Fundamental Frequency Differences Including Language Effects

Adaptation of the fundamental frequency in Dutch and English looking at both second language effects and language-specific effects

Mathilde Theelen

ABSTRACT

This study examines the variability in fundamental frequency of spoken foreign languages and the variation of this frequency between Dutch and English. Fundamental frequency can be seen as the objective variant of pitch and can thus be measured. For measuring the differences, an experiment was set-up, in which speakers of different languages were recorded. Studying this phenomenon is relevant because former studies only looked at either how a second language affects the fundamental frequency or affects different languages, whereas this will be combined in the current study. For the former part of the study, it was found that people do not necessarily change their fundamental frequency when speaking a foreign language. For the latter part of the study, it was found that people speak Dutch with a higher fundamental frequency compared to English.

KEYWORDS

Fundamental Frequency, Second Language, Pitch Differences

INTRODUCTION

Several studies have shown that languages differ in fundamental frequency (Mennen, Schaeffler and Docherty 2012; Bezooijen 1995; Traunmüller and Eriksson 1994, 3). Moreover, according to Järvinen and Laukkanen (2015, 1), speaking a foreign language leads to a higher fundamental frequency when compared to speaking the native language. However, it is not known whether speakers of a native language with a relatively high fundamental frequency also increase their fundamental frequency when speaking a foreign language. Because an increase of the fundamental frequency might have an effect on the health of the vocal folds (Järvinen and Laukkanen 2015, 1), it is worthwhile to investigate when this increase happens.

Therefore, this study will examine two things. The first is to what extent speaking a foreign language affects fundamental frequency. The second is whether people speak Dutch with a higher fundamental frequency compared to English. The decision was made to test Dutch natives who learned English as a second language and English natives who learned Dutch as a second language in pairs of two, one Dutch native participant and one English native. Moreover, the sex

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of the participants will be taken into account, as women speak with a different fundamental frequency than men (Howard 1991, 70).

This paper is divided into three parts. The first part contains an accessible introduction to the concept of fundamental frequency, and deals with the relevance of studying fundamental frequency differences and the theories in second language acquisition. The second part takes a closer look at the specifics of the experiment, namely the methods and the results. The paper ends with a discussion and conclusion of the results.

INTRODUCTION TO FUNDAMENTAL FREQUENCY

Most speech sounds are produced by generating a stream of air that flows from the lungs to the nose or mouth, altering this stream produces different sounds. For example, by constricting the air stream the [p] and [b] are created (Fig. 1). We can also use our vocal folds to differentiate sounds. When the vocal folds are close together, the stream of air produces a vibration (Ladefoged 1996, 92-93). When the vocal folds vibrate and the air is constricted, we produce a [b]. Without the vibration of the vocal folds, we produce a [p]. This lack of vibration holds for most consonants, whereas the vocal folds always vibrate when producing vowels (Rodenburg 1992, 242).

In general, every vibration of the vocal folds leads to a new period of a waveform (Ladefoged 1996, 93). A period corresponds to the time it takes until a new period starts, and can thus be recognised by its repeating character (Howard 1991, 70). In Fig. 2, four periods are shown. One of those periods is selected.

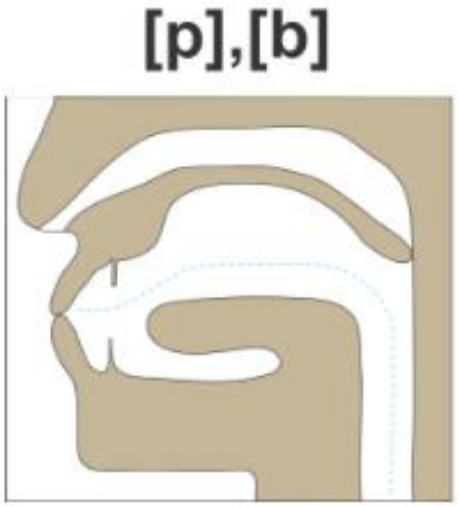


ILLUSTRATION 1 – CONSTRICTION OF THE AIR STREAM (SJERPS, FRANKEN & LOCKWOOD, 2016)

