities of their interlocutors and the social environment (Podesva, 2006, 2007, 2011; Kirtley, 2015). For example, Podesva and Van Hofwegen (2014) demonstrated that the higher-frequency ⟨s̺⟩ was used less frequently in socially conservative contexts, suggesting that speakers modulate their stylistic choices based on perceived safety and acceptance. In the present study's dataset, the podcast *Gender Reveal*—hosted by an openly LGBT+ interviewer—likely created an affirming environment in which queer speakers felt socially safe. Accordingly, the higher-frequency ⟨s̺⟩ that was tentatively observed in this study may only be specific to socially safe spaces.

Conversely, much of the gender-conforming comparison data came from *Where Should We Begin?*, a podcast featuring emotionally intense therapeutic dialogues between couples. While this setting may have also promoted openness and self-disclosure, it likely introduced emotional modulation of speech. Emotional states are known to influence acoustic and articulatory properties, including the production of /s/ (Erickson, 2005). In particular, Ehrette et al. (2002) found that higher CoG values tend to be associated with stress or aggression. While it is unclear whether speakers in *Where Should We Begin?* experienced elevated stress or anger, such factors would likely have resulted in increased CoG values, limiting the generalizability to calmer contexts.

3. Speaker Demographics:

A further consideration concerns speaker demographics. Previous research has shown that /s/ variation can be shaped by race, and broader sociocultural context (Stuart-Smith et al., 2007). While race was not systematically controlled in the present study, efforts were made to ensure a relatively diverse speaker pool across ethnic, cultural, and geographic backgrounds within the United States (see *3.1 Raw Data - Speaker Information* in Appendix). Steele (2019) found that a higher /s/ CoG correlates with masculinity for Black—but not White—speakers. Higher CoG among Black speakers may reflect a strategy to resist racialized stereotypes of hyper aggression and hypermasculinity (Smiley & Fakunle, 2016). This could help explain why the pattern does not extend to white speakers, who are not typically subject to the same racialized expectations. Overall, non-binary speakers in the present study disclosed race more frequently, though it is unclear whether racial diversity was evenly distributed across the podcasts. While race was less explicitly disclosed in the cisgender-focused podcast *Where Should We Begin?*, it should not be assumed that the podcast featured less diversity. The host, who is Belgian-American, selected couples from a wide range of cultural and geographic backgrounds, many of whom were excluded from the present study due to language-based eligibility criteria. As such, there is no evidence to suggest that the findings of this study would not generalize across racial groups. Age and socioeconomic status were not controlled for in this study, and age was underreported by speakers (see *3.1 Raw Data - Speaker Information* in Appendix), limiting conclusions about how these factors interact with /s/ production. Prior work suggests they may matter: for instance, Stuart-Smith et al. (2007) found that in Glaswegian English, working-class girls produced lower-frequency /s/ more similar to working-class boys than to middle-class girls, suggesting that the results of this study may not be fully generalizable across all socioeconomic groups. It is unknown if the socially marked ⟨s̪⟩ is performed evenly across age demographics. Zimman (2013) found that older gay and trans men (in their 40s and 50s) used creaky voice less frequently than their younger counterparts, suggesting that certain queer marked vocal features may vary across generations. Notably, the oldest cisgender gay speaker (aged 49) exhibited the lowest CoG in the sample, yet also demonstrated a relatively high skewness value compared to the other speakers.

Additionally, there was a sampling bias in the selection of cisgender speakers. Parental status was used as a proxy for identifying gender and sexuality in heterosexual couples, resulting in an overrepresentation of partnered parents compared to the general population. As a result, some of the observed effects may reflect differences between parents and non-parents rather than purely gender or sexuality-based variation.

4. *Token Type:*

All acoustic tokens in this study were drawn from instances of the word “so”. Hazenberg (2016) found that the use of “so” as a discourse marker was more common among cisgender women and queer speakers (especially those who presented in more feminine ways). In contrast, cisgender heterosexual men used “so” less frequently, and when they did, it typically functioned as a conjunction rather than a discourse marker. A similar pattern in the use of “so” (as well as a broader marked divergence in the speech patterns of cisgender men) emerged in this study; however, this may reflect the conversational context rather than speaker identity alone. Much of the existing research on /s/ variation in American English has focused on read speech, often using the Rainbow Passage (e.g., Zimman, 2013, 2017; Steele, 2019), which does not include the word “so”. This suggests that the socially marked ⟨s̺⟩ variation is not restricted to this lexical item. There is a possibility that socially marked words may also elicit more socially marked pronunciations—meaning that non-binary speakers might have shown higher CoG values than average because the present study only considered the (potentially queer marked) “so.” However, Hazenberg (2016) argues that due to its high frequency, “so” is unlikely to serve as a site of deliberate identity signaling, and any variation in /s/ reflects unconscious rather than intentional stylistic choices.

Further Research:

Looking ahead, the relatively recent and growing acceptance of singular *they/them* to refer to known individuals—even as some continue to resist its use (Perales et al., 2025)—illustrates how the language of gender non-conforming speakers and the broader queer sociolect will continue to evolve in tandem with shifting cultural understandings of gender and sexuality. Future research should aim to document these ongoing developments and explore additional linguistic features that may characterize queer, non-binary, or femininely aligned styles of speech.

Building on this insight, future research should also explore how queer phonetic expression manifests across different languages. For example, even in non-spoken languages like American Sign Language, research has shown that gay (cisgender) men tend to use more expansive, "hyper-articulated" gestures—those that extend farther from the body—compared to those outside of the queer community (Blau, 2017). Within spoken languages, approximately 83% have some form of an /s/ (Maddieson, 1984), and a growing body of cross-linguistic research has begun to investigate higher-frequency ⟨s̪⟩ production and perception. Production studies have identified socially marked ⟨s̪⟩ variants in Belgian Dutch (Van Borsel et al., 2009) and Peninsular Spanish (Kelley, 2024), but this phenomena was not found in Netherlandic Dutch (Liem, 2019) or Mandarin Chinese (Geng & Gu, 2021). Perception studies further suggest that non-standard ⟨s̪⟩ realizations are associated with homosexuality or femininity in several languages, including British English (Levon, 2014), Danish (Pharao et al., 2014), Puerto Rican Spanish (Mack, 2010), Hungarian (Rácz & Shepácz, 2013), Finnish (Halonen & Vaattovaara, 2017), German (Kachel et al., 2018), and Polish (Czaplicki et al., 2016). Despite these studies, research on socially marked ⟨s̪⟩ variation remains largely limited to European languages. Whether a socially marked ⟨s̪⟩ extends beyond this is still unclear, particularly given the wide cross-linguistic variation in potential sibilant articulations. Expanding this line of inquiry to non-European languages—especially those with larger sibilant inventories, such as Arabic—would help determine whether similar sociophonetic patterns emerge in typologically diverse contexts, or whether phonemic constraints limit the potential for such variation. Polish (albeit still European) presents a particularly promising case for sociophonetic investigation because it features a three-way sibilant distinction and previous research suggests that gender-based variation is already emerging (Czaplicki et al., 2016), making Polish an ideal candidate for testing whether socially marked ⟨s̪⟩ realizations are attested in languages with dense sibilant systems. Additionally, a small subset of languages phonemically contrast alveolar /s/ and dental /s̪/ (Maddieson, 1984), potentially limiting the use of socially marked ⟨s̪⟩. In such cases, fronting may disrupt lexical contrasts, prompting speakers to rely on other articulatory or acoustic cues to index social identity.

