The perception of Dutch /y/ by speakers of Modern Hebrew - The search for the influencing cues

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Abstract
This study continues an investigation into the cross-linguistic perception of the North Standard Dutch (NSD) front rounded vowel /y/ by Modern Hebrew (MH) listeners. Ben-Arieh (2008) reports that when hearing natural stimuli of NSD /y/ vowels, the majority of MH listeners perceived it as their own back vowel /u/. In the current study, an examination of the high vowel space of MH is made in order to try and find the cues to the perception of the high vowel space in MH in general, and the perception of NSD /y/ as MH /u/ in specifically. A perception experiment was performed by Hebrew listeners, who had to identify the stimuli as /i/ or /u/ and rate the goodness of the vowel they had heard. Results: (1) an equal division of the MH /i/ and /u/ categories over the perception space was found; (2) the second formant (F2) and third formant (F3) are both found to be influencing the perception of MH listeners in the high-vowel space. F2 has a major influence on the perception of MH listeners, while F3 has a secondary one; (3) the third formant is found to be a secondary cue but has a small influence on the majority of the listeners who perceived /i/ or /u/ in the production range of the NSD /y/.

1. Introduction

It is well known that every language has its own phonemic inventory. Previous studies show difficulties in production and perception of foreign vowels by adults either hearing a foreign language or learning a second language (L2) (Best, 1995; Flege, 1995)
It is apparent today that when listening to vowels of a foreign language, speakers will perceive it as one of the vowels from the inventory of their first language (L1). This is regarded in the literature as cross-linguistic speech perception, (Levy & Strange, 2008). According to Best's Perceptual Assimilation Model (PAM) L2 sounds are assimilated into L1 phonemic categories by naïve and inexperienced listeners. Non-native sounds which are phonetically close to native sounds will be assimilated to the closest native category. However, non-native sounds which are more phonetically distinct from the native categories, will not be categorized (Best, 1995).
Flege's Speech Learning Model (SLM) divides the perceptual similarity to native sounds into three types, "identical', "similar" and "new. Non-native sounds which are similar to native sounds will be assimilated into the closest native category and new non-native sounds which are more phonetically distinct from the native sounds will be discriminated with less difficulty than the other sound types (Flege, 1987, 1995).

A few studies examined the cross-linguistic perception of front rounded vowels by speakers of a L1 language which does not contain such vowels in its vowel inventory. Front rounded vowels are common in some Germanic languages, such as German, Dutch Swedish etc. Results show two distinct patterns of perception: a back vowel perception pattern and a front vowel perception pattern. That is, listeners whose language lacks front rounded vowels perceive the foreign vowels as their own rounded back vowel or their own unrounded front vowel. American English (AE) and Canadian English (CE) listeners perceive the French and German /y/ as their own back /u/ vowel, although the first formant (F1) and the second formant (F2) are closer to their front unrounded vowel /i/ (Gottfried, 1984; Strange, 2001; Rochet, 1995). Brazilian Portuguese listeners, however, perceive it as their own /i/ (Rochet, 1995). In a study aimed to find out how Modern

Hebrew (MH) listeners would perceive the Northern Standard Dutch (NSD) /y/, MH listeners perceived it as their own back /u/, although the F1 and F2 of the /y/ are closer to their /i/ (Ben-Arieh, 2008). These results show the same back vowel perception pattern as was reported for AE and CE listeners' perception when listening to German and French front rounded vowels, a pattern that was regarded by Levy & Strange (2008) as confusion, since the spectral properties of the L2 vowel were similar to the front un-rounded vowel of the L1. Therefore the expectations were that the AE and CE listeners would perceive German and French /y/ as their own /i/. Perceiving /u/ instead can be regarded as confusion i.e. something is 'confusing' the listeners and makes them perceive back vowel instead of front. Ben-Arieh (2008) has found that MH listeners perceive the NSD /y/ as their own /u/, but did not thoroughly investigate the reasons for that. However, a comparison between the acoustic parameters of the NSD and MH high vowel continua show a possibility that the F3, which is considered to be the cue for rounding (Levy & Strange, 2008) has some influence on the perception of MH listeners. Table 1 presents the average formant values of NSD /y/ and the MH /i/ and /u/ and shows that the F1 and F2 of NSD /y/ are closer to MH /i/, while its F3 is closer to the MH /u/.

Vowel	**F1**	**F2**	**F3**
NSD /y/	240.39 Mel/ 301.5 Hz (SD 34.02)	767.86 Mel/ 1671.7 Hz (SD 104.69)	877.43 Mel/ 2161.5 Hz (SD 65.43)
MH /u/	276.33 Mel/ 359 Hz (SD 31)	562.34 Mel/ 979 Hz (SD 91)	932.12 Mel/ 2445 Hz (SD 151)
MH /i/	265.95 Mel/342 Hz (SD 30)	858.13 Mel/ 2068 Hz (SD 142)	953.20 Mel/ 2562 Hz (SD 172)

Table 1[1]: Average spectral properties of NSD /y/ (Weenink, 1985) and MH /u/ and /i/ vowels, (Most, Amir & Tobin, 2000).

Rochet (1995) addresses the issue and states that it is not yet explained why speakers of Brazilian Portuguese replace the German and French /y/ with their back /u/ vowel, while speakers of AE replace the same vowel with their own unrounded front /i/. Rochet reports that in a L2 vowel imitation task speakers of Haitian produced the French /y/ as /i/ while AE speakers produced it as /u/, and he rules out the possibility that production influences the listeners' perception. According to the results of the tasks, Rochet claims that perception has an influence on production. Evidence for that is seen when L2 speakers replace the /y/ vowel with a vowel from their own language and cannot hear any difference between the non-native sound and the native sound they replaced it with (Rochet, 1995).

