The difference in voice pitch, loudness and reading rate between introverted and extraverted people

Final report by

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Introduction and related work

When we hear someone's voice for the first time, chances are there is already an idea taking shape in our heads about what type of person they are. Research shows there might be some links between the sound of someone's voice and their personality. For example, research by Koutsoumpis and De Vries suggests that there is a positive correlation between voice pitch and emotionality and a negative correlation between speech rate and emotionality [1]. This would suggest that people who are more emotional tend to have higher pitched voices and speak slower. We also tend to perceive persons with lower pitched voices as more dominant [2], [3], more trustworthy [3] and more competent leaders [4]. The impression we get of someone based on their voice can have an impact on for example business decisions, which politicians we vote for, who we hire for a job and our social relationships [5].
Recently, Stern et al. performed a secondary data analysis on eleven different datasets to investigate the relationship between voice pitch and certain personality traits [6]. Most previous research has focused on the link between a person's voice pitch and how others perceive this person's personality. However, the research by Stern et al. used studies with self-reports of the participants' personality traits. The researchers found that voice pitch was correlated with dominance, extraversion, and sociosexual behaviour [6].
Extraverted people tend to find interaction with others energising and stimulating and therefore often enjoy socialising and having many friends [7]. Introverted people are energised and stimulated by solitude and contemplation and usually prefer to have a smaller friend group. According to other studies, also other voice parameters besides voice pitch are linked to extraversion. Research by Borkenau & Liebler showed extraversion is negatively correlated with how soft someone's voice is, both according to self-reports and personality ratings by others [8]. Also according to Mairesse et al., self-reported extraversion is positively correlated with voice loudness [9]. This same research also showed self-reported extraverts have a higher verbal output, meaning they speak faster. This confirmed earlier research by Gill & Oberlander that also showed extraversion to be positively correlated with speech rate [10]. These examples show that some research has been done on the relationships between extraversion and voice pitch, voice loudness and speech rate. However, the amount of research is rather limited and therefore we proposed to investigate these relationships further. Finally, we also wanted to investigate whether the distribution of extraversion and introversion in our sample is representative of the global distribution. According to the Myers-Briggs global research sample, 56.8% of the world population is introverted [11]. This leads to the following four research hypotheses:

'Extraverted people have a lower voice pitch than introverted people',
'Extraverted people have a louder voice than introverted people',
'Extraverted people read aloud faster than introverted people' and
'The probability of someone being introverted is 56.8%.'

Feasibility study

For this research, we wanted to collect audio samples from participants and ask them to fill in a questionnaire. At the moment of designing the feasibility study, we had only developed a hypothesis concerning voice pitch and therefore did not analyse voice loudness and reading rate yet. To record the audio, we used the mobile Phyphox[1] application, version 1.1.10, developed by RWTH Aachen University. We used the function 'audio spectrum' in order to collect the so-called 'peak frequencies', assuming this data could be used to determine someone's perceived voice pitch, as this was the only function in the application that measured voice frequency. Later, we discovered we should use 'fundamental frequencies' instead, as this is the correct measure to determine someone's pitch [12] which the audio spectrum function in the application does not measure. Therefore, we collected new data using the application Audio Recorder[2], version 3.5.15, developed by axet on GitLab, which allows recording raw audio in WAV format that can then be exported and used to determine someone's speaking fundamental frequency as well as other parameters such as loudness and duration of the recording.
For the questionnaire, we used part of the Francis Psychological Types Scale [13] in order to measure extraversion, which will be further elaborated upon in the next section. We created a Google Form in order

[1] https://phyphox.org/
[2] https://gitlab.com/axet/android-audio-recorder

to present the questionnaire to the participants. We first filled in the questionnaire ourselves in order to test whether we could answer the questions with ease and whether the form was saved properly.

Experiment design and data collection

Next, we will describe how we eventually performed the experiment. 19 participants have participated in this research, ten females and nine males. All participants were part of the social circles of the researchers. All participants were between the ages of 20 and 30 year old (M=23.51, SD=2.27). The native languages of the participants were German (n=13), Dutch (n=2), English (n=1), Spanish (n=1), Arabic (n=1) and French (n=1). We will describe the experiment design of both the audio recording and questionnaire hat we used for this research and explain the reasoning behind our decisions.

