Intonation Parameters in Gender Diverse People

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SUMMARY

Objectives/hypothesis: Although intonation is often addressed in speech training for gender diverse individuals, the relationship between intonation and femininity/masculinity ratings remains unclear. The aim of this study was to examine differences in intonation parameters in gender diverse individuals. Moreover, the relationship between acoustic intonation parameters and femininity/masculinity ratings was investigated.

Methods: Speech samples of semistructured speech were elicited from cisgender (cis) (107 ciswomen, 104 cis men), transgender (trans) (19 trans women, 10 trans men), and non-binary (n = 11) individuals using a prosody protocol. An objective acoustic analysis was performed to compare intonation parameters (upward/downward/flat intonation shift, general and final intonation shift, general fundamental frequency range, fundamental frequency variation index) between groups. In addition, a listening experiment was conducted, consisting of a cis and gender diverse listening panel (n = 41). The listeners were asked to rate the femininity/masculinity of speech samples (n = 57) using a visual analogue scale. Correlational analyses were used to examine the relationship between intonation parameters and femininity/masculinity ratings.

Results: Similarity was found in the intonation parameters of participants with a similar gender identity. In non-binary speakers, no significant differences in acoustic intonation parameters were found between these speakers and the cisgender speakers. In addition, no significant correlations were found between the acoustic intonation parameters and the

femininity/masculinity ratings in the groups with cis men, cis women, and non-binary participants. However, moderate to strong significant correlations were found between acoustic intonation parameters and femininity/masculinity ratings in the trans participants.

Conclusions: Intonation is a "speech marker" that distinguishes between groups with a different gender identity. No relationship was observed between intonation and femininity/masculinity ratings for cisgender and non-binary speakers. However, the significant relationship between these parameters for transgender participants (trans men and trans women) provides evidence for intonation exercises in gender affirming voice, speech, and communication training, and therefore contribute to evidence-based intonation training in transgender persons.

KEY WORDS: Intonation, Gender, Transgender, Acoustic analysis, Femininity/masculinity rating

INTRODUCTION

One of the many voice (ie, speaking fundamental frequency [SFF] and resonance), speech (ie, articulation and prosody), and communication challenges faced by gender diverse people is self-perceived voice gender incongruence (ie, the voice is not congruent with the gender identity and/or expression).[1] According to Kennedy and Thibeault,[2] the majority (88% currently, 96% in the past) of the transgender, non-binary, and gender nonconforming community experiences voice-related gender incongruence.

Voice gender incongruence can impact psychosocial well-being and participation in society,[1,3,4] since it can impair confidence in communication, comfort with gender presentation, and functioning in everyday life.[5]

Voice and communication specialists can support and help gender diverse individuals to develop voice, speech and/or communication that feels more comfortable and natural.[6] According to Leyns, Papeleu[7], gender affirming voice, speech, and communication training results in vocal changes and gender attribution that more closely approximate the client's sense of self.[5] These changes are important as eliciting correct gender attribution, which can improve mental health and quality of life (QoL).[5]

There is a great variation in voice and communication changes desired or undertaken by gender diverse people.[5] Previous research suggests that gender affirming voice, speech, and communication training in gender diverse individuals should focus on vocal characteristics considered highly salient to attribution of femininity/masculinity.8, 9, 10 SFF is the most studied vocal parameter.[11] According to Kennedy and Thibeault,[2] there is consensus between feminine, masculine, and gender neutral groups that SFF contributes the most to self-perceived voice gender incongruence. However, this parameter explains only 41.6% of the variance in gender perception.[11] Consequently, other parameters, such as resonance,[12] articulation,[12] and intonation (part of prosody),[13] also contribute to gender perception. Kennedy and Thibeault[2] revealed that participants who desire feminine and/or masculine voices are likely to select intonation as a training target. In addition to SFF and resonance, the suprasegmental parameter (ie, parameters extending over syllables, words, or phrases, for

example, stress, rhythm, intonation vs. segmental parameters involve individual sounds, e.g. vowels and consonants[14]) intonation contributes to voice-related gender incongruence.

Researchers agree that suprasegmental parameters in voice and speech, such as prosody, contain information about the speaker's gender.[8,10,15] Prosody is a suprasegmental parameter that has been described as changes in duration, fundamental frequency (f_o) (intonation) and intensity within the utterance.[16] Generally, intonation is studied more than duration or intensity, since there is more evidence that intonation contributes to gender perception of speech.[11] Intonation is primarily characterized by patterns of f_o changes during speech[17,18] and gives clues as to what type of person is speaking. In other words, this parameter gives an indication about the identity of the speaker and is influenced by biological, cultural, and sociological factors.[17] According to the biological determinism view[19], the speaker's voice and aspects of speaker's socio-cultural positioning (eg, age, gender, sexuality, ...) were seen as biologically determined. However, this perspective only considers the biophysiological influences and ignores other contributors.[20] Research literature, revealed that voices are not automatically gendered by biological processes of sexual determination.[20] Besides the speaker's anatomy of the voice organ, gender-related voice characteristics are also influenced by speaker's voice use practices, listener practices, professional practices, and supra-individual socio-cultural factors.[20] According to Azul,[21] production of speaker's gender is considered as an ongoing, socio-culturally mediated, interactional process beyond the individual's control. This conceptualization is reflected in the "biocultural assemblage view."[20] It could be assumed that gender-related voice and communication characteristics (eg, pitch, resonance, intonation,…) are amenable to behavioral change under control of the gender diverse client,[22] although several influences should be taken into account. According to Schmid and Bradley,[23] transgender people tend to pattern intonation in line with the inner self. Thus, gender identity, as part of socio-cultural positioning, may affect speech production including intonation.[23]

Acoustic intonation parameters

Several studies examined the differences in acoustic intonation parameters between cisgender (cis) women and cis men. In following English-language studies, intonation has been expressed in upward/downward intonation shifts,[24,25] f_o range,[18] and/or f_o changes (ie, variability).[18,26] Differences in acoustic intonation parameters were found, with more upward intonation shifts in the cis women compared to more downward intonation shifts in the cis men[24,27] and smaller downward intonation shifts in the cis women.[24,25] According to Wolfe, Ratusnik,[25] an argument for this finding is that the cis women avoided the lower speaking register. Cis women participants also had a larger f_o range.[18] In addition, the cis women showed more frequent and larger changes in f_o than the cis men, presumably in order to emphasize intonation more.[18,26] Dutch-language studies also revealed differences in intonation between cis men and cis women.[28,29] In these studies intonation was expressed in upward/downward(/flat) intonation shifts,[28,29] f_o range[28], and/or f_o changes (ie, variability).[28] In the study of Leyns, Papeleu[28] the group with cis women used more upward and downward intonation shifts compared to the group with cis men using more flat intonation shifts and the cis women also used larger final intonation shifts. Haan[29] reported that the cis women in their study more frequently (78%) realized a final rise in SFF during question word questions (ie, wh-questions, eg, "Why is the door still open?"), compared to the cis men in which final rises in SFF were less frequently realized (50%) in question word questions. Presumably cis women are more listener-directed and more oriented towards communication than cis men, and consequently their final rises in question word questions may have expressed greater

regardfulness and a more sympathetic attitude towards the interlocutor.[29] In addition, the cis women in the study of Leyns, Papeleu[28] had a wider f_o range and the intonation maneuvers (ie, f_o changes) during speaking were also greater and faster, which resulted in a larger f_o variation index in the cis women group.[28] There has been assumed that cis women's speech is more expressive and melodious than cis men's.[28,30] While some studies in both English- and Dutch-language exposed differences in acoustic intonation parameters between cis men and cis women, there are other English-language studies that did not find differences in terms of intonation.[31,32]

In gender diverse individuals, the purpose of only a few English-language studies was to examine acoustic intonation parameters.[20,23] The study of Hancock, Colton[13] examined 5 intonation parameters (semitone (ST) range, ST slope, percentage of upward intonation, percentage of downward intonation, and percentage of utterances within 2 semitones) in 4 groups: 2 groups with a feminine gender identity (cis women and transgender (trans) women) and 2 groups with a masculine gender identity (cis men and trans men). No significantly different intonation patterns were found between the 4 groups for each intonation measure. Schmid and Bradley[23] examined intonation in gender non-binary individuals. The researchers assumed that non-binary participants combined intonation patterns as typically observed in cisgender speakers, indicating a mix of feminine and masculine traits or neutrality. For example, speakers tended to use downward intonation shifts, which were frequently observed in the speech of cis men, while also using f_o increases which are more likely to be observed in cis women.[23] These studies revealed no differences in intonation between cis and trans participants, and non-binary participants tend to combine intonation patterns typically observed in cisgender speakers. Studies examining differences in acoustic intonation parameters in gender diverse people are limited. Some studies found differences in acoustic intonation parameters in cis and trans speakers, although there were also studies that found no differences in intonation.