More cross-linguistic sociophonetic research on sexual identity is also warranted due to cultural variation in attitudes toward gender and sexuality. Societies differ in acceptance, recognition, and expression of non-normative identities, which shape the linguistic resources available for identity performance. Since the higher-frequency ⟨s̪⟩ is used less frequently in socially conservative contexts (Podesva & Van Hofwegen, 2014), it is possible that cultures less accepting of queer and non-male genders are less likely to present socially marked features. Consequently, production and perception studies in conservative societies should be interpreted cautiously, as speakers may be influenced by stigma, internalized norms, or social desirability biases (Mack & Munson, 2010).

These cultural differences highlight the need to situate sociophonetic variation within broader cultural and ideological contexts, which also applies to the current study's methods. Although it includes a wide range of gender non-conforming identities, it relies on American podcast recordings that represent an American-style construction of gender (non-)conformity, which does not assume to be representative of global constructions of gender (or lack thereof). Additionally this study inferred speakers' GAB based on verbal cues from the recordings rather than through direct self-identification (See *3.2 Raw Data – Phrases Used to Identify GAB* in Appendix). While this methodological choice allows categorization in the absence of explicit data, it may overlook nuances of individual identity and how speakers themselves understand and perform gender, thereby prioritizing research needs over speaker agency and well-being. Future work should emphasize direct community involvement when possible to better respect lived identities and ensure ethical research practices.

Conclusion:

This study found marginal evidence that non-binary speakers produced a socially marked ⟨s̪⟩. While these effects did not reach conventional levels of statistical significance, the patterns observed suggest meaningful trends that warrant further research with larger samples. As expected, AFAB speakers exhibited significantly higher center of gravity (CoG) values than AMAB speakers, consistent with prior findings. For skewness, a marginally significant negative trend emerged: AFAB speakers produced more negatively skewed spectra than AMAB speakers, though this result was not statistically significant.

When examining the interaction between gender identity and gender assigned at birth, CoG values revealed a gradient: cisgender AFAB speakers produced the highest CoG values, followed by AFAB non-binary speakers, then AMAB non-binary speakers, and finally cisgender AMAB speakers, who produced the lowest CoG values. The skewness pattern did not align as neatly with this gradient: while cisgender AMAB speakers showed the most positive skewness values, cisgender AFAB speakers also showed relatively positive skewness, whereas AFAB non-binary speakers exhibited the most negative skewness overall. A near-significant interaction effect for CoG suggests that the difference between non-binary and cisgender speakers was smaller among AFAB speakers than among AMAB speakers.

This marginal interaction effect, taken alongside the significant post-hoc CoG and skewness differences between non-binary and cisgender AMAB speakers, tentatively point to the existence of a shared sociolect among non-binary, queer, and female speakers—acoustically marked by a higher-frequency ⟨s̪⟩. In contrast, a lower-frequency ⟨s⟩ may index masculinity and heterosexuality.

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Appendix:

1.1 Public Notice:

Overview: Audio recordings from the podcasts *Gender Reveal, Where Should We Begin?,* and *Let's Talk Love* will be used for acoustic data analysis in a study about the pronunciation and articulation of the /s/ in gender non-conforming speakers. The primary goal is to better understand how aspects of speech correlate with sexual and gender identities. All data is anonymized, and individual identities will not be disclosed or identifiable in any reports, presentations, or publications. Audio excerpts analyzed will not be redistributed.

Opting Out: If you are someone featured in the publicly accessible podcasts analyzed in this study and wish to opt out or have concerns about the use of your data, please contact the primary researcher. Your request will be promptly honored.

Contact Information: For questions, concerns, or further information, please reach out to:

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Thank you for your understanding and support of ethical research practices.

1.2 Ethics Approval:

UNIVERSITY OF AMSTERDAM
Faculty of Humanities

Amsterdam Institute for Humanities Research
Ethics Committee

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Date	**Our reference**	
24-04-2025	FGW-6299	
Contact	**Telephone**	**E-mail**
Roland Pfau	+31 (0) 20 525 62 34	commissie-ethiek-fgw@uva.nl
Subject		
Project approval notice		

Dear Dr. Titia Benders,

Thank you for your application for approval of your project "Exploring Sibilant Productions in LGBT communities" FGW-6299

I hereby confirm that the Ethics Committee of the Faculty of Humanities of the University of Amsterdam has reviewed and approved your application.

The approval is given under the strict condition that the research will be carried out in the way stated in your application. If any amendments are made, a new application must be submitted.