Flege (1988) reported and argued that an "interlingual identification" occurs when the L2 sound (e.g. /y/) is perceived as /i/ or /u/. The L2 speaker associates the L2 /y/ vowel to a L1 category. Whether /i/ or /u/ is perceived depends on the L1 language.

Rochet (1995) argues that the perception of /y/ as a certain vowel in a given L1 language reflects the way L2 speakers perceive and categorize the high vowel continuum. In the Portuguese case for which Rochet reported Portuguese listeners identifying the French /y/ vowel as /i/ and AE listeners as /u/, the stimuli were generated with varying F2 values while F1 and F3 values were kept constant. Rochet argues that by determining and quantifying the way L2 speakers divide their high vowel continuum in their L1 language and correlating this information with the acoustic characteristics of the L2 target vowel, the cause of perceiving /i/ or /u/ can be found. Ben-Arieh (2008) suggests that F3 might play a role in the perception of NSD /y/ as MH /u/ and therefore the F3 in this was not constant.

[1] Some of the formant values shown in this paper were converted from Hz to Mel with Praat hertzToMel function according to the following formula: [550 ln (1 + x /550)] and some were converted from Mel to hertz with Praat melToHertz function according to this formula: [550 (exp(x / 550) -1)].

Following Rochet's and Ben-Arieh's suggestions this study aims to find the influencing cues for the Hebrew listeners' perception of NSD /y/ as their own /u/.The first research question is: **how is the perceptual space of the MH speakers divided in the F2-F3 space?**

The second research question is: **are both F2 and F3 influencing the perception of the high vowel space of MH listeners?**

The first formant (F1) was not examined in this study because it is approximately the same for NSD /y/ and MH /u/ and /i/, (table 1).

A number of perception experiments have shown that if spectral differences cannot differentiate between two vowels, then a temporal cue such as duration will be used to differentiate between them, i.e. a hierarchy was found between spectral and temporal cues like duration (Bennet, 1968; Liberman & Kubaska, 1979; Weiss, 1976; Gottfried & Beddor, 1988; Escudero and Polka, 2003). Bohn (1995) claims that this behavior or perception strategy is universal and not language-specific.

I suggest that this apparent hierarchy can be found not only between different cue types such as spectral and temporal, but also internally between the spectral cues themselves. I argue that cues are hierarchically identified by the L1 listeners. "Hierarchically identified" means every language has a different hierarchy of spectral cues. I suggest that this spectral hierarchy strategy is universal as the spectral-temporal hierarchy but the cues ranked in that hierarchy are language-specific. Although the answer to the second question should give us the influence of the F2 and F3, the F3 role in the /y/ range needs to be examined. Therefore the third research question is: **can it be determined that the F3 is a secondary cue helping the MH listener to perceive the /y/ more as a /u/ when a sound is ambiguous?**

An investigation into the influence of F3 can shed light on the cues that influence MH listeners' perception and perhaps show an auditory aspect to Butcher (1976)'s "expectation effect". Since all rounded vowels in English are back vowels, Butcher claimed that AE listeners will automatically expect a back vowel to be rounded.

Since AE and MH have the same pattern in perceiving /y/, they might share the expectation effect as well. If F3 influence is found on MH then the speakers should perceive the rounding cue and this should affect their perception of the NSD /y/.

In order to find answers to the three research questions mentioned above, a perception experiment was planned and executed. Synthesized vowels were generated in a matrix of the F2 and F3 of the high vowel continuum of NSD and MH; as opposed to methods in previous studies, a whole matrix of F2 and F3 was generated and not only F2 or a matrix of F1 and F2, which is very commonly used. The experiment was performed by 20 MH native speakers who had to identify and rate 69 vowels. Such an examination of the high-vowel space of MH in a perception experiment was never done before. Vowel goodness rating was included to confirm if it corresponds to the identification pattern.

The hypotheses for the three research questions are as follows:

- The hypothesis for the first research question is that the high vowel space of MH defined by F2 and F3 is divided into /i/ and /u/ categories and both occupy approximately the same space.
- The hypothesis for the second research question is that both F2 and F3 acoustic cues influence the MH perception of the high-vowel space. F2 is the main influencing cue.
- The hypothesis for the third research question is that the F3 is a secondary cue that can influence the perception of the MH listener when a sound is ambiguous and F2 cannot lead to a decision. In such cases, the F3 can take over, influencing the perception of the /y/ towards /u/ or /i/.

Section 2 describes the perception experiment and its method. Section 3 presents the results and includes a general overview of the results, a description of the vowel goodness ratings trend, general perception analysis, and perception in the NSD /y/ range. Section 4 contains the discussion of the results and their implications in reference to the theories and findings above. In section 5 a summary is made.

2. Perception Experiment

2.1 Method

2.1.1 Participants

A total of 20 participants ranging in age from 26-57 years (M = 33, SD = 8.11) have participated in the experiment. All participants were native MH speakers who have no more than 2 years experience with any European language that has a front rounded vowel in its inventory. No participants reported any hearing impairments. The participants were volunteered students and staff in the ABA diploma program of the education department of the university of Tel-Aviv.