According to Leung, Oates,[11] it is also important to examine the extent to which these intonation parameters contribute to femininity/masculinity ratings, since the femininity or masculinity of the voice has been considered as an important indication to a speaker's gender.

Femininity/masculinity ratings

Several studies have explored the relationship between intonation and femininity/masculinity ratings in gender diverse people.[13,24,25,33, 34, 35, 36, 37] In these studies the relationship was investigated between femininity/masculinity ratings and acoustic intonation parameters. Intonation was expressed in upward/downward intonation shifts,[13,24,25] percentage of level shifts,[25] percentage of level intonations,[25] ST range[13,34,35,37] and/or f_o variation.[24,33] Hancock, Colton[13] found significant differences between the groups with participants (cis women, cis men, trans women, and trans men) perceived as masculine and feminine. The group with participants perceived as feminine had more upward intonation shifts and less downward intonation shifts than the group with participants perceived as masculine.[13] Wolfe, Ratusnik[25] also found that they had a higher percentage of upward intonation shifts, but also a higher percentage of downward intonation shifts and less extensive downward intonation shifts. The group with trans women perceived as feminine also had a smaller percentage of level intonations and level shifts, compared to trans women perceived as masculine.[25] Nevertheless, none to small correlations between these acoustic intonation parameters and femininity/masculinity ratings were found.[13,25] Gelfer and Schofield[24] also found no significant correlations between up- and downward intonation shifts and

femininity/masculinity ratings. Several studies revealed no relationship between ST range and femininity/masculinity ratings in trans and cis speakers,[13,34,35] although Owen and Hancock[37] showed that ST range correlates with femininity/masculinity ratings in the trans women and cisgender participants of their study. Gelfer and Schofield[24] found differences between speech samples of the trans women, cis women, and cis men perceived as feminine or masculine. These researchers concluded that speech samples perceived as feminine had a greater variability in f_o than those perceived as masculine. In contrast, Dahl and Mahler[33] found no significant correlations between f_o variation (in ST) and femininity ratings in the trans women and cisgender speakers in their study. Based on these studies, it can be assumed that the contribution of intonation to femininity/masculinity ratings is small. However, according to the study Merritt and Bent[36] changes in SFF and formant frequencies (resonance) are insufficient to effectively alter femininity/masculinity ratings in cis (cis women and cis men) and trans (trans women and trans men) speakers. There is no consensus in the literature on the contribution of intonation to femininity/masculinity ratings. Therefore, further research is needed to determine the impact of targeting intonation within gender affirming voice, speech, and communication training of trans women,[11] trans men and non-binary people and may improve self-perceived gender congruence of speech.

Current study

Studies examining differences in acoustic intonation parameters within the gender diverse population are limited and from these studies it is not clear to what extent frequency changes in intonation patterns contribute to the self-perceived gender congruence of speech.[12,13,25] In addition, language differences can also affect the results, since speakers of different languages will probably place their stress in other places resulting in different intonation patterns.[28] Consequently, there is a need for an objective acoustic analysis of intonation in Belgian-Dutch, gender diverse people. The data of trans and non-binary participants are compared to data of cis individuals. The inclusion of cis and gender diverse individuals allows for a comparison between individuals with the same gender identity (cis women vs. trans women and cis men vs. trans men) and with a different gender identity (cis women vs. trans men, cis men vs. trans women, non-binary AFAB vs. cis women, non-binary AMAB vs. cis women, non-binary AFAB vs. cis men, and non-binary AMAB vs. cis men). The aims of this study are twice.

1. To explore the differences in acoustic intonation parameters, such as f_o shifts, f_o ranges and variation indexes between cis, trans, and non-binary speakers. It can be hypothesized that the acoustic intonation parameters of gender diverse participants will be in line with their gender identity, since the participants in the study of Schmid and Bradley[23] tended to pattern intonation according to their gender identity.
2. To examine the relationship between intonation and femininity/masculinity ratings using a listening experiment. Based on the literature, none[13,25,]33, 34, 35 to small[24,25,37] correlations are expected between acoustic intonation parameters and femininity/masculinity ratings.

In addition to clients' goals and preferences for speech training, the results of this study will help to elucidate the role of intonation in gender expression and attributions of femininity/masculinity and, therefore, contribute to the evidence informing gender affirming voice, speech, and communication training.

METHODS

The protocol of this study was approved by the Ethics Committee of the Ghent University Hospital (B670201941335) and completed according to the 1964 Declaration of Helsinki and its later amendments or comparable ethical standards. Informed consent was obtained from all individual participants included in the study.

Participants

Speakers

The participants were recruited through convenience and snowball sampling. In total, 251 participants were included in the current study. The following inclusion criteria had to be considered: monolingual, native Belgian-Dutch speakers aged between 16 and 65 years, with a self-perceived normal hearing and living in Flanders. Demographic information was collected using a questionnaire.[28] The total group had a mean age of 39 years (standard deviation (SD): 14.2 years) and consisted of 104 cis men, 107 cis women, 10 trans men, 19 trans women, and 11 gender non-binary individuals. Of the 11 non-binary individuals, 8(72.73%) were presumed female at birth and 3 (27.27%) were presumed male at birth. The data of 207 cis persons (n = 207/211) were collected in a previous study.[28] Table 1 gives an overview of the demographic data including the age. Based on the results of the Kruskal Wallis test, no significant differences were found in age between the 5 groups (T = 9.486; $p = 0.050$).

TABLE 1.
Descriptive Results of the Participants' Demographic Data per Gender

	Cis Women (n = 107)	Cis Men (n = 104)	Trans Women (n = 19)	Trans Men (n = 10)	Non-binary Persons (n = 11)	Total (n = 251)
Age (y)						
Mean (SD*)	40.18 (14.574)	40.04 (14.720)	36.84 (11.777)	35.60 (11.108)	26.82 (3.995)	39.10 (14.240)
Median (IQR*)	40 (26-54)	40 (27-54)	35 (29–44)	35.5 (25–47)	27 (22–31)	38 (26–52)
Min-Max*	16–65	16–65	20–60	22–50	21–31	16–65

* *Abbreviations*: IQR, interquartile range, Min-Max, minimum – maximum; SD, standard deviation.

Table 2 summarizes the treatment process of the gender diverse individuals (trans women, trans men, and gender non-binary people). Thirteen out of 19 trans women (68.42%) received gender affirming voice, speech, and communication training for speech feminization (pitch elevation training, including intonation, and articulation-resonance training) with a mean duration of 6 months (SD: 5.3 months). Of the trans men, 30% (3/10) received gender affirming voice, speech, and communication training for speech masculinization with a mean duration of 16 months (SD: 6.9 months). Most trans women and trans men received speech training from the authors (E.D. and C.L.). The trans women all had a desire for a higher speaking pitch and the trans men for a lower one. Therefore, this was the main objective during the training sessions. The intonation exercises were added as a sub-objective. When the participants did not receive gender affirming voice, speech, and communication training from the authors, the researcher asked about the content of the training sessions. In contrast, no one from the non-binary group received gender affirming voice, speech, and communication training. Three trans women (16%) were on gender affirming hormone therapy with estrogens (and have received gender affirmation surgery) and 16 trans women

(84%) with estrogens and antiandrogens. Eight trans men (80%) and 1 non-binary person (9.1%) were on gender affirming hormone therapy with testosterone.

