

**Do voices carry valid information about a speaker's personality?**

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<sup>1</sup> Author contributions: CS came up with the study idea, JS and CS contributed to the study design. All authors performed data collection. RCA wrote the Open Script for which JS simulated data. CS will do the voice analyses, based on scripts by DAP and DF. JS will clean the data. RCA will analyze the data. JS drafted the Stage 1 manuscript and will draft the Stage 2 manuscript. All authors provided critical revisions and approved the final version of the manuscript for submission.

## **Abstract**

Research on links between peoples' personality traits and their voices has primarily focused on other peoples' personality judgments about a target person based on a target person's vocal characteristics, particularly voice pitch. However, it remains unclear whether individual differences in voices are linked to actual individual differences in personality traits, and thus whether vocal characteristics are indeed valid cues to personality. Here, we investigate how the personality traits of the Five Factor Model of Personality, sociosexuality, and dominance are related to fundamental frequency (voice pitch) and formant frequencies. For this purpose, we will conduct a secondary data analysis of a large sample (2,278 participants) from eleven different, independent datasets with a Bayesian approach.

## **Highlights**

- Investigating associations between self-reported personality traits and vocal parameters
- Cue validity of Big 5, sociosexuality, dominance from voice pitch and formant frequencies
- Secondary data analysis with large sample from eleven independent datasets, analyzed with Bayesian approach
- Automatized and reproducible voice analyses using Praat software

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### **Theoretical background**

When meeting new people, we make spontaneous inferences and form first impressions about a wide range of characteristics (e.g. Ambady & Rosenthal, 1992). Besides physical characteristics, such as sex (Bachorowski & Owren, 1999; Puts et al., 2012), body size (Feinberg et al., 2005; Xu et al., 2013), or strength (Sell et al., 2010), we also form stable impressions about other relevant characteristics, including attitudes, intentions, values, beliefs and personality traits (Borkenau & Liebler, 1992; Borkenau et al., 2004; McAleer et al., 2014; Scherer, 1972).

While other peoples' physical appearance might be an important cue to our social evaluations (Naumann et al., 2009), peoples' voices are another factor that influences socially relevant impressions (Borkenau & Liebler, 1992; Mileva et al., 2018; Zuckerman & Driver, 1989). Indeed, when visual cues are absent, e.g., when listening to the radio or hearing a voice on the telephone, people still form judgments about others, based only on acoustic information (Borkenau & Liebler, 1992; Mileva et al., 2018).

Human voices and judgments based on their sound seem to have an association with important life outcomes: Studies have reported that voice characteristics predict mate choice (for an overview see Puts et al., 2014), courtship outcomes (Leongómez et al., 2014), and reproductive success (Apicella et al., 2007). Even voting behavior has been reported to be influenced by politicians' voices, in that participants preferred to vote for candidates with a lower voice pitch (the rate of vocal fold vibrations which influences perceptions of pitch, usually equated with fundamental frequency, e.g. how high or deep a voice sounds), presumably because low pitch sounds more dominant, honest, intelligent, and attractive (Klofstad et al., 2016; Tigue et al., 2012). Further, CEOs with lower voice pitch oversee larger companies, receive higher compensations, and enjoy longer tenures than CEOs with higher voice pitch (Mayew, Parsons, & Venkatachalam, 2013).

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Voice pitch has been associated with personality judgments in multiple studies, showing that men and women with lower voice pitch are perceived as more dominant (e.g. Borkowska & Pawlowski, 2011; Collins, 2000; Hodges-Simeon et al., 2010; Puts et al., 2006; 2007). Furthermore, people with higher pitched voices have been perceived to be more nervous (Apple et al., 1979), less agreeable (Scherer, 1978), and higher in neuroticism (Aronovitch, 1976; Scherer, 1978). Moreover, men with lower voice pitch and lower formant frequencies (defined as resonant frequencies determined by the length and shape of the vocal tract and influence perceptions of vocal timbre, an example for perceivable changes in formant frequencies without changes in pitch is raising formant frequencies when inhaling helium gas) are perceived as more attractive (e.g. Collins, 2000; Feinberg et al., 2011; Hodges-Simeon et al., 2010; Jünger et al., 2018b; Puts 2005; 2006), while vocal attractiveness correlates positively with rated conscientiousness and negatively with rated neuroticism (Zuckerman et al., 1995). These social evaluations and personality judgments based on other peoples' voices are characterized by a high level of agreement between perceivers across different speech contents and contexts (Mahrholz et al., 2018; McAleer et al., 2014; Scherer, 1972). Interestingly, three studies suggest that judgments of extraversion and emotional stability based on voice are somewhat accurate (compared with target people's self-reported personality traits; Borkenau & Liebler, 1992, with  $N = 100$  self-reported personality; Scherer, 1972, with  $N = 59$  self- and peer-reported personality; Scherer, 1978, with  $N = 24$  peer-reported personality).

