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# Adaptation of fundamental frequency in Dutch and English with second language effects

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**Abstract**

This study examines the variability in fundamental frequency[1] of spoken foreign languages and the variation of this frequency between Dutch and English. This is relevant because an increase of the fundamental frequency might lead to vocal fatigue or vocal loading (Järvinen, Laukkanen, 2015, p. 1). Additionally, the relation between those two factors had not been investigated yet.

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.

[1]Fundamental frequency corresponds to the vibration of the vocal folds. A more elaborate explanation will be given in chapter 2.

I would like to thank Paul Boersma, who was my supervisor, David Weenink, Dirk-Jan Vet, Rob Hesselink, Emma Kemp, Sammy Odenhoven, Max Briel, Mayon Bongers, Pierre Theelen, Ivonne Oortman, Marthe Varenhorst and all of the participants.

# Contents

# 1 Introduction

Several studies have shown that languages differ in fundamental frequency (Mennen, Schaeffler & Docherty, 2012; Bezooijen, 1995; Traunmüller & Eriksson, 1994, p. 3). Moreover, according to Järvinen & Laukkanen (2015, p. 1), speaking a foreign language leads to a higher fundamental frequency 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, Laukkanen, 2015, p. 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 of the participants will be taken into account, as women speak with a different fundamental frequency than men (Howard, 1991, p. 70).

This paper can be 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.

# 2 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 to produce different sounds. For example, by constricting the air stream the [p] and [b] are created (Image 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, pp. 92-93). When the vocal folds vibrate, and the air is constricted, we produce a [b], whereas without the vibration of the vocal folds, we produce a [p]. This distinction holds for most consonants, while the vocal folds always vibrate when producing vowels (Rodenburg, 1992, p. 242).

In general, every vibration of the vocal folds leads to a new period of a waveform (Ladefoged, 1996, p. 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, p. 70). In Image 2, four periods are shown. One of those periods is selected.

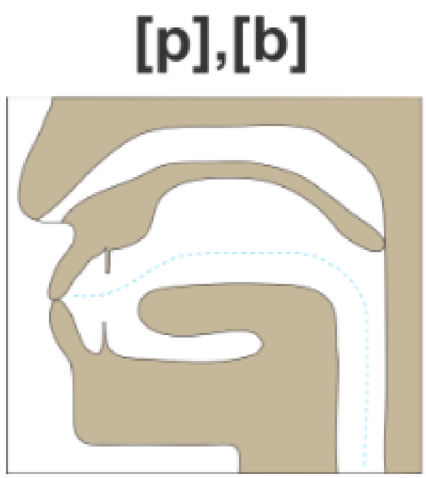



Image 1: Constriction of the air stream (Sjerps, Franken & Lockwood, 2016)

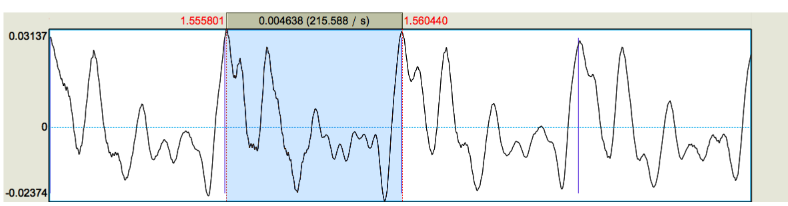



Image 2: The selection of a period of a waveform. 1/0.005608 comes down to 178 Hz, which is the fundamental frequency.

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

*Fundamental frequency = 1 / period of the sound wave*[2]

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, p. 68), without involving logarithmic calculations.

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 to measure the fundamental frequency for a bigger amount of data at once. The downside of using computer programs is that they often make errors. Those errors mainly consist of doubling or halving the pitch[3] (Murray, 2001, p. 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.

[2]The result is in Hertz (Hz).

[3]Fundamental frequency / 2 or fundamental frequency * 2.

# 3 Theories in second language acquisition

The study of second language acquisition[4] is defined by Gass & Selinker (2013, p. 1) as "the study of how second languages are learned. It is the study of the acquisition of a non-primary language; that is, the acquisition of a language beyond the native language. It is the study of how learners create a new language system with only limited exposure to a second language".

There are many theories that describe how people learn a second language, but the best fitting theory for the potential difference in fundamental frequency is unknown, because theories in phonetics and phonology are primarily based on the differences between phonemes (Smith, forthcoming, chapter 9; Gass, Selinker, 2013, pp. 178-190). This is why only a basic overview of the main second language theories will be made. As none of those theories states anything about the fundamental frequency, only assumptions can be made based on the theories.

One of the first theories that explains second language acquisition is called behaviourism. In this theory, mainly provided by Skinner in 1957, it was stated that comprehension and the production of speech happens automatically, and is the result of human behaviour (Aimin, 2013, p. 162). Behaviourism can be linked to the Contrastive Analysis Hypothesis in which researchers looked at the differences between languages. This type of analysis was mainly used in the 1950s and early 1960s and was one of the methods to predict why foreign language learners make mistakes (Ortega, 2009, p. 31). Based on this view, the adaptation of the fundamental frequency would be dependent on the first language of the participants. Assuming that different languages have different fundamental frequencies, someone from Japan would speak English with a different fundamental frequency than someone from The Netherlands. Additionally, practice would lead to more adaptation to the foreign language.