TABLE 2.
Descriptive Results of Gender Diverse Individuals' Speech Training Characteristics

		Trans Women (n = 19)	Trans Men (n = 10)	Non-binary Persons (n = 11)
Gender affirming voice, speech, and communication training		13 (68.42%)	3 (30%)	0 (0%)
Duration (months)	Mean (SD*)	5,75 (5.312)	16,00 (6.928)	.
	Min-Max*	1 - 18	12 - 24	.
Gender affirming hormone therapy				
Estrogens		19 (100%)	.	.
Antiandrogens		16 (84%)		
Testosterone		.	8 (80%)	1 (9.1%)
Duration (months)	Mean (SD*)	18.86 (15.454)	51.75 (43.391)	43.00 (.)
	Min-Max*	4-51	4-144	.

* Abbreviations: SD, standard deviation; IQR, interquartile range, Min-Max, minimum – maximum.

Twelve native Dutch cis speakers were randomly selected from the total group (6 cis women and 6 cis men) and were included in the listening experiment. Their ages ranged from 21 to 56 years, with a mean age of 34 years (SD: 12.2 years).

Listening panel

For the listening experiment 41 individuals (15 cis men, 20 cis women, 2 trans men, 2 trans women and 2 gender non-binary persons) were recruited through convenience and snowball sampling. The inclusion criteria for the listening panel were: monolingual, Belgian-Dutch mother tongue, and a subjectively normal hearing. The listeners were blinded to the research purpose (naïve listeners), had no prior education or experience in this topic, and did not receive information about speakers' characteristics. The mean age of the listening panel was 33 years (SD: 12.7 years) with a range from 18 to 62 years.

Data collection

Speech assessment

A Samson C01U USB Studio Condensor Microphone, with a sampling rate configured at 44.1 kHz and a mouth-microphone distance of 15 cm, was used for recording the speech samples. The software program Praat version 6.1.52 was downloaded on a computer (Dell Latitude 5520). A minimum SNR of 25 dB was required. The mean SNR of all speech samples was 35.1 dB (SD: 5.42 dB).

A prosody protocol (Appendix 1) comprising 6 sentences was completed by each participant.[28] After a period of pretraining (6 sentences), the actual recordings were started. The researcher (cis women) gave 6 (live) assignments, in a neutral way without any intonation or facial expression, each eliciting a target sentence: 2 question word questions (QWQ; items 1 and 6), 2 yes-no questions (YNQ; items 2 and 4) and 2 declarative sentences (DEC; items 3 and 5). The participants were asked to produce the target sentences using habitual speech and to pay attention to the productions of the researcher in order to respond appropriately according to the interrogative or declarative pattern.[16] The target phrases are purposely close to the elicitations of the researcher, making it a semistructured dialogue. The

investigators were allowed to repeat the question once, if necessary. The prompt was repeated when the participant had not heard or understood the question correctly or when a completely different sentence was produced than the target sentence.

The prosody protocol was offered twice to 9 participants with a short break (5–10 minutes) to determine whether or not the speakers responded in the same way to both elicitations and to calculate the test-retest reliability.

Acoustic analysis

Intonation parameters were determined using the Praat software program. The procedure of Leyns, Papeleu[28] was followed. The 6 target sentences were extracted from the speech fragment, resulting in 6 speech samples. Subsequently, a script was executed to extract the voiced parts from the speech samples.[38] Unvoiced segments were left out, since these could influence maximum f_o when calculating the intonation parameters. The following 4 intonation parameters were calculated in Hertz (Hz) and equivalent rectangular bandwidth (ERB). The linear Hertz scale does not correspond with the listener's non-linear perception of pitch, therefore, the ERB scale is preferably used since this scale is based on the selectivity of the human auditory system. The following formula was used to convert Hertz to ERB: $\text{ERB} = 16.7 \log (1+ (f /165.4))$.[39]

(1) *General intonation shift (Hz and ERB) and upward/downward/flat intonation shift*

The general intonation shift is the mean size of the general increase or decrease of the f_o during the utterance. For the calculation of this continuous parameter, the first and last vowel of the sentence were selected and the f_o of the vowels was determined. Subsequently, the general intonation shift was calculated as the difference between end and start f_o. Based on the size and number of this difference, the general intonation shift was categorized as an upward, downward or flat intonation shift. A difference smaller than 1.570884399 ERB was considered as a flat intonation shift.[28] This ERB value was calculated from the Hz value (40 Hz) used by Olivati, Assumpção.[16] A difference larger than 1.570884399 ERB and a positive number could be considered an upward intonation shift, since the f_o increased between start and end. Similarly, a difference larger than 1.570884399 ERB and a negative number could be considered a downward intonation shift. The continuous variable of the general intonation shift expresses only the size of the intonation shift and is therefore presented as an absolute value. Finally, the percentage of upward, downward and flat intonation shifts could be determined.

(2) *Final intonation shift (Hz and ERB)*

The final intonation shift indicates the average size of the upward or downward intonation shift at the end of the utterance. This parameter was calculated as the difference between the f_o at the end of the final rise or drop and the f_o at the beginning. The beginning was located on the last stressed vowel and the end of the final rise or drop was located on the last unstressed vowel. For the calculation of this continuous parameter, the stressed and unstressed vowels were selected and the f_o of the vowels was determined.

In the case that the utterance ended with a stressed vowel (e.g. omlaag), the first and second part of the stressed vowel were selected (eg, omla-ag) and the f_o of both parts was determined, and the intonation shift was derived from the difference in f_o within this vowel.

(3) *General f_o range (Hz and ERB)*

This parameter was calculated as the difference between the minimum (5th percentile) and the maximum f_o (95th percentile) of the utterance. For this calculation the "Intonation and stress trajectory" script was used.[40]

(4) *f_o variation index (Hz/s and ERB/s) of the utterance*

This parameter was determined by the sum of the absolute value in Hz of all upward and downward f_o changes (at least 300 f_o values per second were determined) during the whole utterance (elicited sentence) between percentile 5 and 95 divided by the total duration of the utterance. The f_o variation index reflects the size and speed of the intonation maneuvers. For this parameter the script "Intonation and stress trajectory" was used.[40]

Listening experiment

Listeners were asked to conduct the listening experiment in a quiet room at home and to use (personal) over-ear headphones. The 6 phrases of the prosody protocol were combined into 1 speech sample per speaker. The speech samples of all gender diverse people (19 trans women, 10 trans men and 11 non-binary persons) and 12 cis speakers (6 cis women and 6 cis men) were included for the listening experiment. Five speech samples were offered twice to determine the intra-rater reliability. This yielded a total of 57 speech samples with a mean duration of 11.7 seconds. Listeners had to rate these 57 speech samples, which took approximately 30–45 minutes. This seemed to be a maximum duration to avoid fatigue in the listeners. The anonymous speech samples were presented in randomized order to the cis and gender diverse listening panel, consisting of 41 listeners, by REDCap (Research Electronic Data Capture) software.[41] The raters were able to adjust the intensity level, listened once to each speech sample, and were asked to rate the femininity/masculinity of each sample using a visual analogue scale (VAS) with the anchors "very masculine" (value 0) on the left side, "very feminine" (value 100) on the right side and "neutral" (value 50) in the middle of the scale. In order to distract the listeners from the research purpose and to avoid biased answers as much as possible, 2 other questions regarding the age and vocal quality of the speakers were also presented. The results of these questions were not analyzed and were only used to prevent raters from identifying the research purpose.