2.1.2 Stimuli

The stimuli consisted of 69 synthesized isolated vowel tokens. The vowels were synthesized according to F2 and F3 frequency ranges (appendix 6.1 Fig. 1). The range of the F2 and F3 was decided according to the high-vowel continuum of MH and NSD. The vowel tokens varied along the F2 dimension between 493.87 Mel (800 Hz) and 993.74 Mel (2800 Hz) in 8 steps of 63 Mel. F3 varied between 798.74 Mel (1800 Hz) and 1137 Mel (3800 Hz) in 8 steps of 42 Mel. The F1 dimension was held constant at 350 Hz. F4 was set to the value of F3 + 400 Hz with a minimal value of 3500 Hz (1098.10 Mel). F5 was set to the value of F4 + 600 Hz with a minimal value of 4000 Hz (1162.13 Mel). F6 to F10 formant values were added in order to get a more natural sound by flattening the spectrum and were set to the preceding formant value + 1000 Hz. Throughout the duration of the sound F0 was decreased linearly from 150 Hz to 100 Hz, giving a more natural sound to the synthesized vowels. The tokens' duration was set to 200 milliseconds. 12 vowels were not generated by the definition that F2 frequencies do not to exceed F3 frequencies. A rule to implement that was put into the script and the total number of tokens generated was 69 and not 81. The Mel scale was used in order to make the steps more gradual according to human hearing. The vowel tokens were synthesized with a Praat's (Boersma &

Weenink, 2009) script using a cascade Klatt synthesizer (Klatt, 1980; Weenink, 2009); the values of the formants were converted from Hz to Mel with Praat hertzToMel function according to the following formula: [550 ln (1 + x /550)] and from Mel to Hz with Praat melToHertz function according to the following formula: [550 (exp(x / 550) -1)].

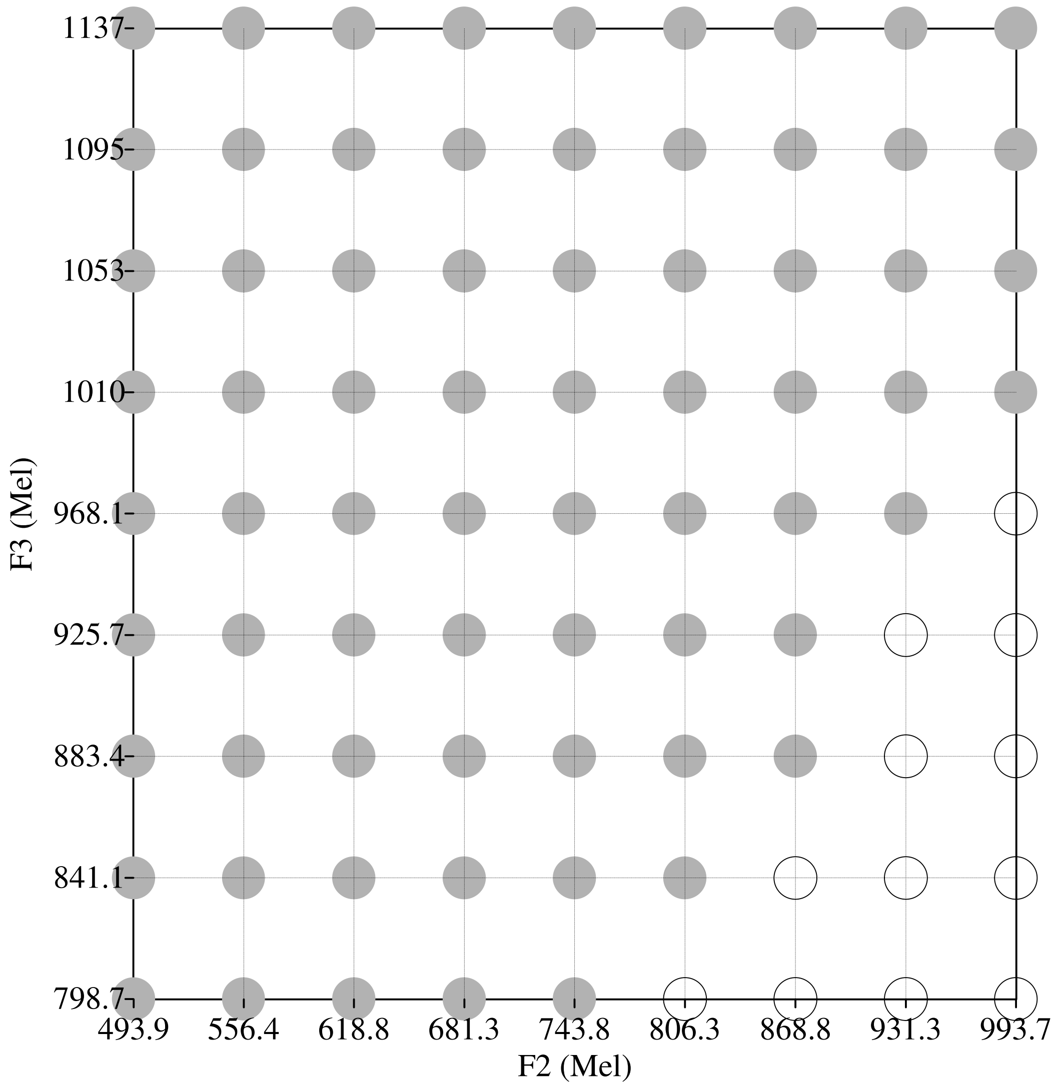

Fig. 2A: 69 tokens used in the perceptual experiment displayed in gray.
The white circles represent the tokens which were not generated.

2.1.3 Procedure

The synthesized 69 vowel tokens were integrated into a Praat (Boersma & Weenink, 2009) experiment and played randomly, in order to minimize effects of the order of the vowel tokens. Two blocks of 69 vowels were played. The interface of the experiment was completely in Modern Hebrew, allowing the participants to understand the instructions and the orthographies of the vowels they had to choose from. This was done in order to minimize exposure to unfamiliar orthographies which could affect the results of the tasks. Levy & Strange (2008) indicate that traditional identification tasks (as the one in this study), are questionable when the participants are unfamiliar with the orthography. In the perception experiment the participants had to perform two tasks after hearing each of the synthesized vowels; (1) a forced-choice identification task in which the participants had to choose between /i/ and /u/; (2) a goodness rating to determine the vowel's quality between 5 levels of quality, namely: Very Bad, Bad, Intermediate, Good and Very Good (Fig. 2B). As opposed to experiment methods used in previous studies, a simple categorization task was selected and not the AXB method in which participants are asked to compare the L2 sound to two L1 vowels. This was chosen in order to simulate a real situation in which a native MH speaker encounters a front rounded vowel, and in this case NSD /y/.