Yours sincerely,

Roland Pfau
Chair Ethics Committee

2.1 Praat Script for CoG and Skewness Extraction:

```
src$= "Wavs"
perc= 0.1
windowType$= "Hamming"
#windowType$= "rectangular"
useFiltering= 1
#useFiltering= 0
filterLow= 100
filterHigh= 15000
filterSmooth= 100
cogPower= 2
skewnessPower= 2
result= Create Table with column names: "result", 0, { "Speaker", "Word",
"WordStart", "WordEnd", "Item", "tMin", "tMax", "tMid", "tMidLower", "tMidUpper",
"CoG", "Skewness" }
fileNames$#= fileNames$#("'src$'/*.wav")
for i to size(fileNames$#)
    @calcCoG(fileNames$#[i])
endfor
exit
procedure calcCoG(.fileName$)
   .shortName$= left$(.fileName$, length(.fileName$)-4)
   .r= Read from file: "'src$'/'.fileName$'"
   .tg= Read from file: "'src$'/'.shortName$'.TextGrid"
   .dt= Down to Table: "no", 6, "yes", "no"
   .ex1= Extract rows where column (text): "tier", "is equal to", "phones"
   .ex2= Extract rows where column (text): "text", "is equal to", "S"

   for .i to object[.ex2].nrow
      .text$= object$[.ex2, .i, "text"]
      .tmin= object[.ex2, .i, "tmin"]
      .tmax= object[.ex2, .i, "tmax"]
      .tmid= (.tmax + .tmin)/2
      .percHalfDur= perc*(.tmax - .tmin)
      .tminN= .tmid - .percHalfDur
      .tmaxN= .tmid + .percHalfDur
```

```
      select .tg
      .wordInt= Get interval at time: 1, .tmid
      .wordText$= Get label of interval: 1, .wordInt
      .wordStart= Get start time of interval: 1, .wordInt
      .wordEnd= Get end time of interval: 1, .wordInt

      select .r
      .exp= Extract part: .tminN, .tmaxN, windowType$, 1, "no"
      if useFiltering= 1
        .f= Filter (pass Hann band): filterLow, filterHigh, filterSmooth
      else
         .f= 0
      endif
      .spec= To Spectrum: "yes"
      .cog= Get centre of gravity: cogPower
      .skewness= Get skewness: skewnessPower
      select result
      Append row
      Set string value: object[result].nrow, "Speaker", .shortName$
      Set string value: object[result].nrow, "Item", .text$
      Set string value: object[result].nrow, "Word", .wordText$
      Set string value: object[result].nrow, "WordStart", fixed$(.wordStart, 3)
      Set string value: object[result].nrow, "WordEnd", fixed$(.wordEnd, 3)
      Set string value: object[result].nrow, "tMin", fixed$(.tmin, 3)
      Set string value: object[result].nrow, "tMax", fixed$(.tmax, 3)
      Set string value: object[result].nrow, "tMid", fixed$(.tmid, 3)
      Set string value: object[result].nrow, "tMidLower", fixed$(.tminN, 3)
      Set string value: object[result].nrow, "tMidUpper", fixed$(.tmaxN, 3)
      Set string value: object[result].nrow, "CoG", fixed$(.cog, 0)
      Set string value: object[result].nrow, "Skewness", fixed$(.skewness, 0)
      removeObject: .exp, .spec
      if .f<> 0
         removeObject: .f
      endif
   endfor
   removeObject: .r, .tg, .dt, .ex1, .ex2
endproc
```

2.2 Montreal Forced Aligner (MFA) Processing Script:

```
# Activate Aligner
conda activate aligner

# Run MFA (and make sure the right files are in the Input/Output folder
mfa align your_input_directory_here english_us_arpa english_us_arpa
your_output_directory_here

#If already run before, clean previous data first
mfa align mfa align your_input_directory_here english_us_arpa english_us_arpa
your_output_directory_here --clean
```

3. Raw Data:

3.1 Speaker Information:

Speaker	Pronouns	Identity Label	Origin	Age	Race
002	They/Them	Non-Binary	Brooklyn, New York		
003	They/Them	Non-Binary	Maryland		Afro-Queer
004	They/Them	Non-Binary			Black
005	She/Her	Woman			Vietnamese-American
006	They/Them	Non-Binary, Genderqueer	Oklahoma	30's	White
009	They/Them	Non-Binary			
011	She/They	Non-Binary, Woman			White
012	They/Them	Diné	Portland, Oregon	30/40's	Indigenous
014	They/Them	Non-Binary, Trans			Black
015	He/They	Non-Binary, Trans	Maine		
017	They/Them	Agender	Arkansas		
021	They/Them	Non-Binary, Genderqueer, Agender	Colorado		

022	She/They	Non-Binary Femme			Mexican-American
025	They/Them	Non-Binary Queer		39	Puerto Rican
033	They/Them	Non-Binary	Seattle		Korean/White
034	They/Them				Mixed (Black/White)
035	He/Ze/They	Genderqueer, Trans	Midwest, South		White
037	She/They	Trans/Queer Woman			
039	He/She/They	Genderqueer			
043	They/Them	Trans-Dimensional	New Jersey		Salvadoran-American
044	She/Her	Woman		Early 30's	
045	He/Him	Man			
046	She/Her	Woman			
048	She/Her	Woman			
049	She/Her	Woman			
050	He/Him	Man			
052	He/Him	Man			
053	He/Him	Man			
055	He/Him	Man		Mid 20's	Latino
056	She/Her	Woman			
057	She/Her	Woman			Portuguese
058	She/Her	Woman	Washington, DC		
059	He/Him	Man			Filipino-White
060	He/Him	Man	California		
062	She/Her	Woman			Taiwanese
063	He/Him	Man		Early 30's	
064	She/Her	Woman		32	
065	They/Them			24	
066	He/Him	Man	Georgia		Indian
067	She/Her	Woman			
068	He/Him	Man			
069	She/Her	Woman			

3.2 Phrases Used to Identify GAB:

Speaker	Pronouns	GAB	Phrase
002	They/Them	AMAB	*I thought I was a boy until my late twenties*
003	They/Them	AMAB	*Everybody has privileges to unlearn, and that's one of those things, you know, the expectations and the privileges and the, just all the bullshit guidelines, or whatever, about how to perform as a man, how to be a man, and I don't really agree with most of that, if not all of it. And that's what I-- It's just, like, a process of unlearning it,*
004	They/Them	AFAB	*When I was growing up, I really identified with that Britney Spears song that was like [Sings] "I'm not a girl not yet a woman." [Laughs] And I thought that was an age thing; I was like "OK – I am not a girl, and I'm not a woman, I'm some secret other thing." [Laughs]*
005	She/Her	AFAB	*There was a particular period in high school where I wore binders and I presented as male in a lot of sort of strange contexts?*
006	They/Them	AFAB	*It was the first gender identity I had besides being a woman which is like something that I didn't identify with for a long time,*
009	They/Them	AFAB	*What I found is that it sort of ungrouped me from the women around me. Um, whereas in the States I had been trying very hard to sort of keep up with, um, my… my peers who identified as women. And, uh, found that I was just doing very badly at it.*
011	She/They	AMAB	*So when I was trying to figure out if I was trans or not, I thought for the longest time, I can't BE a girl, because I like girls. Like when I was growing up I got like, people teased me or bullied me or whatever for like, being a gay guy, and I was like, that's… I'm NOT, like I don't like guys*
012	They/Them	AMAB	*I still feel like, I benefit largely from cis male privilege.*
014	They/Them	AFAB	*"And queer women were the people who made me feel safe enough in my body and comfortable enough being who I was to say "I am no longer a woman." And, like, this is how I want to be identified. "*
015	He/They	AFAB	*I was born and raised female and now I mostly pass as a dude and I like that.*