While there are some studies on personality judgments from voices, literature on vocal characteristics and their actual link to target personality and individual differences is rather scarce. Only three early studies has reported direct associations between some vocal characteristics and personality trait variables: Allport and Cantril (1934) reported that more extraverted people had 'louder, more boisterous and carefree voices' (in  $N = 3$  male speakers

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scoring low, medium and high on judge-rated extraversion, respectively). Mallory and Miller (1958) reported that participants, whose voices were judged as “especially high”, self-reported lower dominance and higher introversion (in total  $N = 372$  without any information on their sex, whereas it remains unclear how many participants had “especially high” voices and were, thus, part of the analyses). Borkenau and Liebler (1992) reported that self-reported agreeableness, but none of the other Big 5 personality traits, correlated significantly with other-rated higher voice pitch (in  $N = 100$  with 50% women). Moreover, a relationship between lower voice pitch and markers associated with more self-reported unrestricted sociosexual behavior has been reported in that lower voice pitch in men, as well as more other-rated attractive voices in both sexes, were associated with self-reporting a higher number of sex partners (Hughes et al., 2004; Puts, 2005).

Nevertheless, no study has directly investigated links between actually measured acoustic parameters and self-reported personality traits. Therefore, this study's aim is to examine which vocal characteristics, if any, are related to self-reported personality traits. For this purpose, we will combine different independent datasets from previous studies for secondary data analysis, resulting in a large sample size to investigate the relationship between vocal characteristics and personality traits.

### **Hypotheses**

Based on previous studies, we hypothesize that voice pitch is a valid cue to the speaker's self-reported personality traits. More precisely, as previous studies reported associations between subjectively judged voice pitch and self-reported dominance and extraversion (Mallory & Miller, 1958), agreeableness (Borkenau & Liebler, 1992), and number of sexual partners (Hughes et al., 2004; Puts, 2005), we hypothesize:

Hypothesis 1: Participants with lower voice pitch will self-report as higher on dominance.

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Hypothesis 2: Participants with lower voice pitch will self-report as higher on extraversion.

Hypothesis 3: Participants with lower voice pitch will self-report as lower on agreeableness.

Hypothesis 4: Participants with lower voice pitch will self-report as higher (more unrestricted) on sociosexual behavior.

Previous research has mostly neglected potential sex differences in the association between voice pitch and personality traits. As voice pitch is highly sexually dimorphic (sex differences in voice pitch are about 5 *SDs*; Puts et al., 2012), it seems plausible, that effects might go in opposite directions for male and female speakers. Thus, we decided to analyze speaker's sex as potential moderator variable. We will also add formant frequencies as a predictor variable in an exploratory manner. Formant frequencies have been reported to influence vocal attractiveness and to be another important variable that might influence social impressions (e.g. Collins, 2000; Feinberg et al., 2011), but have not yet been linked to personality. Further, we will perform a number of exploratory analyses investigating the relationships between voice pitch, formant frequencies and conscientiousness, neuroticism and openness for experiences. We decided to do these analyses in an exploratory manner, as there is evidence that judgments of these self-reported traits are somewhat accurate (e.g. Borkenau & Liebler, 1992), and voice parameters are used by others to form these judgments (Aronovitch, 1976; Scherer, 1978; Zuckerman et al., 1995). However, no study so far has investigated whether voice pitch is, indeed, a valid cue to people's conscientiousness, neuroticism or openness for experiences. Additionally, we will also investigate the associations of voice parameters with sociosexuality (full scale score), and its other two facets besides behavior, namely attitude and desire (Penke & Asendorpf, 2008). Again, judgments of sociosexuality at zero acquaintance have been reported to be somewhat accurate (Stillman & Maner, 2009), and the three facets are intercorrelated (Penke & Asendorpf, 2008), but research on voice pitch as a valid cue to sociosexuality and the three facets is missing in the literature.