Prior to the experiment proper, a text containing a brief explanation and background about the experiment was given to the participants. In addition, they were introduced to the experiment by a trial experiment, familiarizing them with the tasks. The trial experiment contained 5 random synthesized vowels which were taken from the vowel tokens of the main experiment and was presented in the same manner the experiment itself was given. The experiment and the trial experiment were performed by the participant's one at a time in a quiet room and took place in May 2009, at the University of Tel-Aviv. The experiment was performed on an ASUS eee pc 900 laptop, with Sennheiser HD555 headphones.

Fig. 2B: The graphical interface of the perception experiment, with English translations added.

3. Results & Analysis

3.1 Results and General Impression

3.1.1 Perception of MH Listeners

Half of the results of 20 participants were processed due to similarity of the results between the two blocks of 69 vowels. Figure 3A presents the perception of the 69 vowel tokens by the participants. The percentage the perception of the 69 vowel tokens by the participants is displayed in a colored scale starting from 0% (dark blue) and ending in 100% (red). The perception of /u/ can be evaluated from it as well since it is based on the same variable, e.g. 0%-10% /i/ perception (dark blue) is 90%-100% /u/ perception.

The graph shows a division of the perception space into two areas; a part in which the /i/ is perceived and part in which the /u/ is perceived. Between those parts a small transition space is visible in which the participants' judgments were divided equally and in a gradual way until reaching the 100% average perception areas.

The area in blue represents the perception of the vowel tokens in the specific range as /u/ and the area in red represent the perception of the vowel tokens in the specific area as /i/. The main /u/ perception area is represented by dark blue which shows between 90% and 100% perception of /u/ by the participants and the main /i/ perception area is represented by Red which shows between 90% and 100% perception of /i/.

The transition area is represented by the rest of the colors. The sky blue and green areas represent 40% to 50% participants' perception of both /i/ and /u/. In this area, the participants' perception percentage seems to vary especially in the F3 dimension.

Two interdependent trends can be seen: (1) as F2 and F3 increase, the participants seems to perceive the vowel tokens more as /i/; (2) The largest changes seems to concentrate in the transition area and along the F3 dimension. Without looking at any statistic tests yet, the F2 dimension seems to have a strong influence on the perception of the vowel as /i/, while the F3 dimension seems to have a smaller effect generally but stronger along the transition area.

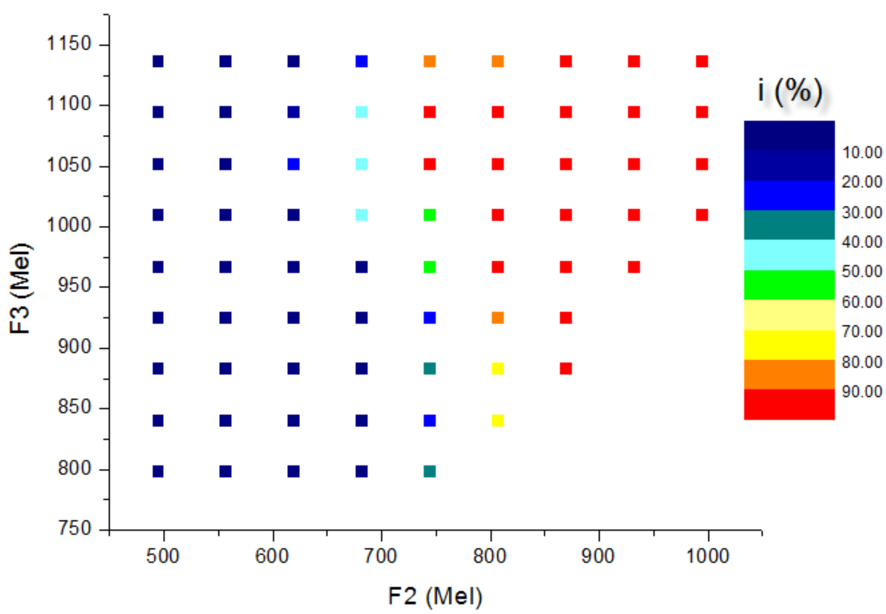

Fig. 3A: Perception results diagram

3.1.2 Vowel Goodness Rating

The vowel goodness ratings obtained in the perception experiment were gathered for every point in the F2-F3 range, separated into the /u/ and /i/ identification results and averaged.

Figures 3B and 3C show the goodness rating of the vowel tokens identified as /u/ and /i/ by the MH speakers. Generally looking at the averages of the goodness rating both by color in the graphs or by figures in appendix 6.2, the highest average figures are around 4 (4 for the /u/, 4.35 for the /i/), which is a 'Good' vowel rating. The size of the circles represents the number of participants who rated the tokens' goodness and displays the goodness ratings of the majority very clearly.

The areas in which the /u/ is considered 'Good' are around the average production area of the MH /u/, i.e. 562.34 Mel/ 979 Hz (SD 91) and 932.12 Mel/ 2445 Hz (SD 151) F3 (see table 1). In these areas the goodness rating seems to slightly decrease as the F3 increases. Beyond the MH /u/ production range, the goodness ratings keep decreasing as the F2 and F3 increases, creating a trend similar to the identification results. The goodness rating of the /u/-identified vowels seems to decrease more when reaching the NSD /y/ production range between 724.69 - 809.40 Mel (1504 - 1846 Hz) F2 and 858.13 - 903.0962 Mel (2068 - 2291 Hz) F3 (Weenink, 1985), and range between 2 to 3, i.e. between Bad and Intermediate. According to the same pattern, the ratings decrease as the F2 and the F3 increase, although in the range of 493.86 - 569.85 Mel (800 - 1000 Hz) F2 the F3 seems to influence the rating less than in other F2 areas.