Statistical analysis

For the statistical analysis of the data SPSS 27.0 (SPSS Corp., Chicago, IL) was used. To calculate the differences in continuous intonation parameters (dependent variables) between the 5 groups with a different gender identity (independent variable) the Kruskal–Wallis test was used. The distribution of the continuous variables was not normally distributed, based on the Shapiro-Wilk normality test (Table 3). The Chi-square test was performed to determine the difference in categorical intonation parameters (dependent variables) between the 5 (gender) groups (independent variables). If at least 1 cell showed an expected value of less

than 20%, a Fisher's Exact test was used. All acoustic intonation parameters are considered as continuous variables, except for the number of upward, downward and flat intonation shifts. In order to obtain data per sentence type, the average of 2 sentences with the same sentence type was taken for each parameter. Post hoc pairwise comparisons with Bonferroni corrections were used. An adjusted significance level of $\alpha = 0.01$ was selected in order to protect against type I error rate, due to the large number of variables and comparisons performed within the current study.[42,43]

TABLE 3.
Statistical Results of the Shapiro-Wilk Normality Test for the Continuous Intonation Parameters

	W Value (Shapiro-Wilk)	*p* Value
General intonation shift		
YNQ*	0.888	< 0.001†
QWQ*	0.934	< 0.001†
DEC*	0.894	< 0.001†
Final intonation shift		
YNQ*	0.891	< 0.001†
QWQ*	0.899	< 0.001†
DEC*	0.804	< 0.001†
General f_o range		
YNQ*	0.902	< 0.001†
QWQ*	0.951	< 0.001†
DEC*	0.931	< 0.001†
f_o variation index		
YNQ*	0.924	< 0.001†
QWQ*	0.942	< 0.001†
DEC*	0.931	< 0.001†

* *Abbreviations:* YNQ, yes-no question; QWQ, question word question; DEC, declarative sentence; f_o, fundamental frequency
† Statistical significance, $p \leq 0.01$.

The intra- (T.P.) and inter-rater reliability (T.P. and C.L.) for the acoustic analysis of 2, manually determined, continuous acoustic intonation parameters were examined in 5 speech samples, randomly selected from all speech samples (n = 251). In addition, among all listeners, the inter-rater reliability for all speech samples and the intra-rater reliability of 5 speech samples were examined. The Intraclass Correlation Coefficient (ICC) was calculated, with a two-way mixed model and definition consistency (single measures) for the inter-rater reliability and absolute agreement (single measures) for the intra-rater reliability. ICC (two-way mixed, absolute agreement, single measures) was also used to examine the test-retest reliability of the prosody protocol. The ICCs were interpreted according to the guidelines of Cicchetti[44] (ICC <0.40 unacceptable; 0.40–0.59 acceptable; 0.60 – 0.74 good; >0.75 excellent).

To assess the correlation between the acoustic intonation parameters and the femininity/masculinity ratings, Spearman correlation coefficients were calculated per group and for the total group. The guidelines of Dancey and Reidy[45] were used to interpret the Spearman correlation coefficients (+/- 1: perfect correlation; +/-0.9 - +/-0.7: strong correlation; +/-0.69 - +/-0.4: moderate correlation; +/-0.39 - +/-0.1: weak correlation; 0: no correlation). All data included in the statistical analysis were expressed in Hz and ERB. Effect sizes were calculated for the Kruskal Wallis test (epsilon-squared (E^2_R)) and for the Fisher's Exact test (Cramer's *V* (*V*)).[46] No effect sizes needed to be calculated for the Spearman correlation, as the correlation is itself a measure of effect size. Therefore, the effect sizes, like the Spearman correlation coefficients, were interpreted according to the guidelines of Dancey and Reidy.[45]

RESULTS

Group differences in acoustic intonation parameters

Categorical intonation parameter

Table 4 presents the descriptive and statistical results of upward, downward and flat intonation shifts in the 5 groups Appendix 1. The Fisher's Exact test revealed significant differences among the groups for 1 yes-no question (sample 2), 1 question word question (sample 6), and both declarative sentences. Based on the descriptive data, in the sentences with significant differences for the total group of participants, the cis women had a higher percentage of upward and/or downward intonation shifts compared to the cis men. The group with cis men had a higher percentage of flat intonation shifts in contrast to the cis women. In addition, the trans women speakers had a higher percentage of flat intonation shifts than the cis women speakers and an equal or higher (except for sentence 1 – lower) percentage of flat intonation shifts than the cis men in the current study. This group of trans women speakers had a lower percentage of up- and downward intonation shifts than cis women and a lower or equal percentage of up- and downward intonation shifts (except for sentence 1 – higher) than cis men. The group of trans men had a higher percentage of flat intonation shifts and an equal or lower percentage of upward and downward intonation shifts than the groups with cisgender speakers. Non-binary speakers had an equal or higher percentage of flat intonation shifts than cisgender speakers (except for sentence 1 and 4 – lower than cis men) and the non-binary participants also had a lower or equal percentage of up- and downward intonation shifts than cis women. In some sentences, non-binary speakers had a lower percentage of upward intonation shifts than cis men (samples 3 and 6) and/or a lower percentage of downward intonation shifts than cis men (sample 2, 3, and 5). Effect sizes representing a weak relationship between the categorical intonation parameter and gender identity are found for the Fisher's Exact test (Table 4).

TABLE 4.
Descriptive and Statistical Results for the Upward/downward/flat (general) Intonation Shifts per Gender for Each Sentence Type

Sentence Type	SS*	Gender	Flat (%)	Downward (%)	Upward (%)	Test	F Value	p Value	Cramer's *V* (*V*)
QWQ*	1	Cis women	48.6	6.5	44.9	Fisher's Exact	16.359	0.022	0.191
		Cis men	70.2	1.0	28.8				
		Trans women	57.9	0.0	42.1				
		Trans men	90.0	0.0	10.0				
		Non-binary persons	54.5	0.0	45.5				
	6	Cis women	28.0	4.7	67.3	Fisher's Exact	33.859	<0.001†	0.266
		Cis men	61.6	0.0	38.4				
		Trans women	63.2	0.0	36.8				
		Trans men	80.0	0.0	20.0				
		Non-binary persons	63.6	0.0	36.4				
YNQ*	2	Cis women	49.5	6.5	43.9	Fisher's Exact	25.108	0.001†	0.232
		Cis men	72.8	1.0	26.2				
		Trans women	94.7	0.0	5.3				
		Trans men	90.0	0.0	10.0				
		Non-binary persons	72.7	0.0	27.3				
	4	Cis women	56.1	3.7	40.2	Fisher's Exact	15.876	0.026	0.184
		Cis men	78.6	1.0	20.4				
		Trans women	78.9	0.0	21.1				
		Trans men	90.0	0.0	10.0				
		Non-binary persons	63.6	0.0	36.4				
DEC*	3	Cis women	68.3	25.0	6.7	Fisher's Exact	32.107	<0.001†	0.261
		Cis men	80.2	11.7	6.1				
		Trans women	84.2	10.5	5.3				
		Trans men	100.0	0.0	0.0				
		Non-binary persons	100.0	0.0	0.0				
	5	Cis women	61.7	26.2	12.1	Fisher's Exact	28.193	<0.001†	0.255
		Cis men	90.3	7.5	2.2				
		Trans women	94.7	5.3	0.0				
		Trans men	90.0	10.0	0.0				
		Non-binary persons	90.9	0.0	9.1				

* *Abbreviations*: SS, speech sample; QWQ, question word question; YNQ, yes-no question; DEC, declarative sentence (1 and 6: QWQ; 2 and 4: YNQ; 3 and 5: DEC).
† Statistical significance, $p \leq 0.01$.

Continuous intonation parameters

The Kruskal–Wallis test exposed significant differences in general intonation shift, final intonation shift, general f_0 range (in Hz and ERB), and f_0 variation index (in Hz/s and ERB/s) among the groups in all sentence types (Table 5). Effect sizes representing a weak relationship between the continuous intonation parameters and gender identity are found for the Kruskal Wallis test (Table 5).