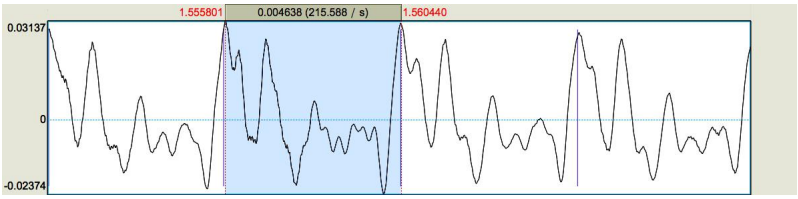


ILLUSTRATION 2 – THE SELECTION OF A PERIOD OF A WAVEFORM. 1/0.005608 COMES DOWN TO 178 HZ, WHICH IS THE FUNDAMENTAL FREQUENCY.

The fundamental frequency can be determined from the speech sounds' period using the following formula (Howard 1991, 71):

Fundamental frequency = 1 / period of the sound wave[1]

Thus, fundamental frequency corresponds to the rate of vibration of the vocal folds. While this can be compared to pitch, there is a significant difference. Pitch only refers to the perception of speech production and is, therefore, not an unbiased parameter. Fundamental frequency, however, can be seen as the objective variant of pitch (Howard 1991, 68), without involving logarithmic calculations[2].

Besides using the formula mentioned above to calculate the fundamental frequency for every period wave separately, there are also many ways to measure the fundamental frequency using computer programs. These computer programs generate curves which correspond to the fundamental frequency for every e.g. 0.003 seconds. This allows for the measurement of a fundamental frequency for a larger amount of data simultaneously. The downside of using computer programs is that they often make errors. Those errors mainly consist of doubling or halving the frequency (Murray 2001, 3).[3] There are ways to check those contours. In the methods section, there will be a description of how this was done in this specific research.

THE RELEVANCE OF STUDYING FUNDAMENTAL FREQUENCY DIFFERENCES

Much research has been carried out concerning the fundamental frequency, but most research is about general factors that influence the fundamental frequency. (Ladd 1984; Lieberman 1967; Maeda 1976, Honda 2004, Hanson 2009). Nevertheless, a lot less research has been conducted on fundamental frequency differences between languages, and in a second language context. This section illustrates, first, why it is relevant to look into the influences on fundamental frequency when speaking a foreign language; and second, why it is relevant to find out whether speakers of

[1] The result is in Hertz (Hz).
[2] This is relevant as the human ear has a logarithmic response to sound.
[3] Fundamental frequency / 2 or fundamental frequency * 2.

Dutch speak with a higher fundamental frequency than speakers of English. After this, the hypotheses and research questions will be presented.

Foreign Language Influences On Fundamental Frequency

Prior research has concluded that the mean fundamental frequency of speakers of English and Finnish increases when speaking a foreign language, whereas the speech rate and the total duration of voiced speech decreases significantly.

Moreover, Järvinen and Laukkanen emphasized that Finnish and female speakers showed a clearer trend towards increased vocal loading due to a larger increase of the fundamental frequency compared to English and male speakers (Järvinen and Laukkanen 2015, 5). As this variability suggests that the factors that cause the increase of the fundamental frequency are dependent on the language that is spoken, it is interesting to test whether the same differences occur in other languages as well.

Another study, by Ullakonoja (2007, 1702) showed that the mean pitch of native Russian speakers of Russian is a lot higher than the mean pitch of Finnish learners of Russian. However, Finnish people do speak at a higher pitch when speaking Russian as opposed to Finnish; and the more experienced they become in Russian, the more they increase their fundamental frequency in this language. It seems that the foreign language learners adapt their fundamental frequency to the Russian level. While, in the study of Järvinen and Laukkanen, it was suggested that their participants possibly increase their fundamental frequency due to a higher mental load, the same conclusion cannot be made when taking the research of Ullakonoja (2007) into account. This is because when people get more experienced using a foreign language, the mental load probably decreases. If the increase of the fundamental frequency would have been affected by a higher mental load, the fundamental frequency would decrease when the experience in a language increases. However, this is not the case for the Finnish learners of Russian. Thus, on the one hand, people tend to increase their fundamental frequency when speaking a foreign language; and on the other hand, people adapt to the fundamental frequency of the foreign language. A more elaborate analysis of the findings will follow in the discussion section.