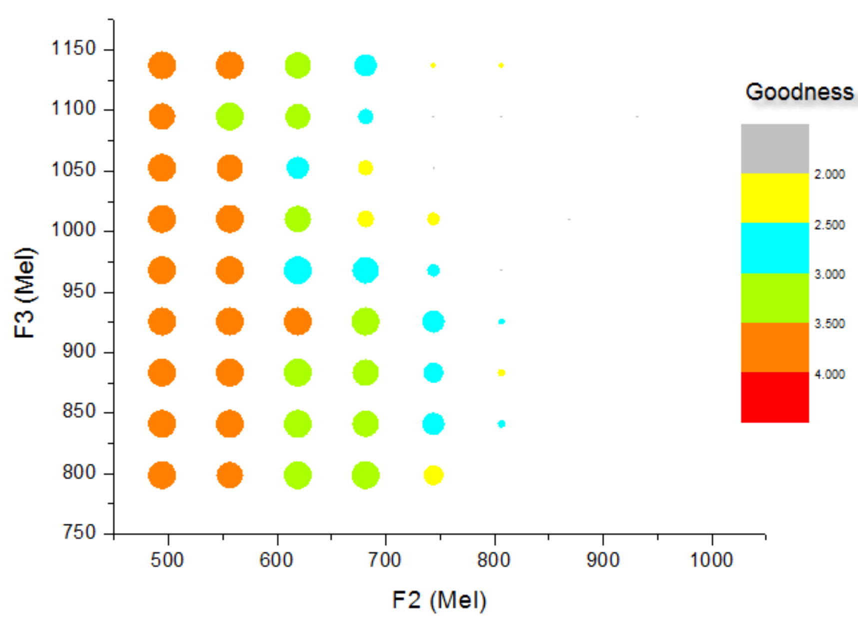

Fig. 3B: Goodness rating of /u/ identified vowel tokens

Looking at the goodness rating of the /i/ identified vowels in figure 3C the highest goodness ratings are concentrated around the average area of the MH /i/ production i.e. 858.13 Mel/ 2068 Hz (SD 142) F2 and 953.20 Mel/ 2562 Hz (SD 172) F3 (see table 1). In an opposite pattern from the /u/ goodness rating case, the /i/ goodness rating is getting lower as long as the F2 and the F3 decrease. In the NSD /y/ vowel production range, the /i/ goodness ratings are even lower and range from 2 to 3, and therefore very much like the /u/ goodness ratings in this range.

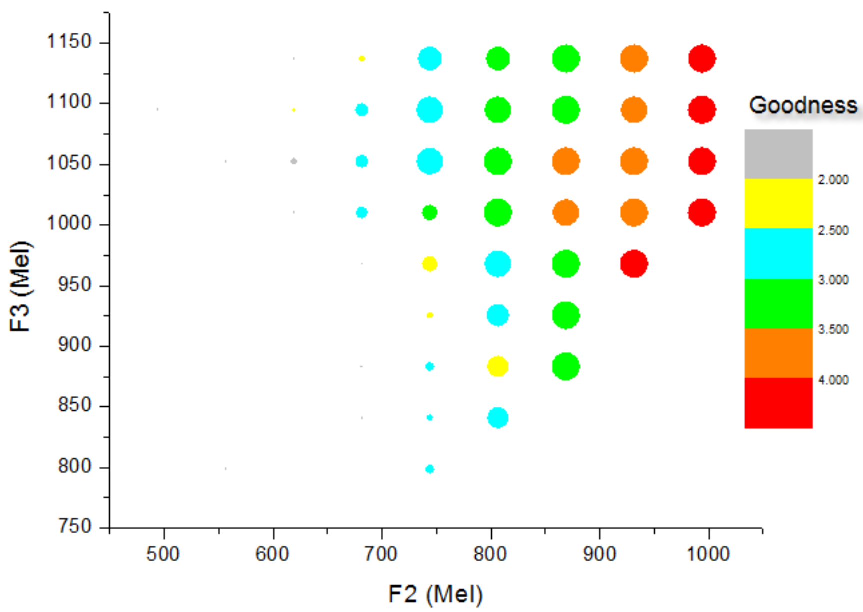

Fig. 3C: Goodness rating of /i/ identified vowel tokens

3.2 Statistical Analysis

The results shown so far can show a general picture on the participants' perception of the high-vowel continuum. The statistical significance of the results and the relationship between the F2 and the F3 cannot be determined without a suitable statistical test.

3.2.1 Introduction to the Statistical Tests

Binary logistic regression was chosen for the analysis of this study.
Such a statistical test allows us to find the probability of a certain outcome while simultaneously looking at a number of potential predictors. Logistic regression is an efficient way to find the relationship between the dependant variable (e.g. perception of listeners) and the independent variables (e.g. formants) which are also known as predictors or risk factors. One of the reasons for using a logistic regression and not a linear one is because the linear regression model has the assumption that the dependent variable is measured on an interval scale. The dependent variable selected was the participants' answer of perceiving /i/ or /u/. The answers have been converted to 0's and 1's (0's for /i/ and 1's for /u/). The predictors selected were the F2 and F3. In order to check the influence of F3 in its own model, the logistic regression was executed again with only F2 as a predictor variable.
The outcome of a logistic regression generates the following estimated log odds equation:
$[\ln ((P_i)/(1-P_i)) = \beta_0 + \beta_1 * X_1 + \beta_2 * X_2]$