TABLE 5.
Continuous Intonation Parameters per Sentence Type between Gender

Sentence type	Cis Women Median (IQR*)		Cis Men Median (IQR*)		Trans Women Median (IQR*)		Trans Men Median (IQR*)		Non-binary Persons Median (IQR*)		T Value (Kruskal Wallis)	p Value (Kruskal Wallis)	Epsilon Squared (E^2_H)
	Hz	ERB	Hz	ERB	HZ	ERB	Hz	ERB	Hz	ERB			
General intonation shift													
YNQ*	47.3 (25.82-71.96)	1.8 (1.05-2.62)	25.1 (12.04-42.00)	1.0 (0.51-1.64)	38.6 (27.17-66.36)	1.5 (1.10-2.5)	16.8 (7.98-29.62)	0.7 (0.34-1.19)	21.9 (20.50-114.24)	0.9 (0.85-3,81)	35.941	<0.001†	0.145
QWQ*	83.9 (51.73-117.81)	3.0 (1.97-3.90)	38.2 (22.58-61.52)	1.5 (0.93-2.29)	58.9 (37.50-113.50)	2.2 (1.48-3.79)	17.7 (11.53-51.98)	0.7 (0.49-1.97)	56.7 (19.03-115.45)	2.1 (0.79-3.84)	58.841	<0.001†	0.241
DEC*	35.3 (22.68-57.67)	1.4 (0.93-2.17)	18.9 (12.23-27.20)	0.8 (0.51-1.10)	17.2 (9.11-50.73)	0.7 (0.39-1.94)	20.62 (16.91-26.26)	0.9 (0.71-1.07)	24.7 (18.85-32.23)	1.0 (0.78-1.29)	44.701	<0.001†	0.193
Final intonation shift													
YNQ*	78.9 (42.13-110.33)	2.8 (1.65-3.71)	26.7 (15.05-50.87)	1.1 (0.63-1.94)	45.0 (24.05-67.00)	1.7 (0.98-2.47)	15.2 (9.63-27.18)	0.6 (0.41-1.10)	38.3 (23.63-49.29)	1.5 (0.97-1.89)	75.783	<0.001†	0.304
QWQ*	69.2 (46.31-97.36)	2.5 (1.79-3.36)	31.0 (12.29-52.42)	1.2 (0.52-2.00)	35.7 (21.69-74.00)	1.4 (0.89-2.68)	13.1 (7.70-41.95)	0.6 (0.33-1.60)	49.9 (13.19-59.83)	1.9 (0.55-2.24)	55.198	<0.001†	0.226
DEC*	19.0 (7.47-38.49)	0.8 (0.17-0.77)	8.7 (3.82-18.59)	0.7 (0.32-1.52)	7.3 (4.50-18.17)	0.3 (0.19-0.76)	7.2 (4.64-18.33)	0.3 (0.20-0.75)	23.1 (3.05-28.82)	0.9 (0.13-1.17)	23.781	<0.001†	0.103
General f_o range													
YNQ*	84.0 (65.50-123.00)	3.0 (2.42-4.03)	47.0 (31.25-78.50)	1.8 (1.26-2.82)	73.0 (51.50-108.00)	2.7 (1.97-3.65)	43.5 (17.88-71.88)	1.7 (0.74-2.60)	7.30 (35.00-149.00)	2.7 (1.39-4.66)	43.976	<0.001†	0.176
QWQ*	110.0 (85.00-14150)	37 (3.01-44.8)	56.0 (35.00-85.75)	2.1 (1.39-3.03)	78.5 (55.00-112.00)	2.8 (2.08-3.75)	48.8 (24.50-67.63)	1.9 (1.00-2.49)	73.5 (53.00-132.00)	2.7 (2.02-4.26)	70.590	<0.001†	0.282
DEC*	75.5 (51.50-99.50)	2.7 (1.97-3.42)	39.3 (26.00-57.38)	1.5 (1.06-2.16)	67.5 (43.00-101.00)	2.5 (1.68-3.46)	33.0 (25.00-58.63)	1.3 (1.02-2.61)	51.5 (32.00-71.50)	2.0 (1.28-2.61)	62.186	<0.001†	0.249
f_o variation index													
YNQ*	194.5 (151.50-244.00)	5.6 (4.72-6.57)	108.0 (81.13-162.00)	3.7 (2.89-4.95)	161.0 (108.50-234.00)	4.9 (3.66-6.39)	110.0 (60.25-136.63)	3.7 (2.25-4.37)	193.5 (87.50-300.00)	5.6 (3.08-7.50)	64.250	<0.001†	0.257
QWQ*	168.5 (134.50-195.50)	5.1 (4.32-5.66)	94.0 (70.00-136.88)	3.3 (2.56-4.37)	130.5 (100.00-205.00)	4.2 (3.43-5.85)	86.3 (68.38-109.63)	3.0 (2.51-3.69)	165.0 (95.00-181.50)	5.0 (3.29-5.37)	76.666	<0.001†	0.307
DEC*	15.5 (122.00-182.00)	4.8 (4.01-538)	89.5 (70.3-126.50)	3.1 (2.56-4.12)	129.5 (95.50-252.00)	4.2 (3.31-6.72)	78.8 (67.88-105.75)	2.8 (2.49-3.58)	102.0 (87.00-147.00)	3.5 (3.07-4.61)	63.419	<0.001†	0.54

* *Abbreviations*: YNQ, yes-no question; QWQ, question word question; DEC, declarative sentence; IQR, interquartile range;
†Statistical significance, $p \leq 0{,}01$

Pairwise comparisons revealed significant differences in continuous intonation parameters between cis women and cis men, between cis women and trans men, and between trans women and cis men (Table 6). Larger values were found in cis women than in cis men and trans men, and in trans women than in cis men.

TABLE 6.
Statistical Results of the Pairwise Comparisons for the Continuous Intonation Parameters for Each Sentence Type

	YNQ*	QWQ*	DEC*
General intonation shift (*p* values)			
Cis women – cis men	< 0.001†	< 0.001†	< 0.001†
Cis women – trans men		= 0.001†	
Final intonation shift (p values)			
Cis women – cis men	< 0.001†	< 0.001†	< 0.001†
Cis women – trans men	< 0.001†	< 0.001†	
General f_o range (p values)			
Cis women – cis men	< 0.001†	< 0.001†	< 0.001†
Cis women – trans men		< 0.001†	< 0.001†
f_o variation index (p values)			
Cis women – cis men	< 0.001†	< 0.001†	< 0.001†
Cis women – trans men	= 0.004†	= 0.001†	= 0.004†
Trans women – cis men			=0.006†

* Abbreviations: YNQ, yes-no question; QWQ, question word question; DEC, declarative sentence.
† Statistical significance, $p \leq 0{,}01$.

Reliability analysis for the prosody protocol and acoustic analysis

Following the guidelines of Cicchetti,[44] good to excellent ICCs were found for test-retest reliability of the prosody protocol, tested with a 5 to 10 minutes break, for the dependent variables (ICC f_o variation index yes-no question: 0.696; ICC f_o variation index declarative sentence: 0.704; ICC general f_o range declarative sentence: 0.747; ICC general f_o range yes-no question: 0.841; ICC f_o variation index question word question: 0.871; ICC general f_o range question word question: 0.943). Excellent ICC-values were found for inter-rater reliability (for both assessors: T.P. and C.L.) and intra-rater reliability (for T.P.), calculated for the manual analyses of the general and final intonation shifts. Inter-rater reliability was 0.816 when calculating ICC-values for the general intonation shift and 0.943 for the final intonation shift. The researchers' intra-rater reliability for both general and final intonation shift was 0.999 and 0.997 respectively.

Correlations between intonation and femininity/masculinity ratings

For the femininity/masculinity rating a visual analogue scale (VAS) was used with the anchors “very masculine” (value 0) on the left side, “very feminine” (value 100) on the right side and “neutral” (value 50) in the middle of the scale. A larger value on the VAS means a more feminine perception by listeners and vice versa.

Spearman correlations coefficients for the total group

For the total group, Spearman correlation showed significant correlations between the acoustic intonation parameters and femininity/masculinity ratings.

Upward/downward/flat intonation shift

For the upward, downward, and flat intonation shifts, a moderate positive correlation was found in 1 yes-no question ($p = 0.002$, $r_s = 0.416$).

General intonation shift

A moderate positive correlation was found for the general intonation shift in yes-no questions ($p < 0.001$, $r_s = 0.472$).

Final intonation shift

For the final intonation shift, a moderate positive correlation was found in yes-no questions ($p < 0.001$, $r_s = 0.603$).

General f_o range

For the general f_o range a moderate positive correlation was found in yes-no questions ($p < 0.001$, $r_s = 0.541$), question word questions ($p < 0.001$, $r_s = 0.577$), and declarative sentences ($p < 0.001$, $r_s = 0.528$).

f_o variation index

Moderate positive correlations were found for the f_o variation index in yes-no questions ($p < 0.001$, $r_s = 0.642$), question word questions ($p < 0.001$, $r_s = 0.602$), and declarative sentences ($p < 0.001$, $r_s = 0.571$).