In contrast to the behaviourism, Noam Chomsky introduced Universal Grammar in the early 1980s. In this approach, people are born with a Language Acquisition Device, which is a specific part of the brain only used for language (Aimin, 2013, p. 162). Inside of this Language Acquisition Device, there are several switches that children set to the language they learn (Briscoe, 1997, p. 1). For example, there could be a switch for the position of the verb. Children who grow up learning a language in which the verb is placed at the end of the sentence set their switch differently compared to children who grow up learning a language in which the verb is placed in the middle of the sentence. The Critical Period Hypothesis falls within the Universal Grammar Theory. According to this hypothesis, the switches cannot be set or changed after a specific age. Opinions about this part of the theory are divided. The main view on learning a

[4]Sometimes the distinction between a second language and a foreign language is made. A second language is a language that has to be learned because of an institutional and social role in the community, whereas a foreign language does not have such a role (Ellis, 1991, pp. 11-12). However, in this research no such distinction will be made and the terms will be used interchangeably.

second language is that foreign accents cannot be overcome easily after puberty, but learning to communicate in a foreign language is still possible (Lenneberg, 1967, p. 176). According to this hypothesis, only participants who learned the second language before puberty would be able to properly change their fundamental frequency.

In 1982 Stephen Krashen introduced the Monitor Theory. In his theory, there are five main hypotheses: the first is the acquisition-learning hypothesis. According to Krashen, acquisition is due to subconscious exposure to language, and not focused on linguistic features, whereas learning is about conscious knowledge of a language. The result of acquiring a language is that you have a feel for correctness, whereas the result of learning a language is that you know the rules (Krashen, 1982, p. 10). The second hypothesis is the natural order hypothesis, in which he states that the acquisition of grammatical structures happens in a predictable order and is very much alike for most foreign language learners (Krashen, 1982, p. 12). The third hypothesis is the monitor hypothesis. In this hypothesis Krashen states that acquisition is responsible for our fluency, whereas learning has the function of editing or monitoring the language (Krashen, 1982, p. 15). The fourth hypothesis is the input hypothesis. According to this hypothesis, the most important is that a language learner needs an input that is "a little beyond" his/her own level (Krashen, 1982, p. 21). The last hypothesis is the affective filter hypothesis, in which Krashen claims that motivation, self-confidence and (minimal) anxiety are important factors in learning a language (Krashen, 1982, p. 31). According to this theory the fundamental frequency most likely only adapts as a result of acquiring a language, not as a result of learning a language, and only if enough input was available.

The last theory that we present is called the Acculturation Model, proposed by Schumann in 1976. In this theory it is claimed that social distance between the native and foreign groups and psychological factors of the language learners like language shock and motivation are crucial in learning a language successfully. Thus, the more acculturated a speaker can become, the more successful he/she will be in learning a language (Schumann, 1990, p. 670). According to this theory, speakers would adapt their fundamental frequency more if they would be acculturated.

# 4 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 done about fundamental frequency differences between languages, and in a second language context. This chapter 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 Dutch speak with a higher fundamental frequency than speakers of English. After this, the hypotheses and research questions will be presented.

## 4.1 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. The researchers, Järvinen & Laukkanen also stated that speaking a foreign language leads to vocal fatigue and vocal loading (Järvinen & Laukkanen, 2015, p. 1). This means that the voice gets tired of speaking. One of the mentioned causes is increased mental stress, but the increased fundamental frequency might have an effect as well.

Moreover, Järvinen & Laukkanen also 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, Laukkanen, 2015, p. 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, p. 1702), showed that the mean pitch of native speakers of Russian is a lot higher than the mean pitch of Finnish learners of Russian. However, the Finnish people speak higher in Russian than in 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 to Russian.

While in the study of Järvinen & 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, which 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, whereas on the other hand, people adapt to to the fundamental frequency of the foreign language. A more elaborate analysis of this problem will follow in the discussion-section in chapter 7.

## 4.2 Influences of different languages on fundamental frequency

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

Moreover, it was found that the fundamental frequency of women speaking Japanese is higher than the fundamental frequency of women speaking Dutch. Bezooijen, the author of this article, 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, p. 253).

Additionally, a number of studies found that bilingual speakers change their fundamental frequency according to the language they speak. Todaka (1995, p. 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.

## 4.3 Hypotheses and research questions

From the former two paragraphs, two main things can be concluded: on the one hand, people who speak in a foreign language tend to increase their fundamental frequency, but 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, and 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 the language itself, or the other way around.

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 the two research 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 & Knapton 2005, p. 2401), there is no problem in simultaneously testing bilingual Dutch and bilingual English speakers.