Influences Of Different Languages On Fundamental Frequency

A number of studies have shown that different languages use different fundamental frequencies. For example, Mennen, Schaeffler and Docherty (2011, 2249) compared the fundamental frequency of English speakers to the fundamental frequency of German speakers. They found that the fundamental frequency of the English natives was significantly higher than the fundamental frequency of the German natives.

Moreover, a study by Bezooijen, found that the fundamental frequency of women speaking Japanese is higher than the fundamental frequency of women speaking Dutch. Bezooijen claims that this is due to a stronger differentiation between the ideal woman and man in Japan compared to the Netherlands; in Japan it is seen as feminine to speak with a higher fundamental frequency (Bezooijen 1995, 253).

Additionally, a number of studies found that bilingual speakers change their fundamental frequency according to the language they speak. Todaka (1995, 264), for example, found that all of his bilingual participants, both male and female, speak with a higher fundamental frequency in Japanese than in English. Thus, there is evidence for a difference in the fundamental frequency between different languages.

Hypotheses and Research Questions

From the former two sections, two main things can be concluded. On the one hand, people who speak in a foreign language tend to increase their fundamental frequency. On the other hand, people who are experienced in a foreign language tend to adapt to this foreign language more, as different languages have different fundamental frequencies. There is a discrepancy between those two findings: it is not known whether people who speak a language with a relatively high fundamental frequency decrease their fundamental frequency when they speak a foreign language.

For this reason, this study will examine two things. The first is to what extent speaking a foreign language affects fundamental frequency. The second is whether people speak Dutch with a higher fundamental frequency than English. Those two things are combined to investigate whether speaking a foreign language affects the fundamental frequency more than speaking a specific language, or whether speaking a specific language affects the fundamental frequency more than speaking a foreign language.

This research can be divided into two research questions:

> To what extent does speaking a foreign language affect the fundamental frequency?
> To what extent do people speak Dutch with a different fundamental frequency than English?

In order to answer these questions, the decision was made to test Dutch people who learned English as a second language and English people who learned Dutch as a second language. As native speakers of a language do not change their fundamental frequency when they speak to a second language learner (Biersack, Kempe and Knapton 2005, 2401), there is no problem in simultaneously testing bilingual Dutch and bilingual English speakers.

METHODS

This section illustrates the methods that were used to conduct the research. The first paragraph shows the used materials, followed by a description of how the recordings were made. After this, the details about the participants, such as age and language level will be described. The last paragraph of this section is about the way the measurements were done.

Materials

For this research, the HCRC Map Task was used. This is a task, developed at the University of Edinburgh, in which Person A has a map with a route on it, whereas person B has a map without a route on it (examples can be found in Fig. 3-6). Person A describes this route to person B (Anderson et al., 1991). This was done in pairs of one English native participant who speaks Dutch as a second language and one Dutch native participant who speaks English as a second language. The crucial factor of the task is that the maps are not identical which increases the difficulty of the task. Thus, the participants need more time to explain the route, which will lead to an increase of the language data. In this experiment, an extra number of maps were used in which the objects on the maps were similar, in order that the amount of data could be controlled more easily. Thus, there were two different versions. One version in which the participants had maps with the same objects and one version in which the participants had maps with differing objects. The task was chosen to prevent oral reading, and stimulate spontaneous speech.