P_i represents one value of the dependant variable.
$(1-P_i)$ represents the second value of the dependant variable.
X_1 and X_2 represent the independent variables, in this study F2 and F3.
β_0 (also known as 'intercept') represents the log odds when the values of the independent variables are zero
β_1 (also known as regression coefficient) represents the logs odds change as a result of a single unit change in X_1

β_2 (also known as regression coefficient) represents the logs odds change as a result of a single unit change in X_2

In the case of this study the equation will be: [ln (P(i)/P(u)) ≈ -31.175846 + 0.029716 * F2 + 0.009565 * F3]

The log odds are simply the log for the following odds formula:

Odds = $e^{(\beta_0 + \beta_1 * X_1 + \beta_2 * x_2)}$

The odds are the chances to perceive /i/ divided by the chances to perceive /u/.

The beta's which are also referred to as the regression coefficients of the predictors are estimated through an iterative maximum likelihood method. A positive coefficient means that the independent variable increases the odds for the outcome; a negative coefficient means that the independent variable decreases the odds of the outcome. By assigning the variables in the equation we will get the log odds of getting one possibility of the dependent variable or the other.

Example:

F2 = 600 Mel, F3 =1000 Mel.

[ln (P(i)/P(u)) ≈ -31.175846 + 0.029716 * 600 + 0.009565 * 1000] =>

To simplify, each of the equation sides is as a power of e (this will remove the ln):

P(i)/P(u) = e^((-31.175846) + (0.029716 * 600) + (0.009565 * 1000)) = 0.0227942721 =>

[P(i)/P(u) = 0.02279427]

This means that the chance to perceive /u/ is now bigger.

In order to see the difference in the influence of the two variables on the odds, we can increase both variables by the same amount, for example by 25 Mel.

The following formula is used:

[ΔOdds = $e^{(\beta 0)} * e^{(\Delta F2 * \beta 1)} * e^{(\Delta F3 * \beta 1)}$]

So, the change in F2 alone is by a factor of:

[$e^{(25 * \beta 1)}$ = 2.10202255]

Now if we would like to see the probability that a participant will perceive /i/, the following equation should be used:

[$P(Y_i = 1)$ = odds (Y_i) / (1+ odds(Y_i))]

Example: [P(i) = 0.02279427 / (1 + 0.02279427) = 2%]

The logistic regression predicts the probability that a participant, who listens to a sound which is defined by Xi, will say the sound is /i/; This probability equals $P(Y_i=1)$.
Yi is the dependent variable which gets a 0 value when the answer is /u/ and 1 when the answer is /i/.

The logistic regression was done with SPSS and Praat[2].
The SPSS logistic regression model generates the equation parameters (the coefficients) and provides significance tests results for the model including the predictors; for the model without the predictors, and for each of the coefficients. The chi-square test results show a difference between the model with the independent variables and without (tables 6F and 6P in the appendix). Sig. Wald shows the significance of the predictors' coefficients β values (tables 6I and 6S in the appendix). Wald is done separately on each independent variable and checks if their influence on the dependent variable is significant (Draper and Smith, 1981; Foster, Stine and Waterman, 1988; Tabachnick and Fidel, 2001).

3.2.2 Results of the Statistical Analysis - General Perception

The results of the logistic regression answer two matters:
(1)The division of the high-vowel space of MH; (2) the influence of F2 and F3 on the perception of the MH listeners.

Figures 3D shows a graph which was drawn according to the results of the logistic regression and shows a division of MH space into the two categories with a border-line/transition area between them. This could already be seen in figure 3A but confirmed with the results of the logistic regression. The two categories seem to occupy the space equally. A line that separates the /i/ and the /u/ space runs from 681.31 Mel (1348.20 Hz) on the upper point to 806.28 Mel (1832.44 Hz) on the lower point. This answers the first research question and supports the analysis that the two occupy the space approximately equally.

[2] Both SPSS and Praat were used due to the different outputs they generate for the logistic regression. Praat generates the odds equation as shown in this paper, but do not generate significance tests results. SPSS generates chi-square and Wald significance tests.