If speaking a foreign language affects the fundamental frequency more than the language itself, the view of behaviourism and the Monitor Theory would explain this as an insufficient amount of language input. The Universal Grammar theory would explain this increase or decrease as a proof for the Language Acquisition Device and the critical period, and the Acculturation Model would explain this as an insufficient degree of acculturation.

However, if the language itself has a bigger effect on the variability of the fundamental frequency and the participants adapt their fundamental frequency to the foreign language, the view of behaviourism and the Monitor Theory would explain this as a sufficient amount of language input and the Acculturation model would explain this outcome as sufficient acculturation of the participants. The Universal Grammar Theory, however, would not be able to explain this with the Critical Period Hypothesis, as the foreign language learners would be able to adapt to a foreign language after the critical period.

Moreover, if there is no difference in fundamental frequency between the languages, there is no variance that can be explained by making use of the second language acquisition theories.

# 5 Methods

This chapter illustrates the methods that were used doing 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 chapter is about the way the measurements were done.

## 5.1 Materials

For this research, the HCRC Map Task was used. This is a task, developed at the University of Edinburgh, in which person A describes a route on a map to person B (Anderson et al., 1991). This was done in pairs of one English native participant who spoke Dutch as a second language and one Dutch native participant who spoke English as a second language. The crucial factor of the task is that the maps are not completely similar, which increases the difficulty of the task. In this experiment, an extra number of maps was used in which the objects on the maps were similar[5]. The task was chosen to prevent oral reading, and stimulate spontaneous speech. Spontaneous speech was favoured over oral reading because Hollien, Hollien & De Jong (1997, p. 2990) found that oral reading results in a higher mean fundamental frequency than in spontaneous speech.

In order to compare the difference 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.

Table 1: Counterbalancing of the languages of the maps and the participants.

| 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. |

[5]This decision was made because the participants in the pilot needed 45 minutes to explain one map. In the actual experiment this would cost too much time. The simplified version would enable the researcher to limit the amount of time needed and end the session after the four simplified maps. At the end, all of the participants in the actual experiment finished eight maps within two hours and did the second part of the experiment as well because only using the first part would not have led to a sufficient amount of data.

Eight maps were used, examples of which are displayed in Appendix 1. Half of the maps were in Dutch, whereas the other half of the maps 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 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).

## 5.2 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. After this, the test was being 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 (Appendix 2 & 3).

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 alright, the participants were asked to say some sentences, or read the first page of the Bible (both in English and Dutch). When everything was alright, the recording was started and the researcher 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.

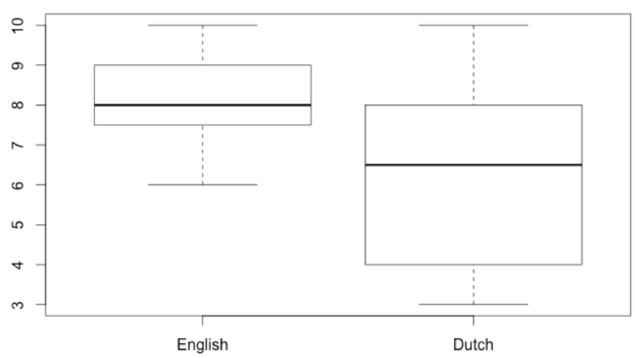
### 5.3 Participants

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 (1997, p. 2990) found that there was only a small difference in fundamental frequency between university students and an otherwise comparable group.

Finding English participants posed difficulties. This is why after a month a compensation of 10,- was offered, which is 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. At the end, there were ten female participants and six male participants.




Graph 1: Language level of the second language of the participants

## 5.4 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 (Appendix 4) in the computer program Praat (Boersma, Weenink, 1992-2015).[6]

Based on those pitch objects, measurements were made automatically by using another Praat script (Appendix 5). 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.

[6] 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, p. 51). With the chosen pitch floor and pitch ceiling, most voices would be accurately captured.

# 6 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.

## 6.1 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.

Table 2: Fundamental frequency values for both the native and the foreign speakers. The results are in Hz.

| | $\mu$ | $\sigma$ | $\mu$ women | $\sigma$ women | $\mu$ men | $\sigma$ 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 |

In this table, the participants in the row 'Dutch L1[7]' are the same participants as in the row 'English L2'. Also, 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 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

[7] L1 stands for first language, whereas L2 stands for second language.

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.

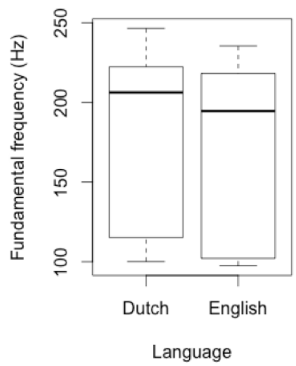
Another outcome of the research of Järvinen & Laukkanen was that women adapt their fundamental frequency more than men (2015, p. 5). Because of this, the same test was done separately for the male and female participants. And again, the results of this study did not correspond to the results of the study of Järvinen & 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 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 participant groups for doing those measurements were relatively small. Especially the groups with male participants were relatively small. 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 (Chapter 7).