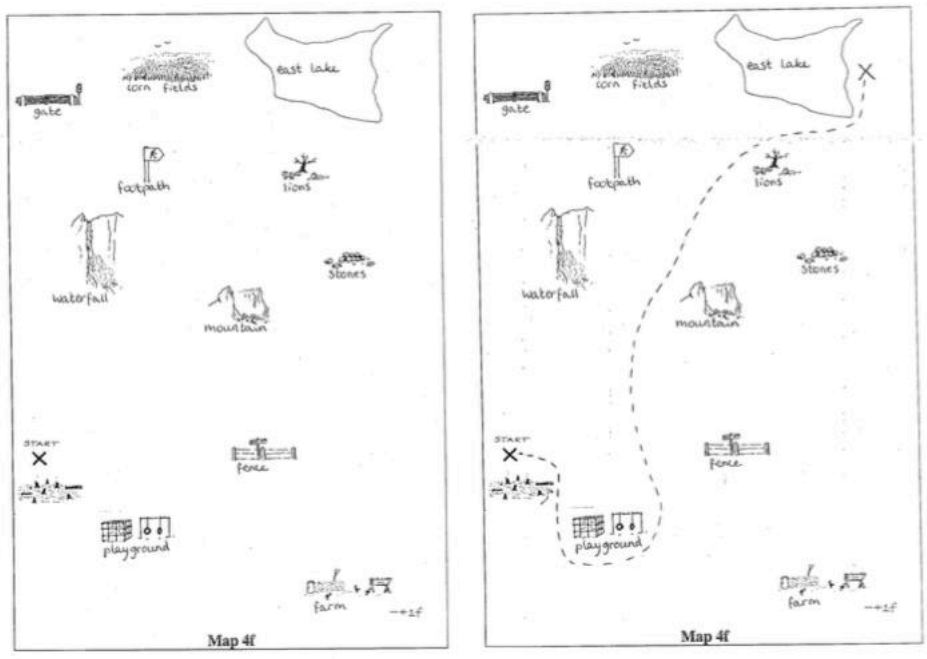


ILLUSTRATION 3 AND 4 – EXAMPLE OF THE EASIER VERSION OF THE MAP TASK (ENGLISH VERSION)

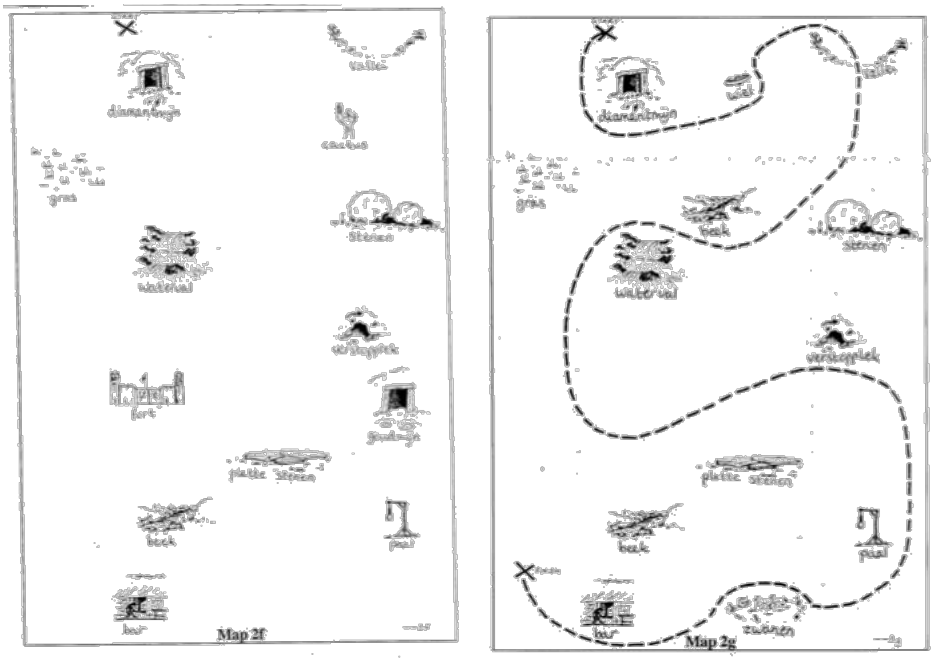


ILLUSTRATION 5 AND 6 – EXAMPLE OF THE HARDER VERSION OF THE MAP TASK (DUTCH VERSION)

Spontaneous speech was favoured over oral reading because Hollien, Hollien and De Jong (1997, 2990) found that oral reading results in a higher mean fundamental frequency than in spontaneous speech.