## Methods

### Participants

A total of 2,278 participants ( $n = 931$  men;  $n = 1,347$  women; aged 16 to 56 years) were recruited in eleven different, independent previous studies focused on other research questions (see Tables 1 and 2 for more information). As the self-reported personality traits differ across studies (see Table 1), the sample size for analyses of the different self-reported personality traits are as follows: dominance with  $N = 988$  ( $n = 492$  women), Big 5 (openness, conscientiousness, extraversion, agreeableness, neuroticism) with  $N = 1,449$  ( $n = 822$  women), and sociosexuality with  $N = 2,082$  ( $n = 1,283$  women). The sample sizes for the current analyses greatly exceed sample sizes from previous studies on voices and personality. Thus, we expect a much higher test power for finding effect sizes comparable to previous studies, or even smaller effects.

### Measures

#### *Personality variables*

All personality measures were taken via self-report questionnaires: Sociosexuality was measured as a full scale score of the three facets behavior, attitude and desire with the SOI-R (Penke & Asendorpf, 2008), Example items for the three facets of sociosexuality are “*With how many different partners have you had sex within the past 12 months?*” for sociosexual behavior, “*Sex without love is OK.*” for sociosexual attitude, and “*How often do you have fantasies about having sex with someone with whom you do not have a committed romantic relationship?*” for sociosexual desire (for details see Penke & Asendorpf, 2008). Dominance was measured with the Interpersonal Adjective List (IAL; Jacobs & Scholl, 2005) or the German version of the revised Interpersonal Adjective Scale (IAS-R; Ostendorf, 2001). Neuroticism, extraversion, openness to experience, agreeableness and conscientiousness were assessed as the dimensions of the Five Factor Model (FFM) of Personality and measured with the German NEO-FFI (Borkenau & Ostendorf, 1993; 12 items per dimension; Sample 2), the

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BFI-10 (Rammstedt & John, 2007; Sample 9), the BFI 42-item version (Lang et al., 2001; Samples 3 and 7), or the BFI 44-item version (John, Donahue, & Kentle, 1991; Samples 4, 8 and 10). Detailed information are shown in Table 1.

### *Voice recordings and analyses*

For voice recordings, participants were instructed to either read an excerpt from a standardized voice passage (e.g. the “rainbow passage”; Fairbanks, 1960; Samples 4, 5, 6, 8 and 11), count from 1 to 10 (Samples 2 and 3), say “A-E-I-O-U” (speaking vowels, Samples 1 and 10), say exactly the same standardized sentence (“Hi, I am a student at McMaster University”, Sample 9), or present themselves (answering the question “What do you think is great about yourself?”, with i.e. “I’m successful at my job”; Sample 7). Detailed information on voice recordings used in the different datasets are shown in Table 1. Length and content of different voice recordings should not affect relationships between personality and vocal parameters, because vocal parameters usually show moderate to strong correlations across different recordings, even independent of length and content (Mahrholz et al., 2018, Puts et al., 2012). Moreover, all recordings are of a neutral content, in which pitch variation is usually very small (Belin et al., 2008). To reduce the influence of loudness of different recordings, we will normalize loudness to 70dB for all recordings before analysis. For all samples with multiple voice recordings per participant (due to a within-subjects design with repeated measures), we will analyze the recordings from the first session only.

All voices will be analyzed using Praat software (Version 6.0.37; Boersma & Weenink, 2018). We will measure the following variables: mean  $F_0$  (fundamental frequency), mean formant frequencies (supralaryngeal vocal tract resonances) from which we will compute  $P_f$  (by standardizing  $f_1$ ,  $f_2$ ,  $f_3$  and  $f_4$  and dividing the sum by four, following Puts et al., 2012). Scripts for acoustic analyses are publicly available on the OSF (Feinberg, 2018; Puts & Cardenas, 2018).