## 6.2 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

# 7 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 the other way around.

## 7.1 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 & Laukkanen (2015, p. 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 & 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 people increased their fundamental frequency when speaking Dutch. For the Dutch people a significant result was not found.

Another result by Järvinen & Laukkanen (2015) was that women adapt their fundamental frequency to the foreign language more than men. But again we found something different. The English females changed their fundamental frequency when speaking Dutch, which was also the case for the Dutch males speaking English. However, for neither the English males nor the Dutch females a significant result was found.

There are several factors that might be the reason that Järvinen & Laukkanen found that speaking a foreign language leads to a higher fundamental frequency, whereas in the current study such an effect was not found. At first, it has to be noted that Järvinen & 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 refuse 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, and according to the study of Ullakonoja (2007, p. 1702), people with a higher language level adapt their fundamental frequency more, the comparison might not have been completely valid.

Apart from the issues with the language level and the sample size, the theories in second language acquisition offer some explanations as well. According to the behaviourist view, differences between the first and the second language of the speakers are the cause of mistakes. Because English people are used to speaking with a lower fundamental frequency, they do increase their fundamental frequency when speaking Dutch, although they do not increase their fundamental frequency sufficiently.

The difference of fundamental frequency might also be explained by the Acculturation model, which states that social distance between native and foreign groups and psychological factors of the language learners like language shock and motivation are crucial in learning a language successfully (Schumann, 1990, p. 670). All of the English participants lived in The Netherlands, whereas none of the Dutch participants lived in an English-speaking country. This might have an effect on the acculturation of the participants, and the effects on the fundamental frequency; maybe this is the reason why the Dutch participants did not change their fundamental frequency significantly when speaking English. In order to confirm this theory, it would have been needed to request the participants for more information about the social distances between the native and foreign groups.

Universal Grammar is not able to explain the difference in fundamental frequency, as the parameters (switches) in the Language Acquisition Device are already set and it is not possible to adapt to a foreign language anymore. However, the participants do adapt to the foreign language.

## 7.2 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 & Docherty (2011, p. 2249) who found that German has a lower fundamental frequency than English, the findings of Todaka (1995, p. 264) who found that English has a lower fundamental frequency than Japanese, and the findings of Bezooijen (1995, p. 253) who found that Dutch has a lower fundamental frequency than Japanese.

If all tests had been done using the same methods, a classification could have been made as follows: Japanese has the highest fundamental frequency, followed by Dutch, followed by English, followed by German. Because the tests that were used were different from each other, a classification like this might not be possible to establish, although it might be possible to make such a classification after doing the same tests on the different languages.

Another thing that should be noted is that Järvinen & Laukkanen (2015, p. 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 in which was questioned whether speaking a language with a relatively high fundamental frequency affects vocal loading as well.

## 7.3 Methodology

The data seems 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 two 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. Moreover, it would be worthwhile to find out whether an increased fundamental frequency indeed has an effect on vocal fatigue and vocal loading.

# 8 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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http://www.sdkrashen.com/content/books/principles$_{a}nd_{p}ractice.pdf.Lastretrievedon02-$
$06 - 2016$