017	They/Them	AFAB	*Personally, I never really thought that much about my gender identity for most of my life. I didn't really ever feel comfortable with 'womanhood.' I always thought shaving my legs was weird, and having to dress a certain way was weird, and I don't know, all my friends around me were super feminine, and it just felt alienating to me.*
021	They/Them	AMAB	*Where do we start on the gender journey? We start being very young. Whenever I tried to perform masculinity I felt like a weird robot. So that, wasn't great. Whenever I tried to pretend to be a man, I wasn't supe dysphoric, or I didn't recognize dysphoria at the time.*
022	She/They	AFAB	*In high school, I went through this period of, like, not know–like, 'cause I've never been super feminine, and, like, I've never known how or anything* --- *We decided to just, like, go with Mija/Mija. And especially because, like, that's what our moms called us.* --- **Note**: "Mija" means "my daughter" in Spanish
025	They/Them	AFAB	*My pronouns in Spanish are ella and la, you know? So, 'cause it's just easier and I don't know* --- **Note:** In Spanish, "ella" and "la" both mean "she" or "her." They make reference that "it's easier" in Spanish because their family is less accustomed to using gender neutral speech in Spanish.
033	They/Them	AMAB	*I was assigned male at birth,*
034	They/Them	AFAB	*How can I get my chest to be smaller and smaller?" because I hated my chest. Yeah, luckily, I've found binders since then so, it works out.*
035	He/Ze/They	AFAB	*Like, it was trans man or trans woman, and that was what, you know, what was out there. And I remember my parents got a book that was, like, the book that was available that I believe it was called "True Selves" about, you know, the female-to-male transsexual, and they read that book. And I think they were just confused cause they were like, that's not what this person seems like who is our child. [Laughs]*

037	She/They	AMAB	*Oh, how do I describe myself in terms of gender – I use a lot of different descriptors. I mean – "she," that's constant. "They," I think, for political solidarity. I use the words "woman," "trans woman," "queer woman," "lesbian," "dyke"...yeah, whatever. As long as they don't call me a man anymore.*
039	He/She/ They	AMAB	*There's still people who -- like my family, for example -- addresses me in boy pronouns,*
043	They/Them	AMAB	*When I found out that the condition that I was born with, the absence of testes was an intersex variation…* *One of my dear friends who passed away, his parents were there, and they're in their 50s, and he edited the short film. So I invited them to come to the feature, and I was like, "Oh, like, they still use he pronouns for me sometimes."*
044	She/Her	AFAB	*In addition to the many health crisis that they have undergone, they also are weathering the [inaudible] of the everyday life raising their two year old child, as well as her two children from a previous relationship. He, being unemployed and she being overfunctioning.* **Note**: These remarks are made by the host, rather than the parents.
045	He/Him	AMAB	*In addition to the many health crisis that they have undergone, they also are weathering the [inaudible] of the everyday life raising their two year old child, as well as her two children from a previous relationship. He, being unemployed and she being overfunctioning.* **Note**: These remarks are made by the host, rather than the parents.
046	She/Her	AFAB	*At first, it was kind of exciting, fun, and then we start having kids, things*
048	She/Her	AFAB	*They have three young children, and their entire life has begun to change, more and faster that they can even get their head around.* **Note**: These remarks are made by the host, rather than the parents.
049	She/Her	AFAB	*His mother had a stroke eight years ago and he was living with her, taking care of her. He did not leave like even once we got pregnant with our son, I was living by myself with our son.*

050	He/Him	AMAB	*I also found out he had a child, 14 years old, I had no idea about.* **Note**: These remarks are made by the wife, rather than the husband.
052	He/Him	AMAB	*I became an instant parent when I got married to four kids who lost their birth mom to suicide.* **Note**: These remarks are made by the new mother, rather than the father.
053	He/Him	AMAB	*Both had a child from their first marriage, that they had had an affair.* **Note**: These remarks are made by the host, rather than the parents.
055	He/Him	AMAB	*And then we would try to have intercourse and then things, like the penis wouldn't stay hard* **Note**: These remarks are made by the wife, rather than the husband.
056	She/Her	AFAB	*Maybe we've started playing and I was aroused and maybe he'd bring me to climax and it would be lovely,*
057	She/Her	AFAB	*Given that they had been dating for quite a few years, but she got pregnant and her Catholic family made it clear that you don't have a child out of wedlock,* **Note**: These remarks are made by the host, rather than the parents.
058	She/Her	AFAB	*There are five years together. They have a 2-year-old* **Note**: These remarks are made by the host, rather than the parents.
059	He/Him	AMAB	*I donated to the sperm bank five years ago*
060	He/Him	AMAB	*And then you are also the parents* **Note**: These remarks are made by the host, rather than the parents.
062	She/Her	AFAB	*We've been married now for 17 years, and we have four children*
063	He/Him	AMAB	*And now I'm married and I have a baby*

064	She/Her	AFAB	*My wife was pregnant and that's when I became unemployed.* **Note**: These remarks are made by the husband, rather than the wife.
065	They/Them	AFAB	*I mean, yeah, like is I dunno, like, I don't know, like, I still, it feels disingenuous to call myself gay when I'm with a cis guy, cis straight guy.*
066	He/Him	AMAB	*So what is the taboo? When you say "we men." Cisgendered straight guys,* **Note**: These remarks are made by the host, rather than the guest.
067	She/Her	AFAB	*Yeah, so, we are a married couple, and we have three kids of our own, 13, soon to be 11 and 7.*
068	He/Him	AMAB	*Yeah, so, we are a married couple, and we have three kids of our own, 13, soon to be 11 and 7.* **Note**: These remarks are made by the wife, rather than the husband.
069	She/Her	AFAB	*Giving birth was the most painful thing I've ever experienced.*

3.3 Token Information

Podcast	Token	Gender ID	GAB	So Type	Preceding Word	Vowel Type	Preceding Vowel
A	1	Non-Binary	AMAB	Conjunction	non-binary	Front	i
A	2	Non-Binary	AMAB	Conjunction	non-binary	Front	i
A	3	Non-Binary	AMAB	Conjunction	yeah	Front	æ
A	4	Non-Binary	AMAB	Adverb	see	Front	i
A	5	Non-Binary	AMAB	Conjunction	∅	∅	∅
A	6	Non-Binary	AMAB	Conjunction	yeah	Front	æ
A	1	Non-Binary	AMAB	Conjunction	∅	∅	∅
A	2	Non-Binary	AMAB	Conjunction	∅	∅	∅
A	3	Non-Binary	AMAB	Adverb	be	Front	i
A	4	Non-Binary	AMAB	Conjunction	tiny	Front	i
A	5	Non-Binary	AMAB	Conjunction	∅	∅	∅
A	6	Non-Binary	AMAB	Conjunction	academia	Central	ə
A	7	Non-Binary	AMAB	Adverb	you	Back	u
A	1	Non-Binary	AFAB	Conjunction	yeah	Front	æ
A	2	Non-Binary	AFAB	Adverb	into	Back	u
A	5	Non-Binary	AFAB	Conjunction	∅	∅	∅