### *Data transformations*



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For  $F_0$  analyses, we will use the variable “mean Pitch”, extracted by Praat.  $P_f$  will be computed using the standardized and aggregated value of the four formants (Puts et al., 2012). All personality measures will be z-standardized.

### **Statistical analyses**

All analyses will be computed with the statistical software R (R Core Team, 2016) and the package brms (Bürkner, 2017) which implements an R interface to the probabilistic programming language Stan (Carpenter et al., 2015). The analysis code is publicly available<sup>2</sup> ([https://osf.io/x4jzq/?view\\_only=936b51fe701b4fc68ce9ece565f6292a](https://osf.io/x4jzq/?view_only=936b51fe701b4fc68ce9ece565f6292a)). All data used for the analyses will be uploaded to the same OSF page. According to recommendations by Kruschke (2018) we will focus on estimating the strength of associations between voice parameters and personality traits. However, to give recommendations for future research, we will implement a decision rule (Makowski & Lüdtke, 2019) where we combine a region of practical equivalence (ROPE) from -0.1 to 0.1 with the 95% highest density interval (HDI) of the estimated effect sizes. This will allow us to differentiate between three scenarios: a) The estimated HDI is completely within the ROPE. Future researchers should not expect to find substantive associations here, unless they think our ROPE was too broad, or can substantially improve on our measurement of voice parameters or dependent variables. b) The HDI overlaps with the ROPE, so we do not know whether the association is outside the ROPE – in other words, our estimates are insufficiently precise and future research with larger samples is needed. c) The estimated effect sizes seem substantial because our HDI is outside the ROPE. Future research should work to better characterize these associations.

As all variables except age and sex will be standardized, we will use weakly informative normal priors (centered on zero, with standard deviations of 3) for all population-level effects

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<sup>2</sup> The analysis code has been produced using simulated data. It currently only includes analyses for the relationship between vocal characteristics and dominance, but analyses for all other personality traits will be identical, but with the respective trait as outcome.

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and the brms default priors for all other parameters. All models will be adjusted for age. Sex will be investigated as a moderator variable. Sex will be effect-coded without weights, with women coded as -1 and men as 1. Age will be adjusted as a linear effect. For one sample, we lack precise age information; it was only recorded that participants were undergraduates.

Therefore, we will use an errors-in-variables approach. In datasets where age was measured, age is entered as measured with a standard error of 0.5 (rounding error). In the undergraduate dataset with unmeasured ages, we assume an age of 20 with a standard error of 3. In effect, this means this dataset will not contribute much to estimating the age effect, but does not have to be excluded because of missing data. Because the personality traits were measured with scales of varying length, we will conduct a robustness check in which we allow not only the intercepts and slopes to vary by study, but also the residual variation.

We will always fit one “simple” model per personality trait to be predicted. In Wilkinson notation, the model will be specified as<sup>3</sup>:

$$\text{Personality\_outcome} \sim (F_0 * \text{sex}) + (P_f * \text{sex}) + \text{me}(\text{age}, \text{age\_se}) + (1 | \text{dataset})$$

To diagnose nonlinearity, we will graph the bivariate relationships between all vocal parameters and all traits in scatterplots overlaid with thin-plate spline smooths (Wood et al. 2016). If visual diagnosis indicates nonlinearity or interactions with sex for certain parameter-outcome combinations, we will fit models allowing nonlinearity via thin-plate splines and/or interactions, respectively. If approximative leave-one-out cross-validation (LOO-IC; Vehtari, Gelman, & Gabry, 2016) favors these adapted models over the simple main effect model (LOO-IC lower than by more than 2 standard errors), we will discuss these models instead.

We will not apply the HDI+ROPE decision rule to nonlinear effects, but simply show them

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<sup>3</sup> Age was not assessed in Sample 9. For this sample, we only have the information that all participants were undergraduate students. We opted to still include this dataset, sampling from a parametric distribution for age in an errors-in-variables approach for this sample, as reflected by the  $\text{me}(\text{age}, \text{age\_se})$  term.