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# 10 Appendix 1

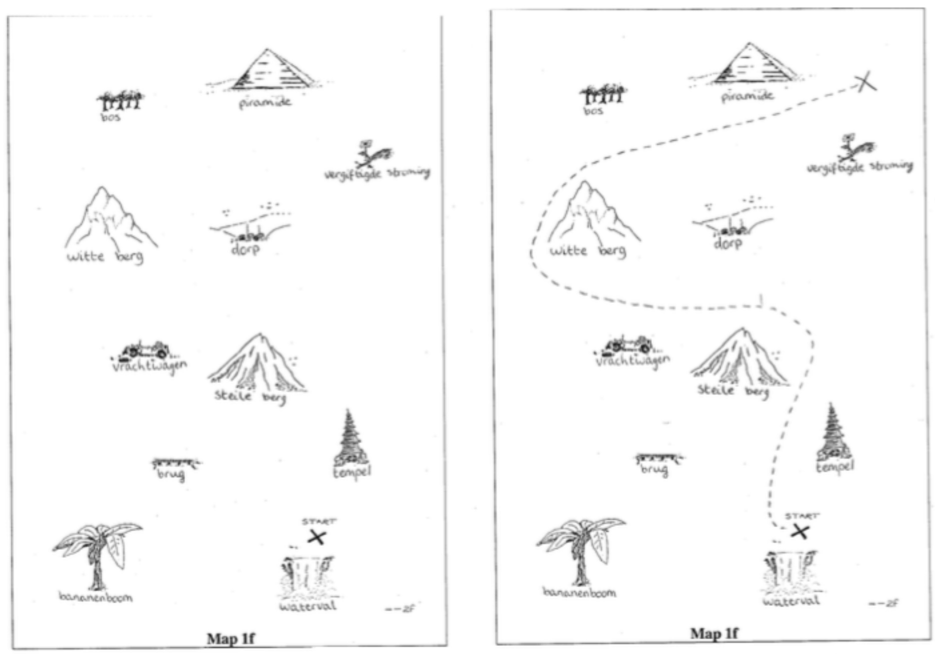



Image 3 & 4: Easier version in Dutch

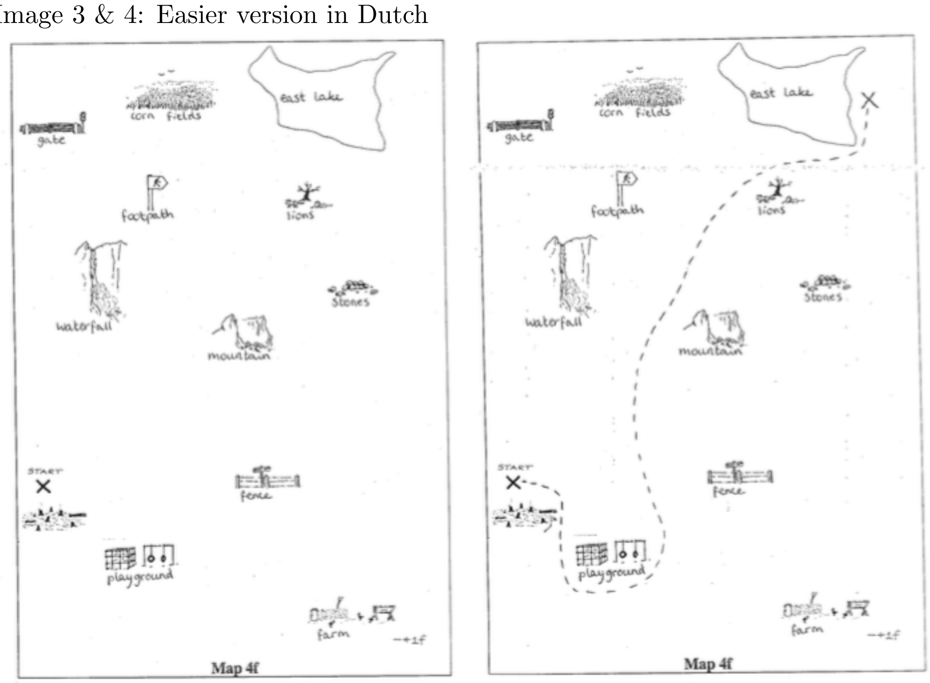
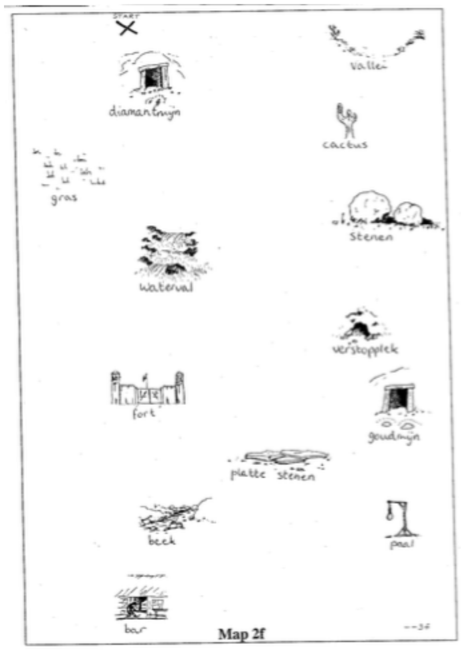



Image 5 & 6: Easier version in English



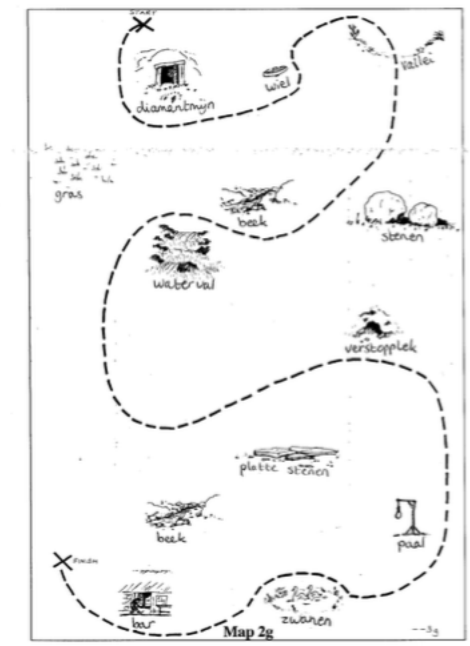



Image 7 & 8: Harder version in Dutch

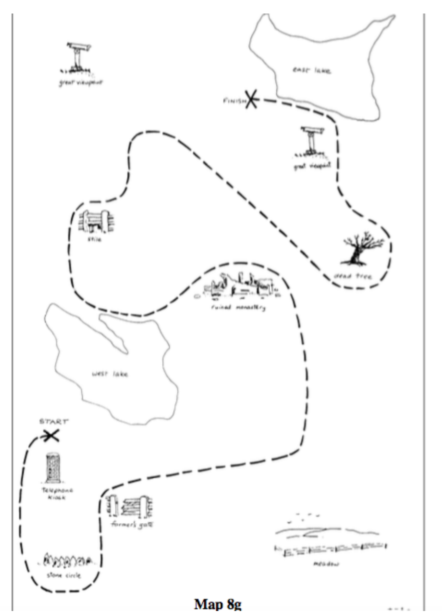



Image 9 & 10: Harder version in English

# 11 Appendix 2

Ik verklaar hierbij op voor mij duidelijke wijze te zijn ingelicht over de aard en methode van het onderzoek. Mijn vragen zijn naar tevredenheid beantwoord.