A	4	Non-Binary	AFAB	Conjunction	∅	∅	∅
A	6	Non-Binary	AFAB	Conjunction	okay	Front	eɪ
A	7	Non-Binary	AFAB	Conjunction	way	Front	eɪ
A	8	Non-Binary	AFAB	Conjunction	okay	Front	eɪ
A	9	Non-Binary	AFAB	Conjunction	me	Front	i
A	10	Non-Binary	AFAB	Conjunction	∅	∅	∅
A	11	Non-Binary	AFAB	Conjunction	know	Back	oʊ
A	12	Non-Binary	AFAB	Adverb	see	Front	i
A	13	Non-Binary	AFAB	Conjunction	exactly	Front	i
A	14	Non-Binary	AFAB	Conjunction	∅	∅	∅
A	1	Cisgender	AFAB	Conjunction	∅	∅	∅
A	2	Cisgender	AFAB	Conjunction	yeah	Front	æ
A	3	Cisgender	AFAB	Adverb	know	Back	oʊ
A	4	Cisgender	AFAB	Adverb	be	Front	i
A	5	Cisgender	AFAB	Conjunction	∅	∅	∅
A	1	Non-Binary	AFAB	Conjunction	way	Front	eɪ
A	2	Non-Binary	AFAB	Conjunction	away	Front	eɪ
A	3	Non-Binary	AFAB	Adverb	you	Back	u
A	4	Non-Binary	AFAB	Conjunction	know	Back	oʊ
A	5	Non-Binary	AFAB	Conjunction	yeah	Front	æ
A	6	Non-Binary	AFAB	Conjunction	∅	∅	∅
A	7	Non-Binary	AFAB	Conjunction	me	Front	i
A	1	Non-Binary	AFAB	Conjunction	uh	Central	ə
A	2	Non-Binary	AFAB	Conjunction	so	Back	oʊ
A	3	Non-Binary	AFAB	Conjunction	so	Back	oʊ
A	4	Non-Binary	AFAB	Conjunction	too	Back	u
A	5	Non-Binary	AFAB	Conjunction	you	Back	u
A	6	Non-Binary	AFAB	Conjunction	so	Back	oʊ
A	7	Non-Binary	AFAB	Conjunction	yeah	Front	æ
A	8	Non-Binary	AFAB	Conjunction	me	Front	i
A	9	Non-Binary	AFAB	Conjunction	yeah	Front	æ
A	10	Non-Binary	AFAB	Conjunction	∅	∅	∅
A	11	Non-Binary	AFAB	Conjunction	me	Front	i
A	12	Non-Binary	AFAB	Conjunction	me	Front	i
A	13	Non-Binary	AFAB	Conjunction	show	Back	oʊ
A	14	Non-Binary	AFAB	Conjunction	yeah	Front	æ
A	15	Non-Binary	AFAB	Conjunction	know	Back	oʊ
A	16	Non-Binary	AFAB	Conjunction	yeah	Front	æ
A	17	Non-Binary	AFAB	Conjunction	so	Back	oʊ
A	18	Non-Binary	AFAB	Adverb	so	Back	oʊ

A	19	Non-Binary	AFAB	Conjunction	so	Back	oʊ
A	20	Non-Binary	AFAB	Conjunction	absolutely	Front	i
A	1	Non-Binary	AMAB	Conjunction	totally	Front	i
A	2	Non-Binary	AMAB	Conjunction	∅	∅	∅
A	3	Non-Binary	AMAB	Conjunction	yeah	Front	æ
A	4	Non-Binary	AMAB	Conjunction	yeah	Front	æ
A	5	Non-Binary	AMAB	Conjunction	me	Front	i
A	6	Non-Binary	AMAB	Adverb	be	Front	i
A	7	Non-Binary	AMAB	Conjunction	absolutely	Front	i
A	8	Non-Binary	AMAB	Conjunction	∅	∅	∅
A	9	Non-Binary	AMAB	Adverb	be	Front	i
A	10	Non-Binary	AMAB	Adverb	be	Front	i
A	11	Non-Binary	AMAB	Conjunction	yeah	Front	æ
A	12	Non-Binary	AMAB	Conjunction	basically	Front	i
A	13	Non-Binary	AMAB	Conjunction	gay	Front	eɪ
A	14	Non-Binary	AMAB	Adverb	dysphoria	Central	ə
A	15	Non-Binary	AMAB	Conjunction	dysphoria	Central	ə
A	3	Non-Binary	AMAB	Adverb	homophobia	Central	ə
A	4	Non-Binary	AMAB	Adverb	transphobia	Central	ə
A	5	Non-Binary	AMAB	Conjunction	∅	∅	∅
A	6	Non-Binary	AMAB	Conjunction	traditionally	Front	i
A	7	Non-Binary	AMAB	Conjunction	know	Back	oʊ
A	8	Non-Binary	AMAB	Conjunction	know	Back	oʊ
A	9	Non-Binary	AMAB	Conjunction	yeah	Front	æ
A	1	Non-Binary	AFAB	Conjunction	∅	∅	∅
A	2	Non-Binary	AFAB	Conjunction	true	Back	u
A	3	Non-Binary	AFAB	Conjunction	∅	∅	∅
A	4	Non-Binary	AFAB	Conjunction	yeah	Front	æ
A	5	Non-Binary	AFAB	Conjunction	yeah	Front	æ
A	6	Non-Binary	AFAB	Conjunction	yeah	Front	æ
A	1	Non-Binary	AFAB	Conjunction	∅	∅	∅
A	2	Non-Binary	AFAB	Conjunction	∅	∅	∅
A	3	Non-Binary	AFAB	Conjunction	family	Front	i
A	4	Non-Binary	AFAB	Conjunction	me	Front	i
A	5	Non-Binary	AFAB	Conjunction	me	Front	i
A	6	Non-Binary	AFAB	Conjunction	yeah	Front	æ
A	7	Non-Binary	AFAB	Adverb	go	Back	oʊ
A	8	Non-Binary	AFAB	Conjunction	so	Back	oʊ
A	9	Non-Binary	AFAB	Conjunction	me	Front	i
A	10	Non-Binary	AFAB	Adverb	me	Front	i