In order to compare the differences in fundamental frequencies, we needed data from all speakers, both when speaking the native language and when speaking the foreign language. Moreover, we wanted to prevent an effect of Dutch on English and the other way around. This is why the test was done according to the counterbalancing schedule in Table 1. For example, condition 1 means that the Dutch participant starts explaining a route in English. After this, the English participant explains a route in English as well. After this, the Dutch participant explains a route in Dutch, followed by the English participant who explains a route in Dutch.

Condition	
1	First English, then Dutch. The Dutch participant starts.
2	First Dutch, then English. The Dutch participant starts.
3	First English, then Dutch. The English participant starts.
4	First Dutch, then English. The English participant starts.

TABLE 1 – COUNTERBALANCING OF THE LANGUAGES OF THE MAPS AND THE PARTICIPANTS

In total eight maps were used, half were in Dutch, the other half were in English. The first four maps were similar to each other, except from the part that one of the participants had a route on the map, and the other participant did not. As the maps featured the same objects in the same locations, the route was relatively simple to explain.

After the first four maps, there was a break to check up on the test setup. If there was not enough data (less than 10 minutes per map), the researcher gave another four maps, sorted in the same way as the first part of the experiment. Those new maps were relatively similar to the ones in the HCRC Map Task; some objects were the same on both maps, whereas others were either moved or only existed on one of the maps. The participants had to find out what the similarities and what the differences were, in order to draw the right route.

As not all participants were highly proficient in both languages, the names on the maps were sometimes simplified. Moreover, since maps with Dutch labels were not available, the text on the HCRC Map task maps was replaced by Dutch text for the Dutch maps. The task was carried out in the same order as the first half of the experiment (Table 1).

Recordings

The test material was recorded in a recording studio within the University of Amsterdam. This recording studio consisted of three rooms: one reception space, one soundproof room to test the participants and one control studio. The participants were first introduced to each other in the reception space. Afterwards, the test was explained to the participants, and they were allowed to ask any questions they had. They also signed an informed consent and filled in a form about their language level.

After this, participants were brought into the soundproof room. In this room stood a table, two chairs and a Solid State Recorder of the type Marantz professional PMD660. This recorder allowed for simultaneous recording on two separate channels. Both channels were connected to a headset with an attached microphone. One of those headsets was of the type Samson QV and the other of the type Shure WH20. The participants chose the headset they preferred and the recording gear was adapted to the loudness of the participants' speech. Using headphones made it easier to distinguish the speakers during the analysis. In order to test whether the settings were suitable, the participants were asked to say a few sentences, or read the first page of the Bible (both in English and Dutch). After this, the researcher started the recording and left the soundproof room.

After the first four maps, there was a short break in which the recordings were paused and started again. The recordings were stored as wav-files on the recording device itself and were later transferred to the researcher's computer.

Participants

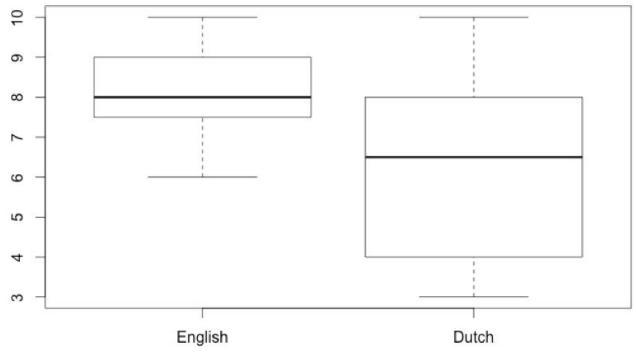
Sixteen subjects with no reported speech or language pathology or hearing impairment were recorded. Eight of them were from the Netherlands and learned English as a second language.

This group was relatively homogeneous: their age ranged from 19 to 29 (M = 22, SD = 3.02) and their self-reported level of English (on a scale from 1-10 where 10 = fluent) ranged from 6 to 10 (M = 8.13, SD = 1.25). This group consisted mainly of university students. This factor did not influence the experiment greatly, as Hollien, Hollien and De Jong found that there was only a small difference in fundamental frequency between university students and an otherwise comparable group (1997, 2990).

Finding English participants posed difficulties. This is why, after a month, a compensation of €10 was offered and why only five of the participants were given a compensation.