Ik stem geheel vrijwillig in met deelname aan dit onderzoek. Ik behoud daarbij het recht deze instemming weer in te trekken zonder dat ik daarvoor een reden behoef op te geven en besef dat ik op elk moment mag stoppen met het experiment. Indien mijn onderzoeksresultaten gebruikt zullen worden in wetenschappelijke publicaties, dan wel op een andere manier openbaar worden gemaakt, zal dit volledig geanonimiseerd gebeuren. Mijn persoonsgegevens zullen niet door derden worden ingezien zonder mijn uitdrukkelijke toestemming.

Als ik nog verdere informatie over het onderzoek zou willen krijgen, nu of in de toekomst, kan ik me wenden tot Mathilde Theelen (telefoon: 0628315615 e-mail: mathilde.theelen@student.uva.nl) of begeleider Paul Boersma (paul.boersma@uva.nl).

Met eventuele klachten over dit onderzoek kan ik me wenden tot de secretaris van de Commissie Ethiek van de Faculteit Geesteswetenschappen van de Universiteit van Amsterdam, commissie- ethiek-fgw@uva.nl (telefoon: 020-525 2543; Spuistraat 210, 1012 VT Amsterdam).

Ik ga akkoord met bovenstaande informatie.
Aldus in tweevoud getekend:

| | |
|---|---|
| ................................ | ................................ |
| Naam proefpersoon | Handtekening |

Ik heb toelichting verstrekt op het onderzoek. Ik verklaar mij bereid nog opkomende vragen over het onderzoek naar vermogen te beantwoorden.

| | |
|---|---|
| ................................ | ................................ |
| Naam onderzoeker | Handtekening |

................................
Datum

# 12 Appendix 3

## Intakeformulier proefpersonen
## Bachelorscriptie Taalwetenschap

---

*Basisgegevens*

Leeftijd: …………

Geslacht: M – V – geen antwoord

---

*Taalachtergrond*

Welke taal/talen werden er toen je opgroeide thuis gesproken?

……………………………………………………………………………………………………

Wat is de moedertaal van je ouders/opvoeders?

……………………………………………………………………………………………………

……………………………………………………………………………………………………

Welke andere talen spreek je, wanneer begon je die te leren en hoe goed spreek je deze talen? (0=niet, 10=vloeiend)

……………………………………………………………………………………………………

……………………………………………………………………………………………………

……………………………………………………………………………………………………

---

*Geschiktheidscriteria*

| | | |
|---|---|---|
| Welke hand is je dominante hand? | LINKS | RECHTS |
| Heb je gehoorproblemen (gehad)? | JA | NEE |
| Heb je taal- of spraakstoornissen (gehad)? | JA | NEE |
| Heb je andere (ontwikkelings)stoornissen (gehad)? | JA | NEE |
| Heb je vandaag alcohol geconsumeerd? | JA | NEE |
| Heb je in de afgelopen 24 uur verdovende/stimulerende middelen gebruikt? | JA | NEE |