Spearman correlation coefficients for the separate groups of speakers

Cis men and cis women

No significant correlations were found between the acoustic intonation parameters and the femininity/masculinity ratings for the groups with cis speakers (cis women and cis men).

Trans men

Strong positive correlations were found for f_o variation index in yes-no questions ($p = 0.009$, $r_s = 0.770$) and final intonation shift in declarative sentences ($p = 0.006$, $r = 0.794$) for the group of trans men.

Trans women

Among the trans women, moderate positive correlations were found for general f_o range in question word questions ($p = 0.002$, $r_s = 0.657$) and declarative sentences ($p = 0.006$, $r_s = 0.605$) and for f_o variation index in question word questions ($p = 0.005$, $r_s = 0.614$) and declarative sentences ($p = 0.004$, $r_s = 0.629$).

Non-binary persons

No significant correlations were found between acoustic intonation parameters and femininity/masculinity ratings in the group with non-binary speakers.

Reliability analysis for the listeners

Following the guidelines of Cicchetti (1994), an excellent mean ICC-value (mean: 0.862; SD: 0.1164; range: 0.485–0.997) was found for the intra-rater reliability and an excellent ICC-value (ICC: 0.798) for the inter-rater reliability.

DISCUSSION

This study represents a novel investigation examining intonation in Belgian-Dutch cis women, cis men, trans women, trans men, and non-binary individuals.

Acoustic intonation parameters

Categorical intonation parameter

The first purpose of this study was to compare speech samples of cisgender and gender diverse people in order to explore differences in acoustic intonation parameters. Statistically significant differences were found in percentages of upward, downward, or flat intonation shifts among the groups of participants (cis men, cis women, trans men, trans women, and gender non-binary participants) for 1 yes-no question (sample 2), 1 question word question (sample 6), and both declarative sentences. Based on the descriptive data, in the sentences with significant differences among the total group of participants, the group of cis women had a higher percentage of up- and downward intonation shifts compared to the cis men with a higher percentage of flat intonation shifts. These findings for the cis speakers were already published in Leyns, Papeleu.[28]

The trans women had a higher percentage of flat intonation shifts than the cis women speakers. This group of trans women also had a lower percentage of up- and downward intonation shifts than the cis women and a lower or equal percentage of up- and downward intonation shifts than the cis men. This was not in line with the hypothesis (ie, acoustic intonation parameters of gender diverse participants are in line with their gender identity). Intonation patterns with more up- and downward intonation shifts, as observed in cis women, were expected. The trans women in this sample may have their own unique intonation pattern (ie, different from the intonation patterns of the cisgender speakers), or this could be explained, since a part of the trans women did not yet receive gender affirming speech training and if the participants did, intonation was only a sub-objective.

The group of trans men had a higher percentage of flat intonation shifts and an equal or lower percentage of upward and downward intonation shifts than the groups with cisgender speakers. These findings were within the expectations: the intonation patterns of the trans men were in line with their gender identity, since more flat intonation shifts and less up- and downward intonation shifts, as observed in cis men, were presented.[23] This could be explained by the intake of testosterone (80%) making higher tones more difficult to achieve[47] or by shame or fear of speaking in a higher register.

The group with non-binary speakers, of which 72.73% (8/11) AFAB, had in almost all sentences an equal or higher percentage of flat intonation shifts than the cis speakers in the current study and they also had a lower percentage of up- and downward intonation shifts than the cis women. In some sentences, the non-binary speakers had a lower percentage of upward intonation shifts (samples 3 and 6) and/or a lower percentage of downward intonation shifts than the cis men (sample 2, 3, and 5). These findings were not initially expected, although it should be noted that these were sometimes small differences in percentage (eg, 2%). Based on the literature, a combination of intonation patterns as typically observed in cisgender speakers, indicating a mix of feminine and masculine traits or neutrality, were expected. In addition, the needs and desires of this group of participants were not identified, and since the majority of non-binary AFAB participants (10/11) did not yet receive gender affirming speech training, intonation patterns in line with the gender assigned at birth were expected. Probably, the non-binary participants started to produce flatter and fewer up- and downward intonation patterns and had their own unique intonation pattern.

Gelfer and Schofield[24] and Haan[29] also found differences in up- and downward intonation shifts between cis women and cis men, with more upward intonation shifts in the group with cis women. However, Gelfer and Schofield[24] found more downward intonation shifts in the group with cis men. This was not the case in the current study. In contrast, Hancock, Colton[13] found no significant differences in percentage upward and downward intonation shifts between the groups with cis women, cis men, trans women and trans men. The previous studies are difficult to compare with the current studies as Gelfer and Schofield[24] included only cis speakers and Hancock, Colton[13] did not include non-binary individuals. In addition, these studies did not consider the percentage of flat intonation shifts.

Continuous intonation parameters

Additionally, for the 4 continuous acoustic intonation parameters (general intonation shift, final intonation shift, general f_0 range and f_0 variation index) statistically significant differences were found among the groups of participants for each sentence type (yes-no questions, question word questions and declarative sentences). In the majority of the sentence types all intonation parameters were statistically significant larger in the cis women in contrast to the cis men, with a significantly greater general intonation shift (in QWQ), final intonation shift (in YNQ and QWQ), general f_0 range (in QWQ and DEC), and f_0 variation index (in all sentence types). This finding was already published in the study by Leyns, Papeleu.[28]

In addition to Leyns, Papeleu,[28] the current study also compared intonation parameters between cis and gender diverse individuals. There were no statistically significant differences between the groups with a similar gender identity (cis men and trans men; cis women and trans women) for all intonation parameters in all sentence types. These findings were within the expectations. Based on a comparison between the groups with a similar gender assigned at birth, the current study found significant differences for all intonation parameters in the majority of sentence types between cis women and trans men. However, only for the f_0 variation index a significant difference was found between the trans women and cis men. This finding may suggest that trans women, who desire speech that is in line with their gender identity, need more focus on intonation, with larger general and final intonation shifts, larger f_0 range and more f_0 variability, during gender affirming voice, speech and communication training than trans men. Nevertheless, gender-affirming speech training for trans men may focus on intonation and other speech parameters that were not measured here.

The findings of the current study were partially in line with the results of Hancock, Colton,[13] who found no significant differences between the groups with cis (cis women and cis men) and trans (trans women and trans men) speakers. However, comparison with the study of Hancock, Colton[13] is difficult since other parameters were used and intonation was examined in different languages (Belgian-Dutch vs. English). Speakers of different languages will probably place their stress in other places resulting in different intonation patterns.[28]

Based on the literature, it was not totally clear what could be expected for the group of non-binary people. Schmid and Bradley[23] was the only study to examine intonation in gender non-binary individuals. Based on their study, it was hypothesized that non-binary people combine intonation patterns typically observed in cis speakers. In the current study, no statistically significant differences between the non-binary and cis participants were found and the intonation parameters of this group were at most half of the time in between those of cis/trans women and cis/trans men. This study provides additional support for the assertion that non-binary individuals combine different gender intonation patterns as described by Schmid and Bradley,[23] but presumably it is also possible that non-binary people have a unique intonation pattern of their own.

Femininity/masculinity ratings

To what extent differences in intonation parameters contribute to femininity/masculinity ratings was investigated in the second purpose of this study. Femininity/masculinity of the speech samples was rated by a cis and gender diverse listener panel during a listening experiment.

Total group

For the total group, consisting of cis, trans, and non-binary people, moderate positive correlations between the intonation parameters (upward/downward/flat intonation shift, general intonation shift, final intonation shift, general f_o range, and f_o variation index) and femininity/masculinity ratings were obtained. Moderate positive correlations between upward/downward/flat, general, and final intonation shifts and femininity/masculinity ratings were only obtained in yes-no questions, in contrast to the other intonation parameters (general f_o range and f_o variation index) where moderate positive correlations were obtained in all sentence types. The more upward and downward intonation shifts (and less flat intonation shifts) and the greater the general intonation shift, the more feminine the speech samples were rated by listeners. The same was true for the final intonation shift: the larger, the more feminine the femininity/masculinity ratings. Speech samples were also perceived more feminine when the general f_o range and f_o variation index increased.