The group of English participants was less homogeneous than the group of Dutch participants: five participants were from the USA, the others were from Australia, the United Kingdom and Canada. Their ages ranged from 23 to 67 (M = 32.63, SD = 14.53) and their level of Dutch ranged from 3 to 10 (M = 6.25, SD = 2.55). The biggest difference between the two groups was found in the level of proficiency of the non-native language (Graph 1). Moreover, some of the participants learned some Dutch as a child and continued later, whereas others only learned Dutch when they were older.

As the English participants were harder to find than the Dutch participants, the pairs were made based on the sex of the English participants. The decision to match the participants based on sex was made to reduce the effects of other factors besides language. In the end, there were ten female participants and six male participants.



GRAPH 1 – LANGUAGE LEVEL OF THE SECOND LANGUAGE OF THE PARTICIPANTS

Measurements

For the measurements, only the data generated using the harder version of the HCRC Map Task was taken into account. This was done because this part of the test took longer than the part in

which the easier version was used; the participants did not have to switch between the two languages as much as in the shorter version and there was more data to track the pitch differences.

In order to make the right measurements, each file was segmented into four fields: one for when the participant spoke English, one for when the participant listened to English, one for when the participant spoke Dutch and one for when the participant listened to Dutch. After this, a Praat pitch object was made automatically by using a Praat script in the computer program Praat (Boersma and Weenink 1992-2015).[4]

Based on those pitch objects, measurements were made automatically by using another Praat script. Because pitch trackers can make errors, which would influence the mean, the decision was made to use the median of the fundamental frequency. Moreover, the pitch objects were checked by selecting a number of periods, dividing this number by the duration of those periods and comparing the values to the values in the Praat pitch object. The results were measured in Hz.

RESULTS

In this section, the results will be presented. First, the influences of the foreign language will be taken into account. After this, the influences of the languages themselves will be discussed.

Foreign Language Influences On Fundamental Frequency

For the second language influences, the expectation was that people would speak with a higher fundamental frequency in their second language than in their first language. In order to test this, the mean of the participants' median fundamental frequency was taken. The results are listed in Table 2.

	μ	σ	μ women	σ women	μ men	σ men
Dutch L1	181.99	55.3	220.64	17.87	117.56	10.2
Dutch L2	177.16	58.78	218.93	14.2	107.55	7.74
English L1	166.04	55.56	205.75	11.97	99.85	2.24
English L2	175.22	58.08	215.07	23.24	108.79	11.61

TABLE 2 – FUNDAMENTAL FREQUENCY VALUES FOR BOTH THE NATIVE AND THE FOREIGN SPEAKERS. THE RESULTS ARE IN HZ.

[4] The pitch floor was set to 50 Hz for both female and male participants. The pitch ceiling was set to 300 Hz for male participants and 550 Hz for female participants. In normal voice, the fundamental frequency is about 90-200 Hz for male voices and 150-310 Hz for female voices (Howard 1991, 51). With the chosen pitch floor and pitch ceiling, most voices would be accurately captured.

In this table, the participants in the row 'Dutch L1[5]' are the same participants as in the row 'English L2'. Likewise, the participants in the row 'Dutch L2' are the same participants as in the row 'English L1'.

As can be seen from Table 2, the highest mean fundamental frequency is found for the Dutch natives speaking Dutch. When the same participants speak English, they lower their fundamental frequency (from 181.99 to 175.22), but they still speak with a higher fundamental frequency than the English participants speaking English (166.04).

English participants who use their native language speak with the lowest fundamental frequency, which they increase when speaking Dutch (166.04 in English compared to 177.16 in Dutch). However, they still speak with a lower fundamental frequency than the Dutch natives (181.99).

For testing whether the differences between the first and second language were significant, the values for fundamental frequency in the second language were subtracted by the values for fundamental frequency in the first language. Calculating the difference between the native and the foreign language made it possible to conduct a t-test against zero.

In general, a difference in fundamental frequency between the foreign language and the native language was not found ($t(15) = 1.00$, $p = 0.3317$). However, since the difference between Dutch and English seemed to influence the fundamental frequency, the same test was done for the languages separately. This led to split results. On the one hand, the English participants change their fundamental frequency significantly when speaking Dutch ($t(7) = 4.09$, $p = 0.00466$). On the other hand, as the result is not significant (although almost significant) for the Dutch participants, it is not possible to conclude the same for this group ($t(7) = -2.18$, $p = 0.06542$).