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visually and discuss them. If we find that the HDI is not within the ROPE or if we find evidence for nonlinear effects, we will also fit an additional model to see whether this association is invariant across datasets by allowing the relevant linear terms in the regression to vary by dataset and comparing models' LOO-ICs. In the case of model non-convergence, we will first increase the number of iterations and the `adapt_delta` parameter, as advised by the `brms` package diagnostics. If this is not sufficient, we will further examine the reasons for non-convergence and potentially set more informative priors or reduce model complexity if absolutely necessary.

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Table 1

Information about the combined datasets on sample sizes, content of voice recordings, used personality questionnaires and publications in which the sample has been used before and purpose of the original study for which the data has been collected.

<b>Dataset number</b>	<b>N (male/female)</b>	<b>Voice recordings</b>	<b>SO I-R</b>	<b>BFI</b>	<b>NEO-FFI</b>	<b>IAL/ IAS-R</b>	<b>Sample characteristics detailed in:</b>	<b>Purpose/topic</b>
<b>1</b>	400 (0/400)	Vowels	X				Jones et al. (2018)	Ovulatory cycle effects and hormonal contraception
<b>2</b>	382 (190/192)	Counting 1-10	X		X	X	Asendorpf, Penke & Back (2011)	Speed Dating
<b>3</b>	284 (141/143)	Counting 1-10	X	X		X	Penke & Asendorpf (2008 Study 2)	Creating a revised version of the sociosexual orientation inventory
<b>4</b>	265 (0/265)	German rainbow passage	X	X			N/A	Ovulatory cycle effects
<b>5</b>	187 (61/126)	Rainbow passage	X				Puts et al. (2016)	Sexual selection on voice pitch
<b>6</b>	186 (186/0)	German rainbow passage	X				Schild, Stern, & Zettler (2019)	The relationship between voice pitch and trustworthiness
<b>7</b>	165 (165/0)	Self-presentation	X	X		X	Kordsmeyer & Penke (2019)	Hormones, personality and mating
<b>8</b>	157 (0/157)	German rainbow passage	X	X		X	Jünger et al. (2018a; 2018b Study 2)	Ovulatory cycle effects
<b>9</b>	108 (44/64)	Standardized sentence			X		N/A	Association of personality and vocal parameters
<b>10</b>	88 (88/0)	Vowels			X		N/A	Intelligence and attractiveness
<b>11</b>	56 (56/0)	Rainbow passage	X				Hill et al. (2013)	Sexual selection of men's traits (dominance and attractiveness)

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Table 2

Additional information about the combined datasets on age span, dropouts, country in which the data has been collected

<b>Dataset number</b>	<b><i>N</i> (male/female)</b>	<b>Age span</b>	<b>Country</b>	<b>Dropouts</b>	<b>Reasons for dropouts</b>
<b>1</b>	400 (0/400)	16-30 years	Scotland	none	N/A
<b>2</b>	382 (190/192)	18-54 years	Germany	$n = 1$ for SOI-R and dominance analyses	Did not fill out these questionnaires
<b>3</b>	284 (141/143)	19-30 years	Germany	$n = 1$ for dominance analyses	Technical problems
<b>4</b>	265 (0/265)	18-35 years	Germany	none	N/A
<b>5</b>	187 (61/126)	18-27 years	USA	none	N/A
<b>6</b>	186 (186/0)	18-56 years	Germany	$n = 2$ dropped out	Did not fill out the questionnaires
<b>7</b>	165 (165/0)	18-34 years	Germany	$n = 1$ dropped out for $F0$ analyses, $n = 5$ for $Pf$ analyses	Did not want their recording to be used for further analyses ( $n = 1$ ) or technical problems ( $n = 4$ )
<b>8</b>	157 (0/157)	18-35 years	Germany	$n = 15$ dropped out for analyses including the BFI and SOI-R	Did not fill out these questionnaires
<b>9</b>	108 (44/64)	Undergraduates at McMaster University	Canada	none	N/A
<b>10</b>	88 (88/0)	19-31 years	Germany	none	N/A
<b>11</b>	56 (56/0)	18-23 years	USA	$n = 9$ dropped out	Did not fill out the questionnaire or technical problems

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