Audio recording

We presented the participants with the fairy tale *'Little Red Riding Hood'* and asked them to read a few sentences out loud and try to speak naturally and effortlessly. In a research project by Mahrholz et al., participants were asked to read both sentences that were socially relevant to them and socially ambiguous, and it appeared that the way their personalities were rated by others was significantly correlated between the two types of content [5]. Therefore, the researchers concluded that "the perceived personality of a male or female speaker will be reliable across varying utterances regardless of what is said". Stern et al. also used datasets with different types of recordings such as people reading out a passage, counting from one to ten or answering a question, stating that "the content of a recording should not affect the relationship between personality and vocal characteristics." [6]. Therefore, someone's voice parameters should not differ between when they read a passage out loud or tell something.
For the audio recording, we decided to let each participant read out loud the same passage. In research, often the 'Rainbow Passage' [14] is used to measure voice parameters [15], [16], [17], [18]. However, this passage can only be found online in English. It was not feasible to reach a significant amount of native English speakers for this research and participants should preferably read a passage in their native language. Research by Zimmerer, Jügler, Andreeva, Möbius and Trouvain showed that native German speakers used a smaller pitch range when speaking French than when speaking their native language and the same was true for native French speakers speaking German [19]. Also, Järvinen found that native Finnish speakers used a higher pitch when speaking English than when speaking their native language [20]. Considering that we knew beforehand that the participants that we would be able to collect for this research would have a diverse range of native languages, we should use a passage that has been translated in most languages. We decided to use a passage from the fairy tale 'Little Red Riding Hood', as this story has been translated in over 160 languages [21].
We decided to make two recordings of the participants' voices in order to calculate an average and increase reliability of the measurements. For the first recording, we asked the participants to read the first two lines of 'Little Red Riding Hood' and for the second recording we asked them to read the third and fourth line.
In order to ensure validity and reliability of our further analysis, we decided to store the recordings in WAV format, since it is recommended to store speech files in WAV for voice analysis [22]. WAV files are not compressed and therefore provide a high quality and accuracy while compressed formats like MP3 lead to lost information due to reduction of the size of the file [23].

Questionnaire

In order to classify people as extraverted or introverted, we wanted to use a validated questionnaire. For the datasets that were used in the research [6] that inspired this experiment, the Five Factor Model of Personality, also known as the Big Five, was used to measure extraversion among other traits. This test provides specific scores on different personality traits [24]. However, these are scores on a continuous spectrum and for this experiment we wanted to create two distinct groups. The Francis Psychological Types Scale (FPTS) (Appendix 1) is a questionnaire based on the original psychological type theory by Jung [25] that states that personality traits are rather dichotomous [26]. According to Jung, people tend to get more energy either from being with others or from being alone, and can therefore be classified as either extraverted *or* introverted [25]. The FPTS bases this classification on ten binary questions, and if a participant scores as

'extraverted' on more than half of the questions, they are classified as extraverted and otherwise as introverted. The aim of the FPTS was to "develop scales that could be freely used in research and which could be completed in a reasonable amount of time" [27]. Research by Robbins, Francis & Powell [28], Village [7] and Francis, Wulff, & Robbins [29] reported a cronbach's alpha of 0.84, 0.85 and 0.84 respectively for the extraversion-introversion scale, which is above the required minimum of 0.70 [30]. Since this shows the test has good internal consistency, we decided to use the extraversion-introversion scale of this questionnaire.

Analysis methods

Audio recordings

After collecting the audio recordings, we performed an audio analysis in Python. Mainly, we used the open source audio analysis Python package Librosa[3], version 0.9.2, developed by Brian McFee and many other contributors [31]. Librosa can be used to extract features in audio signals using different signal processing techniques and can be then also be used to visualise these [32].
The code corresponding to the methods and some examples are published in a GitHub repository[4].

Voice Pitch

To detect the voice pitch of a study subject, the speaking fundamental frequency of their voice had to be estimated. Fundamental frequency (F0) is an acoustic measure which reflects the rate of vocal fold vibration [33]. Speaking fundamental frequency (SFF) is the average fundamental frequency and the "most important correlate of perceived pitch" [34]. It shows the prime tendency of the vibration frequency of the vocal folds during connected speech [35]. Therefore, the raw audio recordings should be split into voiced and unvoiced/silent speech. The voiced period is also often termed as the pitch period [36]. For that we chose a threshold of ten decibels below which signals are considered as silent. Sounds lying at around ten decibels are as loud as one's breathing [37]. When people read or speak, they take different lengths of unvoiced/silent pauses between words and sentences. By eliminating these breaks and pre-processing all recordings the same way, comparability was ensured too. We applied the YIN algorithm on the speech audio clip to estimate F0. YIN is an autocorrelation based method with a lower error-rate compared to other well-known techniques [38]. The result is a time series of fundamental frequencies in Hertz. Ultimately, to obtain SFF we computed the mean of the emerged time series. As there were two recordings of each participant, we finally took the average of their two SFFs.
Collecting two recordings respectively helped us to verify this method. Overall, there was only a small deviation in the resulting SFFs between the two recordings of each participant. The mean of all deviations lay at about 4.30. We could observe that there was less variation when the speech was recorded inside and without wearing a mask. Most of the recordings were collected under these conditions (14 out of 19). The deviation mean of such recordings was approximately 2.43.

Loudness

The loudness of a recording may vary depending not only on how loud someone read but also under which circumstances the recording was conducted. The best option would probably have been a professional recording studio. Unfortunately, we did not have access to one. Nevertheless, we conducted all recordings carefully in a very silent environment and used approximately the same distance between all study subjects and the phone. Two different smartphones but from the same manufacturing year were used. Also, the settings in the Audio Recorder application were configured identically.
To measure the perceived loudness of a participant's voice we used a free and flexible audio loudness meter in Python called pyloudnorm[5], version 0.1.0, developed by Christian Steinmetz and other contributors. The package follows the widely adopted ITU-R BS.1770 recommendation for measuring the perceived loudness of audio signals [39]. Pyloudnorm's integrated loudness method returns the loudness of a signal in dB LUFS.