Also, it has to be noted that a difference in fundamental frequency between the foreign speakers and native speakers does not mean that the fundamental frequency increases, as Dutch seems to be a language with a higher fundamental frequency than English. It might be possible that people adapt their fundamental frequency to the language they learn to speak.

Another outcome of the research of Järvinen and Laukkanen was that women adapt their fundamental frequency more than men (2015, 5). Because of this, the same test was done separately for the male and female participants. And again, the results of this study did not correspond to the results of the study of Järvinen and Laukkanen (2015). For English, the female participants did change their fundamental frequency significantly ($t(4) = 4.37$, $p = 0.01199$), whereas the male participants did not change their fundamental frequency significantly ($t(2) = 1.41$, $p = 0.2919$). For Dutch, on the other hand, the female participants did not change their

[5] L1 stands for first language, L2 for second language.

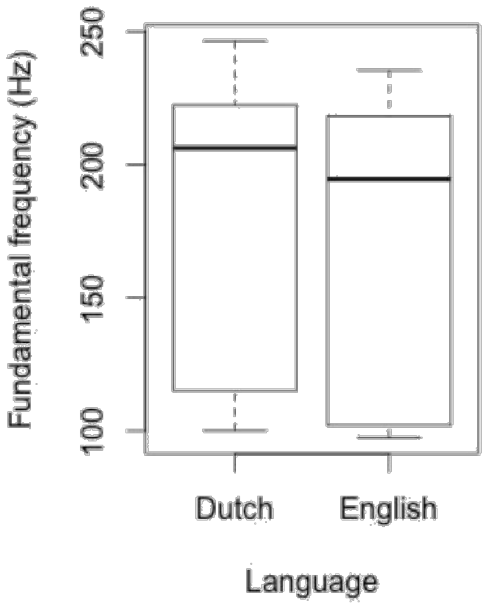
fundamental frequency significantly (t(4) = 0.328, p = 0.328), whereas male participants did change their fundamental frequency significantly (t(2) = -4.8695, p = 0.03968). Thus, the effect of the sex of the participants turned out to be the completely opposite in the two languages.

It has to be noted that the participating groups for those measurements were relatively small, in particular the groups with male participants. A larger sample size is needed to confirm or refute the findings of this research. A broader analysis of the results will be in the discussion section (section 7).

Influences of Different Languages on Fundamental Frequency

For the difference between the two languages, it turned out that the fundamental frequency of the participants speaking Dutch was higher than the fundamental frequency of the same participants speaking English (Dutch M = 179.57, SD = 55.19, English M = 170.63, SD = 55.11). With a paired samples t-test, this gave a significant result (t(15) = 4.32, p = 0.000608). The results are displayed in Graph 2.

What can be noticed is that the standard deviation is relatively large. This is due to differences in female and male voices. When the female and male participants are analysed separately, the standard deviations are smaller (Dutch women M = 219.78, SD = 15.24, Dutch men M = 112.56, SD = 9.78, English women M = 210.41, SD = 18.11, English men M = 104.32, SD = 8.94). Doing a paired samples t-test on this data still leads to a significant result (males: t(5) = 3.2057, p = 0.02384, females: t(9) = 3.0921, p = 0.01289). Thus, people speak with a higher fundamental frequency in Dutch compared to English.



GRAPH 2 – FUNDAMENTAL FREQUENCY FOR DUTCH AND ENGLISH

DISCUSSION

This study sought to investigate two separate phenomena. The first is to what extent speaking a foreign language affects the fundamental frequency. The second is in how far speakers of Dutch and English differ in fundamental frequency. Those two things are combined to investigate whether speaking a foreign language affects the fundamental frequency more than the language itself, or speaking a specific language affects the fundamental frequency more than speaking a second language.