A	1	Non-Binary	AFAB	Conjunction	yeah	Front	æ
A	2	Non-Binary	AFAB	Conjunction	through	Back	u
A	3	Non-Binary	AFAB	Adverb	be	Front	i
A	1	Non-Binary	AMAB	Conjunction	umbrella	Central	ə
A	2	Non-Binary	AMAB	Conjunction	∅	∅	∅
A	3	Non-Binary	AMAB	Conjunction	me	Front	i
A	4	Non-Binary	AMAB	Conjunction	∅	∅	∅
A	5	Non-Binary	AMAB	Conjunction	∅	∅	∅
A	6	Non-Binary	AMAB	Conjunction	me	Front	i
A	7	Non-Binary	AMAB	Conjunction	∅	∅	∅
A	1	Non-Binary	AFAB	Conjunction	yeah	Front	æ
A	2	Non-Binary	AFAB	Conjunction	me	Front	i
A	3	Non-Binary	AFAB	Conjunction	know	Back	oʊ
A	4	Non-Binary	AFAB	Conjunction	know	Back	oʊ
A	6	Non-Binary	AFAB	Conjunction	the	Central	ə
A	7	Non-Binary	AFAB	Conjunction	yeah	Front	æ
A	1	Non-Binary	AFAB	Conjunction	probably	Front	i
A	2	Non-Binary	AFAB	Conjunction	she	Front	i
A	3	Non-Binary	AFAB	Conjunction	me	Front	i
A	4	Non-Binary	AFAB	Conjunction	community	Front	i
A	5	Non-Binary	AFAB	Conjunction	probably	Front	i
A	6	Non-Binary	AFAB	Conjunction	especially	Front	i
A	7	Non-Binary	AFAB	Conjunction	too	Back	u
A	8	Non-Binary	AFAB	Conjunction	me	Front	i
A	9	Non-Binary	AFAB	Conjunction	know	Back	oʊ
A	10	Non-Binary	AFAB	Adverb	be	Front	i
A	11	Non-Binary	AFAB	Conjunction	yeah	Front	æ
A	12	Non-Binary	AFAB	Conjunction	yeah	Front	æ
A	13	Non-Binary	AFAB	Conjunction	yeah	Front	æ
A	14	Non-Binary	AFAB	Conjunction	be	Front	i
A	15	Non-Binary	AFAB	Adverb	through	Back	u
A	1	Non-Binary	AMAB	Conjunction	so	Back	oʊ
A	2	Non-Binary	AMAB	Conjunction	∅	∅	∅
A	3	Non-Binary	AMAB	Conjunction	yeah	Front	æ
A	4	Non-Binary	AMAB	Conjunction	anyway	Front	eɪ
A	5	Non-Binary	AMAB	Conjunction	∅	∅	∅
A	6	Non-Binary	AMAB	Conjunction	story	Front	i
A	7	Non-Binary	AMAB	Conjunction	∅	∅	∅
A	8	Non-Binary	AMAB	Conjunction	know	Back	oʊ
A	9	Non-Binary	AMAB	Conjunction	angry	Front	i

A	10	Non-Binary	AMAB	Conjunction	∅	∅	∅
A	11	Non-Binary	AMAB	Conjunction	yeah	Front	æ
A	12	Non-Binary	AMAB	Conjunction	me	Front	i
A	13	Non-Binary	AMAB	Conjunction	yeah	Front	æ
A	14	Non-Binary	AMAB	Conjunction	yeah	Front	æ
A	15	Non-Binary	AMAB	Conjunction	∅	∅	∅
A	16	Non-Binary	AMAB	Conjunction	yeah	Front	æ
A	17	Non-Binary	AMAB	Conjunction	∅	∅	∅
A	18	Non-Binary	AMAB	Conjunction	∅	∅	∅
A	1	Non-Binary	AFAB	Conjunction	yeah	Front	æ
A	2	Non-Binary	AFAB	Conjunction	me	Front	i
A	3	Non-Binary	AFAB	Conjunction	probably	Front	i
A	4	Non-Binary	AFAB	Conjunction	North Carolina	Central	ə
A	5	Non-Binary	AFAB	Conjunction	Montana	Central	ə
A	6	Non-Binary	AFAB	Conjunction	safety	Front	i
A	7	Non-Binary	AFAB	Conjunction	you	Back	u
A	8	Non-Binary	AFAB	Conjunction	you	Back	u
A	9	Non-Binary	AFAB	Adverb	be	Front	i
A	10	Non-Binary	AFAB	Adverb	be	Front	i
A	12	Non-Binary	AFAB	Conjunction	do	Back	u
A	1	Non-Binary	AFAB	Conjunction	Ohio	Back	oʊ
A	2	Non-Binary	AFAB	Conjunction	me	Front	i
A	3	Non-Binary	AFAB	Conjunction	yeah	Front	æ
A	4	Non-Binary	AFAB	Conjunction	too	Back	u
A	5	Non-Binary	AFAB	Conjunction	absolutely	Front	i
A	6	Non-Binary	AFAB	Conjunction	anyway	Front	eɪ
A	1	Non-Binary	AMAB	Conjunction	story	Front	i
A	2	Non-Binary	AMAB	Conjunction	know	Back	oʊ
A	1	Non-Binary	AMAB	Conjunction	way	Front	eɪ
A	2	Non-Binary	AMAB	Conjunction	uh-huh	Central	ə
A	3	Non-Binary	AMAB	Conjunction	∅	∅	∅
A	1	Non-Binary	AMAB	Conjunction	∅	∅	∅
A	2	Non-Binary	AMAB	Conjunction	∅	∅	∅
A	3	Non-Binary	AMAB	Conjunction	me	Front	i
B	1	Cisgender	AFAB	Adverb	you	Back	u
B	2	Cisgender	AFAB	Adverb	you	Back	u
B	1	Cisgender	AMAB	Adverb	value	Back	u
B	2	Cisgender	AMAB	Conjunction	yeah	Front	æ
B	3	Cisgender	AMAB	Conjunction	yeah	Front	æ