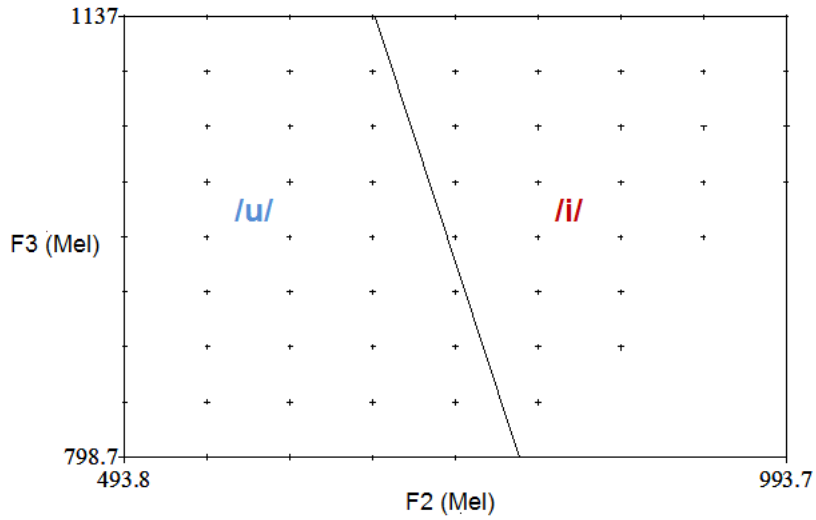

Figure 3D /i/-/u/ division drawn according to the logistic regression analysis

As seen in the last section, the constant coefficient (β_0) is -31.175846. The fact that it is a negative number means that if the independent variables will be zero then the perception of the vowel would be /u/. The coefficients of the F2 and F3 are 0.029716 and 0.009565 respectively. These show that the influence of F2 on the odds is larger than the influence of the F3 per Mel. Finding out by how much the chances for F2 or F3 will increase when the value of the formant is increased shows that every increase of F2 by 25 Mel the odds for /i/ increases by a factor of 2.102 and for every increase of F3 by 25 Mel, the odds of /i/ increase by a factor of 1.270. We can clearly see that F2 has a more dominant effect on the odds, and in fact it is larger by a factor of 1.655 to an increase in the same size of the variable F3. This of course is the factor only when the increase is by 25 Mel. In general it can be said that the increase in odds for a certain change in F2 is the third power of the increase in odds for the same change in F3. In that case, the increase in odds is independent of the difference in Mel and corresponds to the difference between the coefficients. These show that the F2 influence on the perception is the largest and the main one from the two independent variables. As shown by the SPSS results, the logistic regression model is found to be significantly different with the F2 and F3 independent variables than without them ($\chi^2 =$ 1312.064; df = 2, p< 0.001). F2 and F3 coefficients are found significant: (Wald = 267.332; df = 1, p<0.001) for the F2 coefficient and (Wald = 71.149; df = 1, p<0.001) for the F3 coefficient. In order to see if the F3 in the model F2-F3 is significant by itself, an additional logistic regression was done on the same data, only this time setting the F2 as the independent variable and keeping the participants' perception as dependent variable. The chi-square score of the F2 model (1224.880) was deducted from the chi-square score of the F2-F3 model (1312.064). The F3 part in the F2-F3 model was found significant with ($\chi^2 = 87.184$; df = 1, p<0.001).

Assigning F2 and F3 values in the logistic regression equation and converting the odds into probabilities as explained in the previous section can show the different probabilities of perceiving /i/ across the MH high-vowel space. Taking the average /u/, the /i/ of MH and a point in the transition area and checking probabilities of perceiving an /i/, confirms the results discussed in section 3.1. 4% probability of perceiving an /i/ i.e. 96% probability of perceiving an /u/ is found for the average /u/ values (F2: 562.34 Mel/ 979 Hz, F3: 858.13 Mel/ 2445 Hz). 97% probability of perceiving /i/ is found for the average /i/ values (F2: 858.13/2068 Hz, F3: 953.2 Mel/ 2562 Hz). When checking the probabilities for a point in the transition area (F2:760 Mel/1649 Hz, F3: 900 Mel/ 2275 Hz), 50% probability for perceiving /i/ is given. The results so far show that F2 is the main cue in the high-vowel space of MH and that F3 is a secondary cue in the high-vowel space of MH. Probabilities show that there are two main areas in the MH vowel-space in which the /i/ and /u/ are clearly perceived, and one small transition area.

What is going on in that transition area and especially in the NSD /y/ range? How the F3 is behaving there? These questions are addressed in the next section.

3.2.3 Illustration of the Results for the NSD /y/ range

Now that the general perception of the high-vowel space by MH speakers has been described and the influence of the F2 and F3 on the perception is clear, the third research question still needs to be examined. Can it be determined that the F3 is a secondary cue, helping the MH listener to perceive the /y/ more as a /u/ when a sound is ambiguous?

In this section, the results of the logistic regression will be examined for the /y/ range area and the role of the secondary F3 cue will be checked.

According to Weenink (1985), the male NSD /y/ vowel production ranges and means are: 724.69-809.40 Mel (1504 - 1846 Hz), mean 767.86 Mel (1671.7 Hz) for the F2 dimension. 858.13-903.09 Mel (2068 - 2291 Hz), mean 877.43 Mel (2161.5 Hz) for the F3 dimension. Figure 3E displays the production range of NSD /y/ in the high-vowel space of MH.

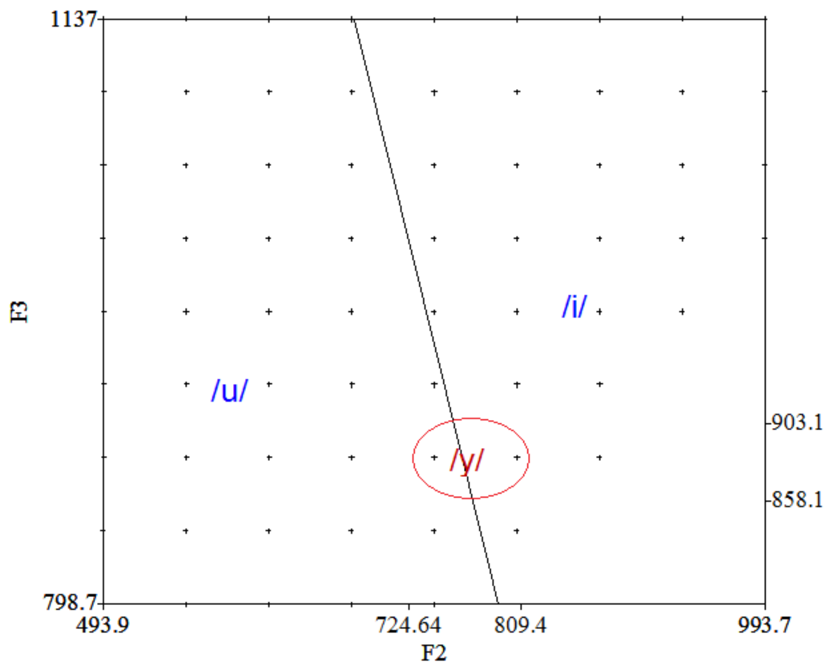

Fig.3E: Production range of NSD /y/ in the high-vowel space of MH.