---

# 13 Appendix 4

```
########################################################
#
# NAME: f0_trim&check.psc
#
# DESCRIPTION
# This script carries out all the repetitive actions involved in the checking
# of F0 tracks. The scripts calculates the Pitch object, derives the PitchTier
# object, and trims the PitchTier traces if there are spikes in the raw tace.
# # The f0 traces get trimmed using Yi Xu's trimming algorithm (see
ProsodyPro)
# http://www.phon.ucl.ac.uk/home/yi/ProsodyPro/
# The script then plots two traces in the Picture window: the raw trace of the
Pitch
# object in grey, and the trimmed trace of the PitchTier object in black, and
then
# it pauses. At this point, the user can check and fix if need be.
# The Pitch and PitchTier objects only get written to file when the user
clicks
# the 'Continue' button. So if the user corrects either of these objects after
# examining evidence in the Picture window, the corrected versions will be
written to
# file.
#
# INPUT REQUIREMENTS
# For each item to be processed, there should be a TextGrid and a sound
file.
# Items are included for processing if there is a TextGrid. The TextGrid is
already
# segmented so that there is a interval tier on tier 1. The section of the F0
# track between the end of interval one and the start of the final interval is
# visualized for checking.
#
# INPUT PARAMETERS
# The f0 range of the speaker is set by the user. This limits the f0 extraction
# algorithm, and makes the visualisation of the f0 trace in the Picture
window
# more specific. Because this range matters, it is easiest to run this script
# for each speaker separately. The silence threshold is also relevant for the
# f0 extraction algorithm. The maxbump threshold is a parameter in Yi Xu's
trimming
# algorithm: any upward or downward spike that exceeds this threshold gets
levelled.
#
# BY:   Bert Remijsen
```

```
# LAST CHANGE: 21/01/2013
#
# ADJUSTED BY: Mathilde Theelen
# LAST CHANGE: 24/04/2016
#
####################################################

form Make and check Pitch objects for batch
comment The TextGrid and sound files are located in:
text inputdir /Users/mathildetheelen/Desktop/Studie/J3Scriptie/Files
comment Search term and extension to select files to be processed (* means
all):
word term *
comment output files are written to input dir.
comment Minimum and maximum of range within which F0 is detected (set
by speaker):
positive left_range 50
positive right_range 300
comment Parameter for Pitch object - get an F0 measurement every (s):
positive step 0.005
comment Parameter for Pitch object - silence threshold (default is 0.03):
positive silence 0.03
comment Parameter for PitchTier modification: this is the threshold, (in
Hz),
comment above which bumps get levelled by Yi Xu's algorithm:
positive maxbump 1
comment The section of the F0 track between the end of interval one and
the start
comment of the last interval is plotted to the Picture window, with the Pitch
object
comment  (raw f0 - in grey) and PitchTier object (trimmed f0 - in red)
overlaid.
endform

Create Strings as file list... listfile 'inputdir$'/'term$'.TextGrid
end = Get number of strings

for fileteller from 1 to 'end'
 select Strings listfile
 file$ = Get string... 'fileteller'
 bare$ = file$ - ".TextGrid"

 echo Processing 'file$', file 'fileteller' out of a total of 'end'
 Read from file... 'inputdir$'/'bare$'.TextGrid
```

```
  textgridID = selected ("TextGrid", 1)
  Read from file... 'inputdir$'/'bare$'.wav
  soundID = selected ("Sound", 1)

# Create the Pitch object. I am using the default values. Sometimes
# I lower the silence threshold from .03 to .02.
# This makes it more likely that periodicity in lower-intensity
# parts of the waveform are recognised as voiced.

  To Pitch (ac)... 'step' 'left_range' 15 yes 'silence' 0.45 0.01 0.35 0.14
'right_range'
  pitchID = selected ("Pitch", 1)
  Down to PitchTier
  call domain
  call yixutrimming

#
# Display and play for checking
#

  Erase all
  Viewport... 0 8 0 5

  select 'textgridID'
  Black
  Line width... 1
  Draw... 'beg_t' 'fin_t' yes yes yes

  select 'pitchID'
  Line width... 5
  Grey
  Draw... 'beg_t' 'fin_t' 'left_range' 'right_range' no

  select PitchTier 'bare$'
  Line width... 2
  Red
  Draw... 'beg_t' 'fin_t' 'left_range' 'right_range' no
  Marks left every... 1.0 25 yes yes no

  #select 'soundID'
  #Play

  pause ok? 'beg_t' 'fin_t'
  Erase all
```

```
#
# Save f0-related objects
#

  select PitchTier 'bare$'
  Write to text file... 'inputdir$'/'bare$'.PitchTier
  select 'pitchID'
  Write to binary file... 'inputdir$'/'bare$'.Pitch


#
# Remove files
#

  select 'soundID'
  plus 'textgridID'
  plus 'pitchID'
  plus PitchTier 'bare$'
  Remove

endfor

procedure domain
   select 'textgridID'
   nlabels = Get number of intervals... 1
   ori_beg_t = Get end point... 1 1
   beg_t = ori_beg_t - 0.1
   ori_fin_t = Get starting point... 1 nlabels
   fin_t = ori_fin_t + 0.1
endproc

#
# The following part is Yi Xu's trimming algorithm.
#

procedure yixutrimming
select PitchTier 'bare$'
	maxedge = 0.0
	maxgap = 0.033
	n = Get number of points
	npulses = n

	first = Get value at index... 1
```

```
        second = Get value at index... 2
        penult = Get value at index... n-1
        last = Get value at index... n
        tfirst = Get time from index... 1
        if npulses < 3
                printline Please add at least 3 pulse marks before proceeding!
                exit
        endif
        tlast = Get time from index... n
        for k from 1 to 3
                call Trim
        endfor
        Remove point... 1
        Add point... tfirst second + (first-second) / 1000
        Remove point... n
        Add point... tlast penult + (last-penult) / 1000
endproc

procedure Trim
        for i from 2 to n-1
                tleft = Get time from index... i-1
                tmid = Get time from index... i
                tright = Get time from index... i+1
                gap1 = tmid - tleft
                gap2 = tright - tmid
                left = Get value at index... i-1
                mid = Get value at index... i
                right = Get value at index... i+1
                diff1 = mid - left
                diff2 = mid - right
                if diff1 > maxbump and diff2 > maxedge and gap1 < maxgap
and gap2 < maxgap
                ... or diff2 > maxbump and diff1 > maxedge and gap1 <
maxgap and gap2 < maxgap
                        Remove point... i
                        Add point... tmid left+(tmid-tleft)/(tright-tleft)*(right-
left)
                endif
                if diff1 > maxbump and gap2 >= maxgap
                        Remove point... i
                        Add point... tmid left + maxbump
                endif
                if diff2 > maxbump and gap1 >= maxgap
                        Remove point... i
```

```
			Add point... tmid right + maxbump
		endif

		diff1 = left - mid
		diff2 = right - mid
		if diff1 > maxbump and diff2 > maxedge and gap1 < maxgap and gap2 < maxgap
		... or diff2 > maxbump and diff1 > maxedge and gap1 < maxgap and gap2 < maxgap
			Remove point... i
			Add point... tmid left+(tmid-tleft)/(tright-tleft)*(right-left)
		endif
		if diff1 > maxbump and gap2 >= maxgap
			Remove point... i
			Add point... tmid left - maxbump
		endif
		if diff2 > maxbump and gap1 >= maxgap
			Remove point... i
			Add point... tmid right - maxbump
		endif
	endfor
endproc
```