B	4	Cisgender	AMAB	Adverb	you	Back	u
B	5	Cisgender	AMAB	Adverb	be	Front	i
B	1	Cisgender	AFAB	Conjunction	uh	Central	ə
B	2	Cisgender	AFAB	Conjunction	idea	Central	ə
B	3	Cisgender	AFAB	Conjunction	yeah	Front	æ
B	4	Cisgender	AFAB	Conjunction	know	Back	oʊ
B	5	Cisgender	AFAB	Conjunction	∅	∅	∅
B	6	Cisgender	AFAB	Conjunction	∅	∅	∅
B	7	Cisgender	AFAB	Adverb	be	Front	i
B	1	Cisgender	AFAB	Conjunction	day	Front	eɪ
B	2	Cisgender	AFAB	Conjunction	two	Back	u
B	3	Cisgender	AFAB	Adverb	be	Front	i
B	4	Cisgender	AFAB	Conjunction	∅	∅	∅
B	1	Cisgender	AFAB	Conjunction	∅	∅	∅
B	2	Cisgender	AFAB	Conjunction	∅	∅	∅
B	3	Cisgender	AFAB	Conjunction	∅	∅	∅
B	1	Cisgender	AMAB	Conjunction	anyway	Front	eɪ
B	2	Cisgender	AMAB	Conjunction	way	Front	eɪ
B	1	Cisgender	AMAB	Conjunction	probably	Front	i
B	2	Cisgender	AMAB	Conjunction	∅	∅	∅
B	3	Cisgender	AMAB	Conjunction	yeah	Front	æ
B	4	Cisgender	AMAB	Conjunction	okay	Front	eɪ
B	1	Cisgender	AMAB	Conjunction	to	Back	u
B	2	Cisgender	AMAB	Conjunction	you	Back	u
B	3	Cisgender	AMAB	Conjunction	guilty	Front	i
B	1	Cisgender	AFAB	Adverb	see	Front	i
B	2	Cisgender	AFAB	Adverb	me	Front	i
B	3	Cisgender	AFAB	Conjunction	∅	Front	i
B	1	Cisgender	AFAB	Conjunction	yeah	Front	æ
B	2	Cisgender	AFAB	Conjunction	okay	Front	eɪ
B	1	Cisgender	AFAB	Conjunction	know	Back	oʊ
B	2	Cisgender	AFAB	Conjunction	know	Back	oʊ
B	1	Cisgender	AMAB	Conjunction	∅	∅	∅
B	2	Cisgender	AMAB	Conjunction	∅	∅	∅
B	3	Cisgender	AMAB	Conjunction	∅	∅	∅
B	4	Cisgender	AMAB	Conjunction	∅	∅	∅
B	1	Cisgender	AMAB	Conjunction	credibility	Front	i
B	2	Cisgender	AMAB	Conjunction	to	Back	u
B	3	Cisgender	AMAB	Conjunction	yeah	Front	æ

B	4	Cisgender	AMAB	Conjunction	way	Front	eɪ
B	1	Cisgender	AFAB	Conjunction	me	Front	i
B	2	Cisgender	AFAB	Conjunction	know	Back	oʊ
B	1	Cisgender	AMAB	Conjunction	∅	∅	∅
B	2	Cisgender	AMAB	Conjunction	∅	∅	∅
B	3	Cisgender	AMAB	Conjunction	∅	∅	∅
B	4	Cisgender	AMAB	Conjunction	∅	∅	∅
B	5	Cisgender	AMAB	Conjunction	∅	∅	∅
B	6	Cisgender	AMAB	Adverb	∅	∅	∅
B	7	Cisgender	AMAB	Conjunction	∅	∅	∅
B	1	Cisgender	AFAB	Conjunction	∅	∅	∅
B	2	Cisgender	AFAB	Conjunction	do	Back	u
B	3	Cisgender	AFAB	Adverb	∅	∅	∅
B	1	Non-Binary	AFAB	Conjunction	∅	∅	∅
B	2	Non-Binary	AFAB	Conjunction	yeah	Front	æ
B	3	Non-Binary	AFAB	Adverb	know	Back	oʊ
B	4	Non-Binary	AFAB	Conjunction	∅	∅	∅
B	2	Cisgender	AMAB	Conjunction	definitely	Front	i
B	3	Cisgender	AMAB	Conjunction	crazy	Front	i
B	4	Cisgender	AMAB	Conjunction	yeah	Front	æ
B	5	Cisgender	AMAB	Conjunction	specifically	Front	i
B	6	Cisgender	AMAB	Conjunction	specifically	Front	i
B	7	Cisgender	AMAB	Adverb	be	Front	i
B	8	Cisgender	AMAB	Adverb	be	Front	i
B	9	Cisgender	AMAB	Conjunction	know	Back	oʊ
C	1	Cisgender	AFAB	Adverb	you	Back	u
C	2	Cisgender	AFAB	Conjunction	okay	Front	eɪ
C	3	Cisgender	AFAB	Adverb	be	Front	i
C	4	Cisgender	AFAB	Adverb	okay	Front	eɪ
C	1	Cisgender	AMAB	Adverb	you	Back	u
C	2	Cisgender	AMAB	Conjunction	yeah	Front	æ
C	3	Cisgender	AMAB	Adverb	do	Back	u
C	4	Cisgender	AMAB	Conjunction	yeah	Front	æ
C	5	Cisgender	AMAB	Conjunction	psychotherapy	Front	i
C	6	Cisgender	AMAB	Conjunction	you	Back	u
C	7	Cisgender	AMAB	Conjunction	so	Back	oʊ
C	8	Cisgender	AMAB	Conjunction	∅	∅	∅
C	9	Cisgender	AMAB	Conjunction	oh	Back	oʊ
C	10	Cisgender	AMAB	Conjunction	so	Back	oʊ
C	11	Cisgender	AMAB	Conjunction	clunky	Front	i

C	1	Cisgender	AFAB	Conjunction	relationality	Front	i
C	2	Cisgender	AFAB	Conjunction	∅	∅	∅
C	3	Cisgender	AFAB	Conjunction	∅	∅	∅
C	4	Cisgender	AFAB	Conjunction	circuitry	Front	i
C	5	Cisgender	AFAB	Conjunction	∅	∅	∅
C	6	Cisgender	AFAB	Conjunction	∅	∅	∅
C	7	Cisgender	AFAB	Conjunction	vulnerability	Front	i
C	8	Cisgender	AFAB	Adverb	see	Front	i
C	9	Cisgender	AFAB	Conjunction	actually	Front	i
C	10	Cisgender	AFAB	Adverb	know	Back	oʊ
C	11	Cisgender	AFAB	Adverb	you	Back	u

4.1 Trial Model - *Vowel Type (4-Level Contrast):*

```
model <- lmer(CoG ~ Gender_ID * GAB + So_Type + Vowel_Type +
                (1 + Vowel_Type + So_Type | Speaker),
              data = data)

# Set 4-level Contrast Vowel_Type
contrastMatrix <- matrix(c(
  -1/4, -1/4, -1/4,   # 1 (Front)
  3/4, -1/4, -1/4,   # 2 (Central)
  -1/4,  3/4, -1/4,   # 3 (Back)
  -1/4, -1/4,  3/4    # 4 (∅)
), nrow = 4, byrow = TRUE)
```