Separate groups of speakers

In addition, correlations were calculated between acoustic intonation parameters and femininity/masculinity ratings for the 5 groups separately. In the groups with cis women, cis men, and non-binary speakers, no significant correlations between the acoustic intonation parameters and femininity/masculinity ratings were obtained. Among the trans women, moderate positive correlations were found for the general f_o range and f_o variation index in question word questions and declarative sentences. Strong positive correlations were found in trans men for the final intonation shift in declarative sentences and for the f_o variation index in yes-no questions.

Stronger correlations were found in the current study between intonation and femininity/masculinity ratings than in previous studies.[13,25] Only Gelfer and Schofield[24] and Owen and Hancock[37] found a significant correlation respectively between variability in f_0 and ST range and femininity/masculinity ratings. The results of the listening experiment are difficult to compare with these studies.[13,25] For example, in the current study cis women, cis men, trans women, trans men, and non-binary individuals were included. In contrast to Wolfe, Ratusnik[25] who included only trans women, Gelfer and Schofield,[24] Dahl and Mahler,[33] Hardy, Boliek,[34] Hardy, Rieger,[35] and Owen and Hancock[37] who included only trans women and cis individuals, and Hancock, Colton[13] who did not include non-binary individuals. In addition, other intonation parameters were used and other languages were investigated (Belgian-Dutch vs. English). There were also differences in perceptual assessment. In the study of Wolfe, Ratusnik[25] a semantic differential scale was used and in Hardy, Boliek[34] and Hardy, Rieger[35] a direct magnitude estimation scale was used. A Likert scale was used in Dahl and Mahler[33] (5-point) and in Gelfer and Schofield.[24] This in contrast to Hancock, Colton[13] and Owen and Hancock,[37] where VAS was used. The current study also used a VAS which resulted in reliable ratings. The standard deviations and ranges of the perceptual scores were greatest in the gender diverse groups (trans men, trans women, and non-binary individuals). This indicates a greater distribution and more interindividual information, since the full scale was used and not only the extremes. Wolfe, Ratusnik[25] assembled a listening panel consisting of voice and communication specialists. In contrast, the current study included naïve listeners who had no prior education or experience with the topic. According to Hancock, Krissinger,[48] naïve listeners have more variability in evaluating gender of voices, since they have no experience with rating voices, but their scores are consistent with the evaluation of (trained) voice and communication specialists.

The participant's speech samples were evaluated by a listening panel consisting of cis, trans and non-binary individuals. In comparison, in previous studies, listening panels typically consisted of cis individuals. Probably, based on the idea that gender diverse listeners would evaluate speech samples differently, since this group is more aware about their own speech than cis persons. However, Brown, Dahl[49] found no influence of rater's age and gender on femininity/masculinity ratings and also Quinn, Oates[50] found no differences between femininity/masculinity ratings performed by listeners with different gender identities.

The findings of the current study provide preliminary evidence that intonation plays a role in femininity/masculinity ratings of trans men and trans women, as also described by Leung, Oates,[11] and therefore could be included in gender affirming speech training for trans men and trans women.

Prosody protocol

The prosody protocol, developed by Leyns, Papeleu,[28] elicited semi-structured speech samples in order to measure acoustic intonation parameters. Good to excellent ICCs were found for test-retest reliability of the prosody protocol, which indicated consistent responses of the participants to the questions between the first and second measurement. The protocol also consisted of a pre-training session that gave the participants time to get used to the questioning before starting the actual speech recordings. Additionally, using a semi-structured dialogue made the prosody protocol stronger, as the instructions elicit continuous speech that closely resembles spontaneous habitual speech and based on the study of Lieberman[51] of most human communication is spontaneous. The prosody protocol is a helpful assessment tool and may be useful in clinical practice to measure and follow-up

intonation objectively during gender affirming voice, speech, and communication training. However, the validity and reliability of the prosody protocol must be further determined. Further, cross-linguistic research is necessary to investigate whether this protocol can detect the same gender related differences in other languages.

Strengths, limitations, and future research

The current study has several strengths. This intonation study is unique because it was the first study to include cis, trans, and non-binary participants, unlike previous studies typically focused on 1 or 2 subgroup(s).[24,52] In addition, a large sample of participants was included. A standardized prosody protocol with good test-retest reliability was used and the acoustic intonation parameters were expressed in Hz and ERB. In addition to an objective analysis of intonation, the contribution of intonation to femininity/masculinity ratings was also investigated using a listening experiment with a cis and gender diverse listening panel.

Besides strengths this study also contains several limitations. Sample sizes of the groups of participants were not equal, with smaller groups for gender diverse people compared to cis people. The group with gender non-binary participants was younger compared to the participants in the other groups. This may have influenced the results, since previous research showed differences in intonation parameters between younger and older age groups.[28] In the study of Leyns et al,[28] the group with elder people (+55 years) had a more expressive intonation, with larger general and final intonation shifts, a larger general f_0 range, and a larger f_0 variation index. However, gender diverse individuals with a large age range were included given the difficult recruitment. Future studies should include groups with equal sample sizes and an equal age distribution. Secondly, stress may have affected the spontaneity of the participants' utterances.[53] Depending on profession, hobby or previous speech training, for some subjects this may have been the first time of speaking into a microphone. Some participants will have used a different intonation pattern, with a more or less dynamic intonation, compared to their habitual, spontaneous speech. Therefore, calculating the test-retest reliability was important. This was already done in the current study with a break of 5 to 10 minutes. A longer break (eg, 1 week) would be interesting in order to determine whether or not the speakers responded in the same way to the elicitation after a longer period of time. A 1-week break might cause the participants to be less stressed before the study, because they already know what is expected of them and probably, as a result, their intonation will be more in line with their habitual spontaneous speech. In addition, semi-structured tasks allow for some experimental control while still approximating spontaneous speech. However, it may not capture shifts as they would naturally occur in a conversational or narrative context, thereby limiting the ecological validity. In further research, it will be important to also include additional speech tasks, in order the measure the acoustic intonation parameters in spontaneous speech, such as describing a picture or responding short questions (e.g. 'What is your favorite season and why?'). Finally, the cis and gender diverse listening panel was not evenly distributed in terms of age and gender and the hearing status of the listeners was not objectively determined. Convenience sampling resulted in younger listeners and mostly cis listeners. The unequal distribution of the listening panel according to age and gender identity could possibly have influenced femininity/masculinity ratings. In the study of Kausler and Puckett,[54] older adults were less able to remember the speaker's gender resulting in a less accurate assessment. Nevertheless, Brown, Dahl[49] found no major influence of listener's gender and age on femininity/masculinity ratings. However, 30 listeners (20 cisgender and 10 gender diverse listeners) were included in the study and the listening panel had to rate the voice of only 1 trans man.[49] Therefore, in future research, it is important to

acknowledge an equal distribution of age and a representative gender distribution during the recruitment of a listening panel and to objectify the hearing status using an audiometric examination.

Clinical implications

The results of the current study gave insights in the acoustic intonation parameters and the relationship with femininity/masculinity ratings in cis, trans, and gender non-binary people. The findings of the current study may shed more light on the relevance of intonation exercises in gender affirming voice, speech and, communication training for gender diverse individuals. These findings may suggest that it is relevant to include intonation in speech training for trans men and trans women: except for 1 intonation parameter in 1 sentence type, no significant differences were found between the cis men and trans women (ie, participants with a similar gender presumed at birth), and moderate to strong correlations between acoustic intonation parameters and femininity/masculinity were found in the groups with trans women and trans men.