[3] https://github.com/librosa/librosa
[4] https://github.com/valeriatisch/voice-vs-personality
[5] https://github.com/csteinmetz1/pyloudnorm

LUFS are Loudness Units relative to digital Full Scale. A 10 dB LUFS increase correlates with doubling of a perceived loudness [40].
We took dB LUFS measurements of all full length samples as well as of only the corresponding merged voiced clips where only voiced periods were extracted, as were already retrieved previously in order to determine voice pitch. The average loudness of all complete samples, meaning including the unvoiced/silent periods, was -26.93 dB LUFS. As expected, the loudness of the voiced clips were always louder and amounted to -24.66 dB LUFS on average. We were again not interested in the influence of the silent breaks, but only in the loudness of the subject's voices. From now on, we consider just the resulting loudness of the voiced clips in this report. The loudness varied in a range from -21.16 to -32.36 dB LUFS. The standard deviation between each two recordings was in general very small; the mean standard deviation of two recordings lay at about 0.58.

Reading Duration

The reading duration describes how long someone needs to read a passage from the beginning until the end and is measured in seconds. It may differ when the recording started and the participant started to read or when the participant finished and the recording stopped. Therefore, we first trimmed each recording by removing the leading and trailing silence with Librosa. The remaining silent periods were not removed for this task as these are considered part of someone's reading rate.
Our study subjects read the fairy tale in six different languages. Because of this, they read a different amount of words with different lengths. The reading duration among different languages is not comparable. For that reason, we only took the reading rates of our largest group which consisted of native German speakers. 13 out of 19 people stated German as their native language.

Questionnaire

For the questionnaire, we used the Francis Psychological Types Scale, which consists of ten binary questions with one answer indicating extraversion and the other indicating introversion and works rather intuitively. If a participant scores five points or less on extraversion, they are classified as introverted and in case of more than five points on extraversion, as extraverted [13].

Statistical methods

We will next describe the different statistical methods we used to test the different hypotheses. When looking at the first hypothesis concerning the relationship between voice pitch and extraversion, we separated the male and female samples, since males on average have a lower voice pitch than females and also the relationship might be different for both groups [41]. We did not find any literature indicating there should be a difference in loudness and reading rate between females and males. Also, the previously mentioned studies did not split up males and females for these two parameters [8], [9] ,[10]. We did not split our sample up either. For the first three hypotheses, we first checked whether voice pitch, loudness and reading rate were normally distributed, either for the complete sample or split up between females and males when relevant. In case the parameter was normally distributed, we applied an independent samples t-test to compare the voice parameters between the extraverted and introverted group. When variances in both groups were equal, the Student's t-test was applied and in case it was unequal, we applied Welch's t-test. When a voice parameter was not normally distributed, we applied the Wilcoxon signed-rank test.
For the fourth hypothesis concerning the distribution of extraversion-introversion, we applied a binomial test to investigate whether the sample distribution was equal to the global distribution [11].
Regardless of which test was used, we set alpha at 0.05 for each hypothesis.

Results

In the next section, we present the results of our experiment. At the end of this section, a table will be presented that shows the outcomes of all the performed statistical tests. You can find all the data in our GitHub repository[6].

[6] https://github.com/valeriatisch/voice-vs-personality

Results Gender and Extraversion Scores

In this research, ten females and nine males participated. Based on the Francis Psychological Types Scale, eight participants were classified as extraverted and eleven as introverted (Figure 1). As can be seen in Figure 2 and Figure 3, extraversion scores were normally distributed, with no overrepresentation of extraverted or introverted people. For the first hypothesis we split up the sample in males and females. Figure 4 shows on the left that four females were classified as extraverted and six as introverted. On the right, Figure 4 shows that the scores were normally distributed. For the males, Figure 5 shows on the left that four males were classified as extraverted and five as introverted and on the right that the scores were mostly normally distributed.

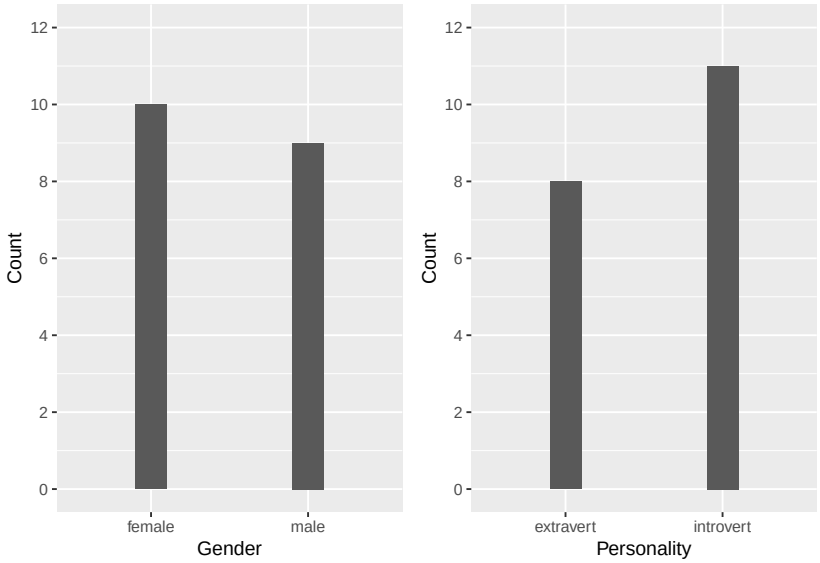

Figure 1: Number of participants by gender (left) and by personality(right)