4.1.1: Trial Model Results (CoG Only):

Predictor	Estimate	Std. Error	*t*-value	*p*-value	Significance
(Intercept)	7816	326.55	23.94	< 0.001	***
Gender ID (+NB -CIS)	199	389.66	0.51	0.612	
GAB (+AFAB -AMAB)	-1711	422.15	-4.05	< 0.001	***
So Type (+CONJ -ADV)	-225	191.88	-1.17	0.255	
Vowel Type (+FRONT -CENTRAL)	-183	322.46	-0.57	0.576	

Vowel Type (+FRONT -BACK)	-254	187.22	-1.36	0.199
Vowel Type (+FRONT -NONE)	161	183.09	0.88	0.388
Gender ID*GAB (+NB -CIS) (+AFAB -AMAB)	819	581.22	1.41	0.167

4.2 Final Model - CoG & Skewness:

```
# Load data
data <- read.csv2("your_data_file.csv",
                  header = TRUE,
                  fileEncoding = "UTF-8",)

#Get rid of empty columns/rows (if needed)
data <- data[!apply(data, 1, function(row) all(is.na(row) | row == "")), ]
data <- data[, !apply(data, 2, function(col) all(is.na(col) | col == ""))]

#Combine Central and Front vowels into one category ("Front")
dataSubset <- data
dataSubset$Vowel_Type[dataSubset$Vowel_Type == 'Central'] <- 'Front'

View(dataSubset)

# Factor variables
dataSubset$Gender_ID <- as.factor(dataSubset$Gender_ID)
dataSubset$GAB <- as.factor(dataSubset$GAB)
dataSubset$So_Type <- as.factor(dataSubset$So_Type)
dataSubset$Preceding_Vowel <- as.factor(dataSubset$Preceding_Vowel)
dataSubset$Speaker <- as.factor(dataSubset$Speaker)

# Set contrast Gender_ID
contrastMatrix.Gender_ID = matrix(c(-1/2, 1/2), ncol = 1)
colnames(contrastMatrix.Gender_ID) = "+NB-Cis"
contrasts(dataSubset$Gender_ID) <- contrastMatrix.Gender_ID
contrasts(dataSubset$Gender_ID)

#Set Contrast GAB
```

```
contrastMatrix.GAB = matrix(c(1/2, -1/2), ncol = 1)
colnames(contrastMatrix.GAB) = "+AFAB-AMAB"
contrasts(dataSubset$GAB) <- contrastMatrix.GAB
contrasts(dataSubset$GAB)

#Set Contrast So_Type
contrastMatrix.So_Type = matrix(c(-1/2, 1/2), ncol = 1)
colnames(contrastMatrix.So_Type) = "+Conj-Adv"
contrasts(dataSubset$So_Type) <- contrastMatrix.So_Type
contrasts(dataSubset$So_Type)

#Set "∅" to "None"

levels(dataSubset$Vowel_Type)[levels(dataSubset$Vowel_Type) == "∅"] <- "None"

dataSubset$Vowel_Type <- factor(dataSubset$Vowel_Type, levels = c("Front",
"Back", "∅"))
contrastMatrix <- matrix(c(
  -1/3, 1/3,   # 1 (Front)
  2/3, 1/3,   # 3 (Back)
  -1/3, -2/3    # 4 (∅ / None)
), nrow = 3, byrow = TRUE)

# Assign names
colnames(contrastMatrix) <- c("vowel.f1 (F v B)", "vowel.f2 (F v N)")
rownames(contrastMatrix) <- c("Front", "Back", "∅")

# Apply contrasts
contrasts(dataSubset$Vowel_Type) <- contrastMatrix

# Load lme4
library(lme4)
library(lmerTest)

#CoG

# Fit 1st (Trial) model (CoG) (Singular)
```

```
modelSubset <- lmer(CoG ~ Gender_ID * GAB + So_Type + Vowel_Type +
                (1 + Vowel_Type + So_Type | Speaker),
              data = dataSubset)

# Fit 2nd (Final) model (CoG) (Removed Random Slope Vowel_Type)
modelSubset <- lmer(CoG ~ Gender_ID * GAB + So_Type + Vowel_Type +
                      (1 + So_Type | Speaker),
                    data = dataSubset)
summary(modelSubset)

#Calculate Confidence Intervals (CoG)
confint(modelSubset)

#Skewness

dataSubset$Skewness <- as.numeric(dataSubset$Skewness)

#Fit 1st (Trial) Model (Skewness) (Singular)
modelSubset <- lmer(Skewness ~ Gender_ID * GAB + So_Type + Vowel_Type +
                      (1 + Vowel_Type + So_Type | Speaker),
                    data = dataSubset)

#Fit 2nd (Final) Model (Skewness) - Remove Vowel Type Random Slope
modelSubset <- lmer(Skewness ~ Gender_ID * GAB + So_Type + Vowel_Type +
                      (1 + So_Type | Speaker),
                    data = dataSubset)
summary(modelSubset)

#Calculate Confidence Intervals (Skewness)
confint(modelSubset)
```

4.3 Post-Hoc Model:

```
# Load required package
library(MASS)   # for contr.sdif()
library(lme4)   # for lmer()
library(lmerTest)  # for p-values with lmer()
```

```
data <- read.csv2("your_data_file.csv",
                  header = TRUE,
                  fileEncoding = "UTF-8",)

data$Group <- with(data, ifelse(Gender_ID == "Cisgender" & GAB == "AMAB",
"AMAB_cis",
                                ifelse(Gender_ID == "Non-Binary" & GAB ==
"AMAB", "AMAB_NB",
                                       ifelse(Gender_ID == "Non-Binary" & GAB
== "AFAB", "AFAB_NB",
                                              ifelse(Gender_ID == "Cisgender"
& GAB == "AFAB", "AFAB_cis", NA)))))

# Make sure your Group variable is a factor with the correct order
data$Group <- factor(data$Group, levels = c("AMAB_cis", "AMAB_NB", "AFAB_NB",
"AFAB_cis"))

# Apply sliding difference contrasts
contrasts(data$Group) <- contr.sdif(4)

# Ensure contrast matrix that was applied
contrasts(data$Group)

# Run the mixed effects model (CoG)
model <- lmer(CoG ~ Group + (1 | Speaker), data = data)
summary(model)
confint(model)



# Run the mixed effects model (Skewness)
data$Skewness <- as.numeric(data$Skewness)
model <- lmer(Skewness ~ Group + (1 | Speaker), data = data)
summary(model)
confint(model)
```