Foreign Language Influences On Fundamental Frequency

For the influence of the foreign language, we hypothesized that people would increase their fundamental frequency when speaking a foreign language. This was already shown in research that looked at fundamental frequency differences between English and Finnish. This study by Järvinen and Laukkanen (2015, 3) showed that both groups (English and Finnish) increased their fundamental frequency when speaking a foreign language. Additionally, they showed that female participants increase their fundamental frequency more than male participants. Moreover, it was shown that Finnish participants increased their fundamental frequency more than English participants.

In this research, the same distinctions were made for Dutch and English, but we also compared the fundamental frequency differences between those languages. Whereas Järvinen and Laukkanen found a significant difference for the foreign language influences, this difference could not be found in the data of this study. Dividing the data into two groups showed that only the English-speaking people increased their fundamental frequency when speaking Dutch. For the Dutch speakers a significant result was not found.

Another result by Järvinen and Laukkanen (2015) was that women adapt their fundamental frequency to the foreign language more than men. But again the present study found something different. The English-speaking females changed their fundamental frequency when speaking Dutch, which was also the case for the Dutch males speaking English. However, no significant result was found for either the English males or the Dutch females.

There are several factors that might be the reason that Järvinen and Laukkanen found that speaking a foreign language leads to a higher fundamental frequency, but in the current study such an effect was not found. First, it has to be noted that Järvinen and Laukkanen used bigger

participant groups (a total of 43) compared to this study (a total of 16). A larger sample size is needed to confirm or refute the findings of this research.

Another factor is the differences in language levels between the participants, as the second language learners of English in this research have a higher language level than the second language learners of Dutch. According to the study of Ullakonoja (2007, 1702), people with a higher language level adapt their fundamental frequency more. Thus, the comparison might not have been completely valid.

Influences Of Different Languages On Fundamental Frequency

For the influence on fundamental frequency of speaking either Dutch or English, the outcome was that people speak with a higher fundamental frequency when they speak Dutch compared to when they speak English. The outcome that different languages have different fundamental frequencies corresponds to the findings of Mennen, Schaeffler and Docherty (2011, 2249) who found that German has a lower fundamental frequency than English. Similarly, Todaka (1995, 264) found that English has a lower fundamental frequency than Japanese, and Bezooijen (1995, 253) found that Dutch has a lower fundamental frequency than Japanese.

If all the tests had been done using the same methods, the following classification could have been made: Japanese has the highest fundamental frequency, followed by Dutch, English, and finally German. Because the applied tests were different from one another, such a classification might not be possible to establish.

A further thing that should be noted is that Järvinen and Laukkanen (2015, 5) claimed that speaking with an increased fundamental frequency is considered to be one of the contributing factors in vocal loading. However, it was not possible to find a study which questioned whether speaking a language with a relatively high fundamental frequency affects vocal loading as well.

Methodology

The data appears to suggest that the difference in fundamental frequency between speaking Dutch and speaking English is larger than the difference in fundamental frequency between speaking a native language and speaking a foreign language, although it has to be noted that there was some variability in the data.

One of the causes of this variability was that the HCRC Map Task was used. The decision to use this task was made because it would lead to semi-spontaneous language. The disadvantage of using this task was that the maps differ in their objects and routes. Some routes were easier to explain than others, and some sounds might have affected the fundamental frequency more than

others. For further research, it might be preferable to do an oral reading task as well, or to develop another test in which the outcomes of the tests are more similar.

Another disadvantage of using this task is that some people are better at explaining routes than others, which led to differences in the duration of the tests. Some participants finished the task within 30 minutes, whereas others needed up to 2 hours to get to the same point. It might have been better to use smaller maps and let the participants speak for a limited amount of time, so that the amount of data was more equal per participant.

For further research, it might be interesting to use bigger and more homogeneous participant groups, or compare more languages with each other.

CONCLUSION

This study attempted to find out whether speaking a different language and speaking in a foreign language has an effect on the fundamental frequency. By using the HCRC Map Task, semi-spontaneous data was generated. A comparison of two different languages, Dutch and English, led to the conclusion that native speakers of English speak Dutch with a significantly higher fundamental frequency than English, whereas Dutch people speak English with a (non-significantly) lower fundamental frequency compared to Dutch. Moreover, Dutch has a significantly higher fundamental frequency than English.

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