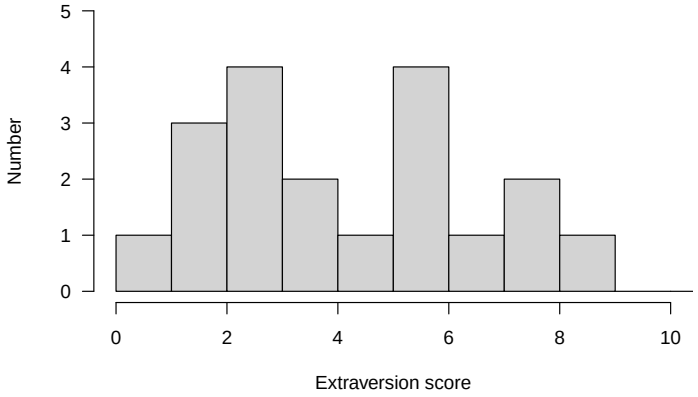

Figure 2: Extraversion scores distribution (all)

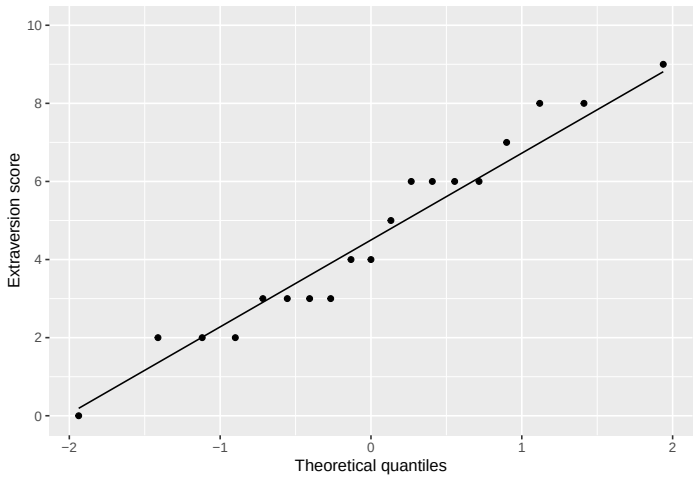

Figure 3: Q-Q plot extraversion scores (all)

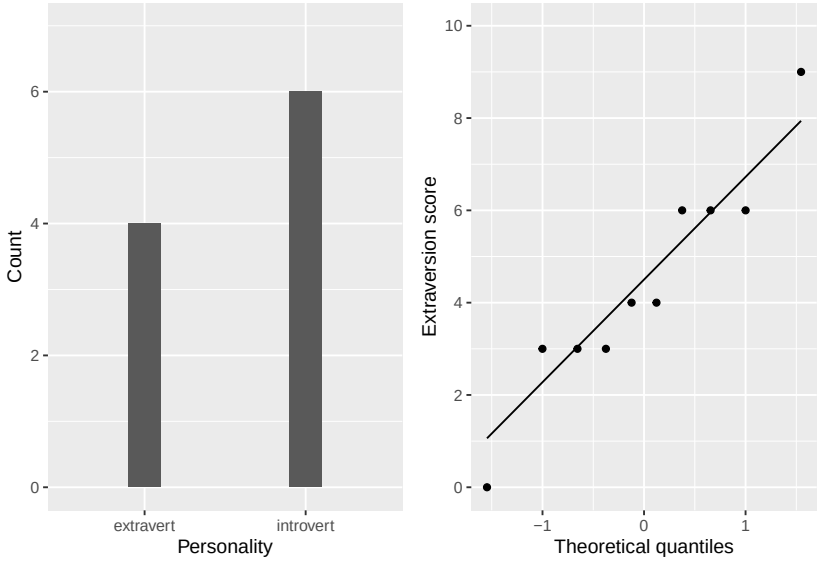

Figure 4: Number of females by personality (left) and Q-Q plot extraversion scores (females) (right)