The aims of the intonation training will depend on the wishes and the needs of the client. Intervention that focuses on more variation in f_o, more upward and downward intonation shifts, larger intonation shifts, and a wider f_o range may result in a more feminine perception of speech, since these parameters had higher values in the cis and trans women of the current study. In contrast, when the client desires speech masculinization, the aim is to achieve more flat intonation patterns with less variation in f_o, and a smaller f_o range, since these parameters had lower values in the cis and trans men of the current study. To date, there is no consensus in the literature about the specific communicative needs of non-binary, genderqueer, gender diverse, gender fluid, bigender, and agender/neutrois individuals.[2,55] In general, gender affirming voice, speech, and communication training likely focus on cisnormative or stereotypical patterns of communication including intonation. “There is a tendency to treat the notions of sex and gender as “pre-given traits or ‘natural facts,’ that reside in individuals.”[56] Nevertheless, professional support for gender diverse individuals needs to be individualized,[57] since “The voice reveals the inner self. It is a reflection of the personality of the individual.”[1] For example, not all gender diverse AFAB persons who identify as male, wish to present themselves with a male voice.[57] Speakers can engage in different voice use practices, with the focus on different voice characteristics, although they identify with a similar gender category.[20] This is especially important when approaching non-binary individuals. After all, it is a diverse group that will position itself variably in terms of gender and other categories of sociocultural belonging.[57] Voice and communication specialists will have different views on how a voice, representing a particular gender position of the speaker, should sound and what professional practices might be the most appropriate to support a speaker in conveying the socio-cultural positioning in accordance with the predetermined wishes and needs.[20] These specialists help individuals to find and develop voice and communication that reflects the speaker's sense of gender.[5] Although this was not questioned, it is possible that the non-binary participants, 72.73% of whom were AFAB, desired a more masculine perceived voice, as the non-binary participants produced higher percentage flat and lower percentage up- and downward intonation shifts, as was also found among the trans men. In addition, it may also be possible that non-binary individuals are more likely to desire speech feminization or a neutral voice. In the present study, most of the intonation values of the non-binary subjects were in between those of the cis women and cis men. Consequently, it is also possible that the non-binary participants had the desire to combine the intonation patterns typically observed in cis women and cis men in order to achieve a mix of both. There

is a lack of knowledge in the literature regarding the voice, speech, and communication related needs and wishes of gender non-binary people and consequently there is a need for future research.

The results of this study may inform voice and communication specialists providing gender affirming voice, speech, and communication training in a gender diverse population about the relevance to include intonation as training target. The effects of intonation training on acoustic and perceptual intonation parameters in gender diverse people should be investigated in future research.

CONCLUSIONS

The purpose of this study was to examine differences in intonation parameters in gender diverse people (cis men, cis women, trans men, trans women, and gender non-binary people) and to investigate the relationship between the acoustic intonation parameters and femininity/masculinity ratings. Significant differences in intonation parameters were found among groups with a different gender identity (cis women – cis men; cis women – trans men). However, only in 1 intonation parameter in 1 sentence type, significant differences were found between the cis men and trans women. Similarity was found in the acoustic intonation parameters of participants with a similar gender identity (cis women – trans women; cis men – trans men). In the group with non-binary speakers, no significant differences in acoustic intonation parameters were found with the cisgender speakers. The listening experiment showed no significant correlations between the acoustic intonation parameters and the femininity/masculinity ratings in the groups with cis men, cis women, and non-binary participants. In contrast, moderate to strong significant correlations were found respectively in the trans feminine and trans masculine participants. Therefore, there is preliminary evidence that intonation is related to rated femininity/masculinity in trans men and trans women.

The prosody protocol may be useful as an assessment tool in clinical practice to measure and follow-up intonation objectively during gender affirming voice, speech, and communication training. The results of the current study may provide support for intonation in gender affirming voice, speech, and communication training, and therefore contribute to evidence-based intonation training in gender diverse individuals.

Appendix 1: Prosody Protocol

Based on Olivati, Assumpção[16] and Gussenhoven and Rietveld[58]

Dutch Version

Ik ga u enkele vragen stellen. Het is de bedoeling dat u deze telkens beantwoordt in één korte zin, zoals u normaal spreekt.

Een vraag kan bijvoorbeeld zijn: “Hoe vraag je aan een vriend of hij koffie of thee wil?” Dan stelt u de vraag: “Wil je koffie of thee?” (voorbeeldopdracht 1).

Nu is het aan u. U mag eerst enkele keren oefenen. Daarna start de opname.

Pretraining

A) MEDEDELENDE ZIN

Hoe zeg je dat je nog veel werk hebt vanavond?

Uitgelokte doelzin: “Ik heb nog veel werk vanavond.”

B) JA-NEEN-VRAAG

Hoe vraag je aan een vriend of hij meegaat naar de winkel?

Uitgelokte doelzin: “Ga je mee naar de winkel?”

C) ALTERNATIEVE VRAAG

Hoe vraag je aan een vriend of hij wijn of bier wil?

Uitgelokte doelzin: “Wil je wijn of bier?”

D) VRAAGWOORDVRAAG

Hoe vraag je hoeveel het brood kost?

Uitgelokte doelzin: “Hoeveel kost het brood?”

E) MEDEDELENDE ZIN

Hoe zeg je dat je spaghetti gaat maken.

Uitgelokte doelzin: “Ik ga spaghetti maken.”

F) JA-NEEN-VRAAG

Hoe vraag je aan een vriend of hij dat gedaan heeft?

Uitgelokte doelzin: “Heb jij dat gedaan?”

Vanaf nu start de opname.

1) VRAAGWOORDVRAAG

Hoe vraag je waarom de deur nog open staat?

Uitgelokte doelzin: “Waarom staat de deur nog open?”

2) JA-NEEN-VRAAG

Hoe vraag je of de lonen omlaag gaan?

Uitgelokte doelzin: “Gaan de lonen omlaag?”

3) MEDEDELENDE ZIN

Hoe zeg je dat jullie de hele dag binnen hebben gezeten?

Uitgelokte doelzin: “We hebben de hele dag binnen gezeten.”

4) JA-NEEN-VRAAG

Hoe vraag je aan een vriend of hij al gekookt heeft?

Uitgelokte doelzin: “Heb je al gekookt?”

5) MEDEDELENDE ZIN

Hoe zeg je dat het gewoon niet anders kan?

Uitgelokte doelzin: “Het kan gewoon niet anders.”

6) VRAAGWOORDVRAAG

Hoe vraag je aan een vriend waarom hij zijn auto wil verkopen?

Uitgelokte doelzin: “Waarom wil je je auto verkopen?”

Dat was de laatste opdracht. Bedankt voor uw deelname!

English Version (Forward Backward Translation From Dutch)

I'm going to ask you some questions. You are supposed to answer these in 1 short sentence, as you normally speak.

For example, a question might be, “How do you ask a friend for coffee or tea?” So, then you ask the question: “Would you like coffee or tea?”.

Now it's up to you. First, you can practice a few times. Then, I will start the recording.

Pretraining

A) DECLARATIVE SENTENCE

How do you say you still have a lot of work tonight?

Elicited target phrase: “I still have a lot of work tonight.”

B) YES-NO QUESTION

How do you ask a friend to go to the store?

Elicited target phrase: “Are you going to the store?”

C) ALTERNATIVE QUESTION

How do you ask a friend if he wants wine or beer?

Elicited target phrase: “Do you want wine or beer?”

D) QUESTION WORD QUESTION

How do you ask how much the bread costs?

Elicited target phrase: “How much does the bread cost?”

E) DECLARATIVE SENTENCE

How do you say you're going to make spaghetti?

Elicited target phrase: “I'm going to make spaghetti.”

F) YES-NO QUESTION

How do you ask a friend if he did that?

Elicited target phrase: “Did you do that?”

From now on, the recording will start.

1) QUESTION WORD QUESTION

How do you ask why the door is still open?

Elicited target phrase: “Why is the door still open?”

2) YES-NO QUESTION

How do you ask if the wages are going down?

Elicited target phrase: “Are the wages going down?”

3) DECLARATIVE SENTENCE

How do you say you've been indoors all day?

Elicited target phrase: “We've been indoors all day.”

4) YES-NO QUESTION

How do you ask a friend if he has cooked yet?

Elicited target phrase: “Have you cooked yet?”

5) DECLARATIVE SENTENCE

How do you say that there is simply no other way?

Elicited target phrase: “There is simply no other way.”

6) QUESTION WORD QUESTION

How do you ask a friend why he wants to sell his car?

Elicited target phrase: “Why do you want to sell your car?”

That was the last sentence. Thank you for your participation!

CONFLICT OF INTEREST

The authors declare that they have no conflict of interest.

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