# 14 Appendix 5

```
#########################################################
#
# NAME: f0_median
#
# DESCRIPTION
# This script measures the median fundamental frequency for four fields that
# are made in a TextGrid.
#
# INPUT REQUIREMENTS
# For each file there needs to be a sound file, a Textgrid, a Pitch object and
# a PitchTier object.
#
# BY: Mathilde Theelen, and a part by Paul Boersma, however gotten from
Bert
# Remijsen (Remijsen, 2015).
# LAST CHANGE: 09/05/2016
#
#########################################################

form Script to extract measurements on duration and f0.
   comment Fields in filenames are separated by underscores.
   comment The TextGrid and PitchTier files to be ananlysed are located in:
   word location /Users/mathildetheelen/Desktop/Studie/J3Scriptie/
   comment Write output to the following file:
   text outputfile
/Users/mathildetheelen/Desktop/Studie/J3Scriptie/outputfiles/.txt
   comment Restrict the analysis using following filter (* stands for any
value):
   word searchterm *
endform

Create Strings as file list... listfile 'location$'/'searchterm$'.TextGrid
last = Get number of strings
counter = 1

for fileteller to last
select Strings listfile
filename$ = Get string... fileteller
string$ = filename$ - ".TextGrid"
bare$ = string$
   lengte = (length(string$) - 3)
   itemref$ = left$(string$,lengte)

   #
```

```
    # Parse the string into a string array - this piece of code
    # was scripted by Paul Boersma.
    #

    ifield = 0
    repeat
      ifield += 1
      separator = index (string$, "_")
      if separator <> 0
        field'ifield'$ = left$ (string$, separator - 1)
        string$ = mid$ (string$, separator + 1, 10000)
      else
        field'ifield'$ = string$
      endif
    until separator = 0

#
# Read in the TextGrid
#

echo Processing 'bare$', file 'fileteller' out of a total of 'last'
Read from file... 'location$'/'bare$'.TextGrid
textgridID = selected ("TextGrid", 1)

#
# Measure median f0s
#

label1$ = Get label of interval... 1 2
begin_interval_1 = Get starting point... 1 2
eind_interval_1 = Get end point... 1 2
duur_interval_1 = begin_interval_1 - eind_interval_1

label2$ = Get label of interval... 1 4
begin_interval_2 = Get starting point... 1 4
eind_interval_2 = Get end point... 1 4
duur_interval_2 = begin_interval_2 - eind_interval_2

label3$ = Get label of interval... 1 6
begin_interval_3 = Get starting point... 1 6
eind_interval_3 = Get end point... 1 6
duur_interval_3 = begin_interval_3 - eind_interval_3

label4$ = Get label of interval... 1 8
```

```
begin_interval_4 = Get starting point... 1 8
eind_interval_4 = Get end point... 1 8
duur_interval_4 = begin_interval_4 - eind_interval_4

begin_interval = Get starting point... 1 2
eind_interval = Get end point... 1 8
duur_interval = begin_interval - eind_interval

Read from file... 'location$'/'bare$'.PitchTier
pitchtierID = selected ("PitchTier", 1)

# 0.0 is auto bij time step, 75 is pitch floor, 600 is pitch ceiling
To Pitch: 0.05, 75, 600
f0_median_1 = Get quantile: begin_interval_1, eind_interval_1, 0.50,
"Hertz"
f0_median_2 = Get quantile: begin_interval_2, eind_interval_2, 0.50,
"Hertz"
f0_median_3 = Get quantile: begin_interval_3, eind_interval_3, 0.50,
"Hertz"
f0_median_4 = Get quantile: begin_interval_4, eind_interval_4, 0.50,
"Hertz"

echo ['counter'] 'bare$' 'tab$' 'tab$' 'label1$' 'tab$' 'f0_median_1:2' 'tab$'
'label2$' 'tab$' 'f0_median_2:2' 'tab$' 'label3$' 'tab$' 'f0_median_3:2' 'tab$'
'label4$' 'tab$' 'f0_median_4:2'
fappendinfo 'outputfile$'
counter = counter +1

select 'textgridID'
plus 'pitchtierID'
Remove

endfor
```