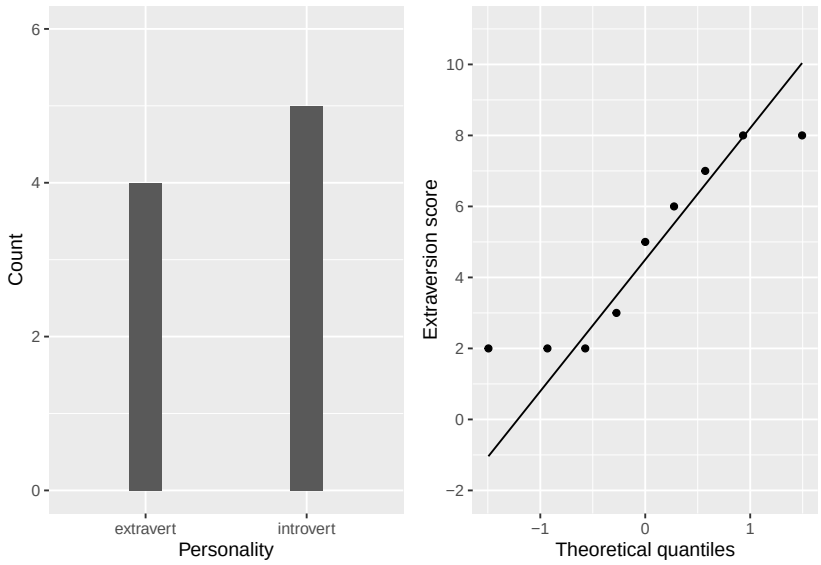

Figure 5: Number of males by personality type (left) and Q-Q plot extraversion scores (males) (right)

Results Voice Pitch

Typical values for SFF are 120 Hz for men and 210 Hz for women [42]. In our sample, the means were close to, but slightly higher than these values, with a mean of 131.90 Hz (SD=21.40) for males and 222.25 Hz (SD=19.54) for females (Figure 6). The female sample also showed a slightly larger range of values than the male sample. Figure 7 shows the SFF for both females and males were approximately normally distributed by approximation.

The boxplots (Figure 8) show that extraverted females had a slightly lower voice than introverted females and. Introverted females had a bigger pitch range than extraverted females. Figure 9 shows that the SFF of females was normally distributed and considering the variances were equal, a one-sided Student's t-test was performed. The result showed the voice pitch of extraverted females (M=217.9, SD=16.2) was not significantly lower than that of introverted females (M=225.1, SD=22.5); t(8)=-0.55, p>0.05.

Figure 10 shows that for the voice pitch of males, the opposite of the females was the case and extraverted males had a higher voice pitch than introverted males. Figure 11 shows the SFF for males was normally distributed with one quite extreme outlier and considering the variances were equal, a one-sided Student's t-test was performed. The result showed the voice pitch of extraverted males (M=128.3, SD=14.7) was not significantly lower than that of introverted males (M=134.7, SD=27.1); t(7)=-0.42, p>0.05.

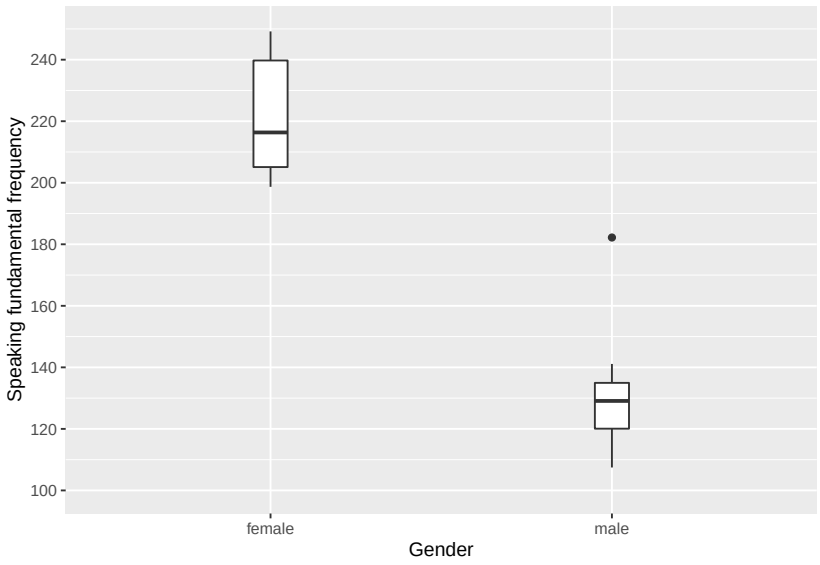

Figure 6: Voice pitch by gender

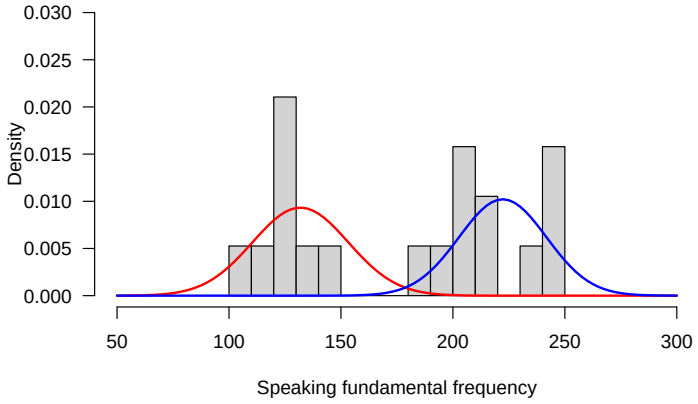

Figure 7: Voice pitch distribution (all)

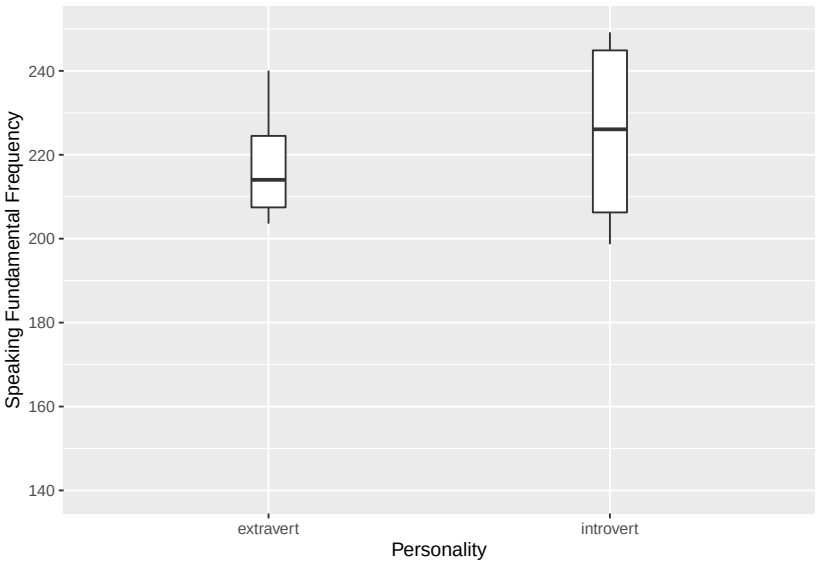

Figure 8: Voice pitch of females by personality

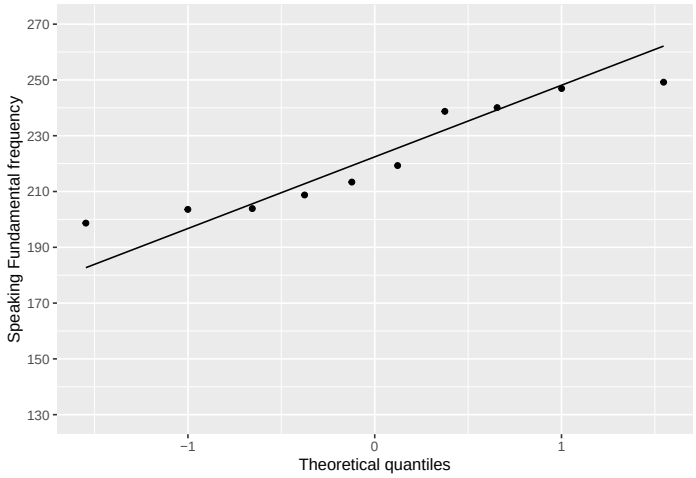

Figure 9: Q-Q plot Speaking Fundamental Frequency (females)

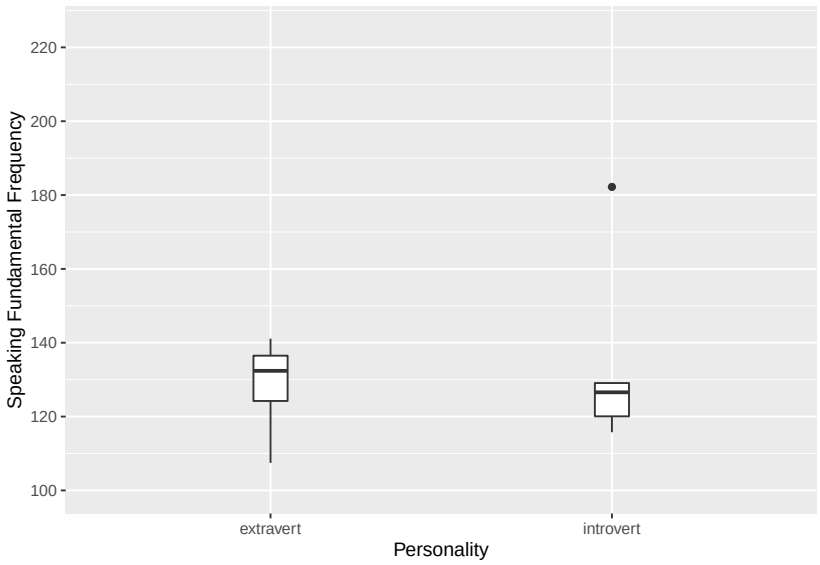

Figure 10: Voice pitch of males by personality

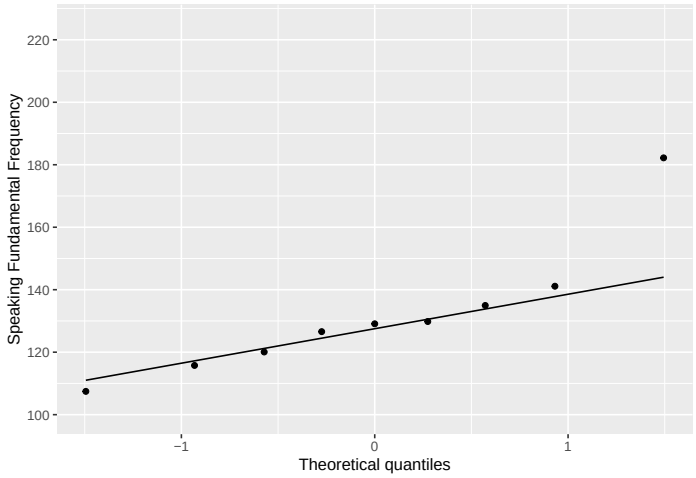

Figure 11: Q-Q plot Speaking Fundamental Frequency (males)

Results Loudness

For loudness, the sample was *not* split up in females and males. Figure 12 shows there was almost no difference in loudness between the extraverted and introverted participants and there was one extreme outlier in the introverted group. Figure 13 shows loudness was normally distributed for the entire sample with only a few outliers and considering the variances were equal, a one-sided Student's t-test was performed. The result showed the voices of extraverted participants (M=-23.6, SD=1.4) were not significantly louder than those of introverted participants (M=-25.4, SD=3.1); $t(17)=1.55$, $p>0.05$.

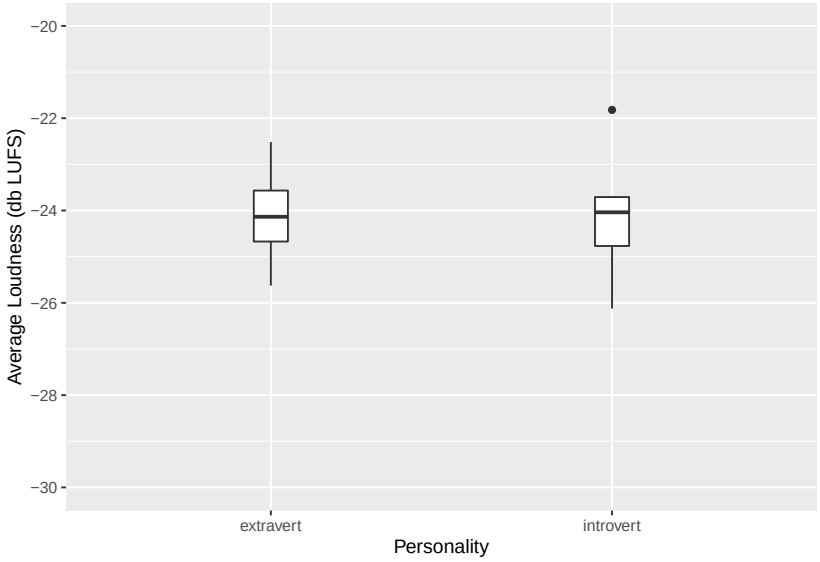

Figure 12: Loudness by personality

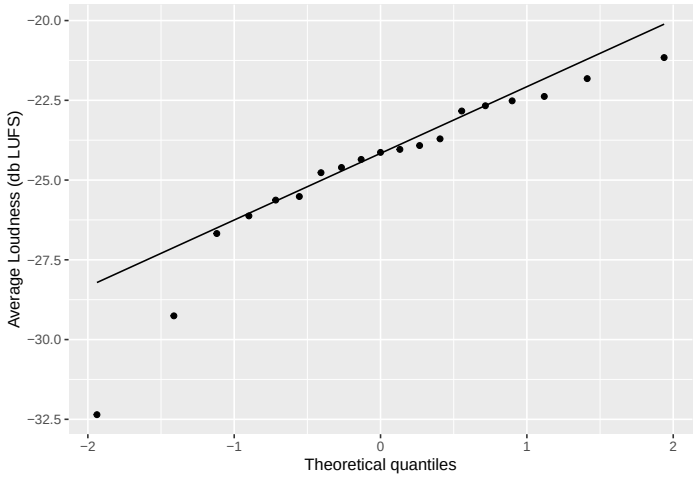

Figure 13: Q-Q plot Loudness (all)

Results Reading Duration

For reading duration, a smaller sample of only native German speakers was used. Figure 14 shows extraverted people have a shorter reading duration than introverted people, which means they read faster. The introverted group shows some extreme outliers. Figure 15 also shows reading duration was not normally distributed. Since the variances were equal, a one-sided Wilcoxon signed-rank test was performed. The result showed the extraverted participants (Mdn=19.47) did not read significantly faster than introverted participants (Mdn=21.1); W=14.5, p>0.05.

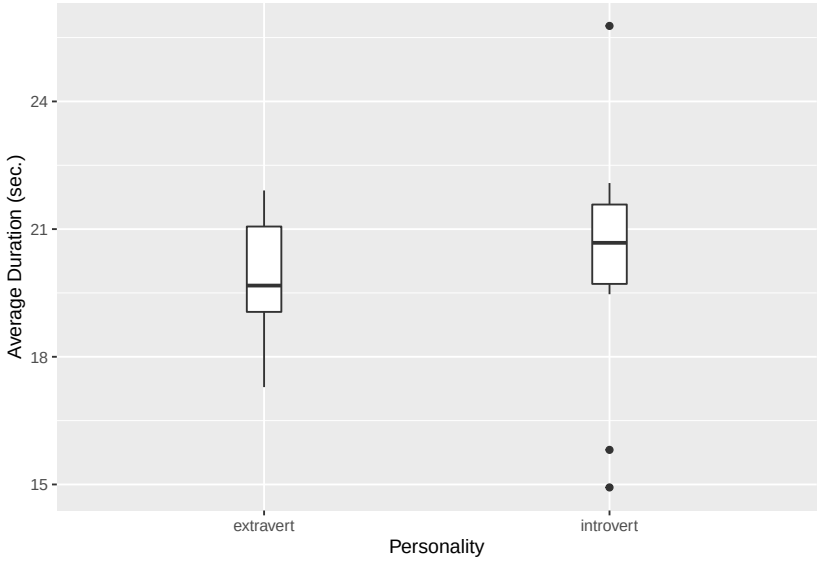

Figure 14: Reading duration by personality

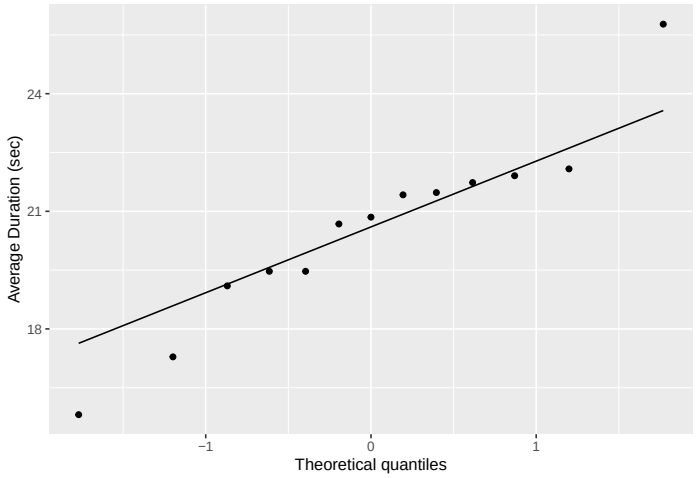

Figure 15: Q-Q plot reading duration (all)

Results extraversion-introversion distribution

Out of nineteen participants, eleven were introverted and eight were extraverted (Figure 1). In order to determine whether the distribution in the research sample was similar to that in the global population, we performed a binomial test. The test showed that the proportion of introverts in the sample of 0.579 is similar to that in the global population of 0.568, p=1. This means the alternative hypothesis that states that the probability of being introverted is *not* equal to 0.568 does not get accepted and the null hypothesis that states that it *is* equal, does not get rejected.

Table 1: Statistical tests

Parameter	test	M(E)	SD(E)	M(I)	SD(I)	df	test statistic	Sig.
Voice pitch Females	Student's t-test	217.9	16.1	225.1	22.4	8	t=-0.54867	0.2991
Voice pitch Males	Student's t-test	128.3	14.7	134.7	27.1	7	t=-0.4225	0.3427
Loudness	Student's t-test	-23.59	1.4	-25.43	3.1	17	t=1.5482	0.06999
Reading duration	Wilcoxon signed-rank test	n.a., Mdn(E)=19.5		n.a., Mdn(I)=21.1		n.a.	W=14.5	0.2318
Extra-Intro distribution	binomial test	n.a., POS=0.579				n.a.	n.a.	1

E = Extraverted, I = Introverted, Mdn = median, POS = Probability of success

Conclusion & discussion

Based on the results, there appeared to be no significant differences in voice pitch between extraverted people and introverted people, both in the female and male sample. This is not in line with the results of the study by Stern et al. [6]. There also did not appear to be a significant difference in loudness between extraverted and introverted people, which means the research findings by Borkenau & Liebler [8] and Mairesse et al.[9] were not confirmed. Also no significant difference was found for reading duration, which is not in line with previous studies by Gill & Oberlander [10] and Mairesse et al. [9]. However, it did appear that the probability of someone being introverted was equal to the 56.8% that was previously found in the global research sample by the Myers Briggs Company [11].

The main drawback of this experiment was the small sample size. According to power calculations, two groups of 127 females and two groups of 192 males were required. Due to time and resource restraints, we were only able to find ten female and nine male participants. For further research, we therefore recommend collecting a larger sample. If resources permit, we also recommend using better quality audio recording tools, rather than mobile phones, and acquiring a space that can be used as a recording studio. Perhaps if these improvements are made, findings will be more in line with previous research. For future research, it could also be interesting to test for other voice parameters, such as variability in voice pitch, loudness and speech rate. Also, if the sample size is large enough, it could be invesitgated whether the relationships between voice parameters and extraversion differ, for example, between different age groups or different countries.

Appendix

Appendix 1: Francis Psychological Types Scales, extraversion-introversion scale

	Extraversion (E)	Introversion (I)
Do you tend to be more...	Active	Reflective
Are you more...	Sociable	Private
Do you prefer...	Having many friends	A few deep friendships
Do you...	Like parties	Dislike Parties
Are you...	Energised by others	Drained by too many people
Are you...	Happier working in groups	Happier working alone
Do you tend to be more...	Socially involved	Socially detached
Are you more...	Talkative	Reserved
Are you mostly...	An extravert	An introvert
Do you...	Speak before thinking	Think before speaking

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