When looking at the /y/ range on figure 3A, 50% to 60% participants' perception of /u/ and 70% to 80% participants' perception of /i/ is seen (separately for every token in the /y/ range). This range is part of the transition area between the /i/ and /u/ perception of the participants in which the F3 seems to have considerable influence.

Figure 3F shows the /y/ production range, which resembles a rectangle. The border line seen in figure 3D, is crossing right in the middle of this /y/ production range. The probabilities from the logistic regression results illustrate the perception in the /y/ range. The lower left point of the rectangle has a P(i) = 19%, and therefore a P (u) of 81%. The upper left point of the rectangle has a P (i) of 27% i.e. P (u) of 73%. The lower right point has a P (i) of around 75% and the upper right point of the rectangle has a P (i) of 82% i.e. P (u) of 18%. These show the following: (1) an 8% probability change across the vertical view on the left side of the rectangle and 7% probability change across the vertical view on the right side of it; (2) 55% change when moving along the upper horizontal view of the rectangle and 56% when moving along the lower horizontal view of the rectangle.

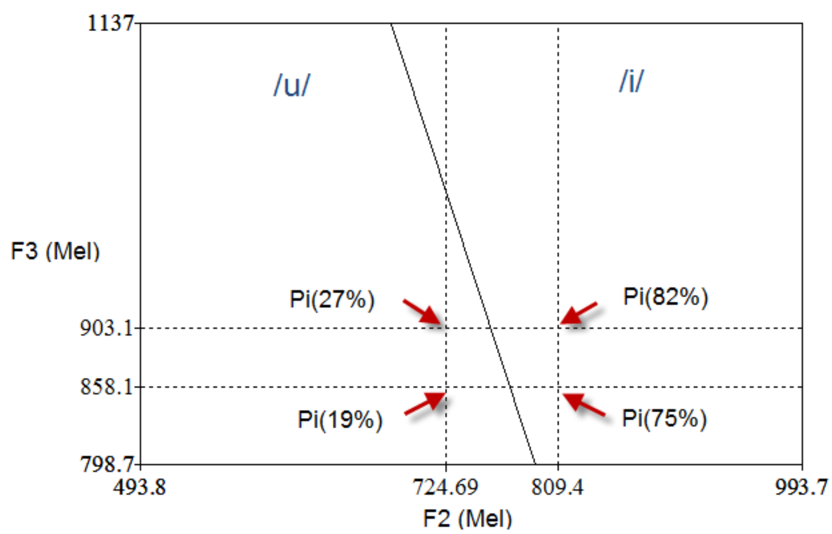

Figure 3F: Logistic regression perception border lines in the NSD /y/ range

Taking the average value of the F2 of the NSD /y/ in reference to rectangle points as seen in figure 3G, shows 11% change in the /i/ perception probability along the vertical view. The range runs from 46% of perceiving /i/ to 57% of perceiving /i/. This shows that the F3 can influence the majority perception from /i/ to /u/ and vice versa. However these are fuzzy perception areas and the difference between 46% and 57% is not that large. Even though the 50% is crossed, it is still not a clear perception of /u/ or /i/. Therefore it seems that the third research question cannot be fully answered. Although the influence of the F3 is seen in the /y/ range, it cannot be clearly established if the F3 takes over when MH listeners encounter an ambiguous sound.

A look into the average values of NSD /y/ reveals that the P(i) at that point is 51% which means that at that point the majority of MH listeners perceive /i/. This result is different from what is found in Ben-Arieh (2008), who reports the majority of MH listeners perceive the NSD

/y/ as /u/. However, the stimuli used there were natural and only in the /y/ production range as opposed to the stimuli used in this study. This could probably affect the results.

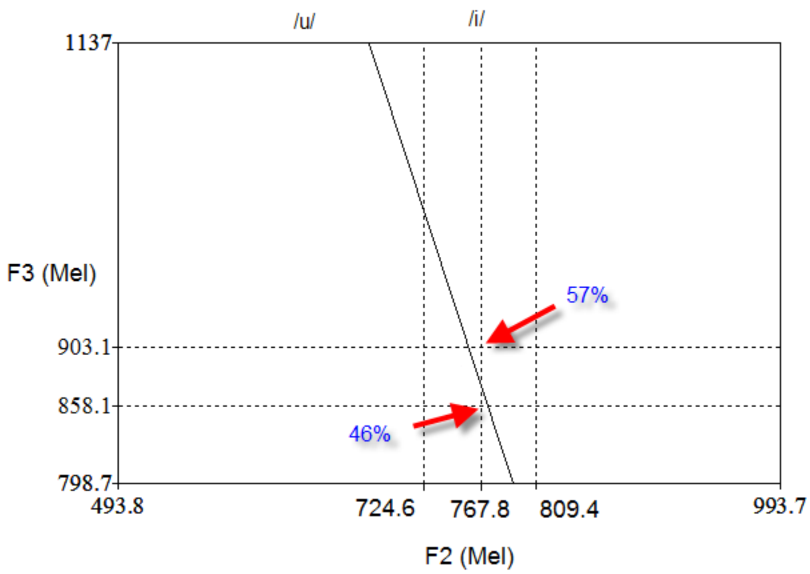

Figure 3G: F3 perception probability change across the NSD /y/ average F2

4. Discussion

The results of this study shed some light on internal perception issues in MH and cross -linguistic perception. Three research questions were raised.

To find the reason of the specific perception of a foreign sound as mentioned before and in Rochet (1995), the key would be to find out what determines and quantifies the way listeners of L2 categorize the high-vowel space in their L1 and then correlating the results with the characteristic of the target L2 (Rochet, 1995). Therefore the first research question was: how is the perceptual space of the MH speakers divided in the F2-F3 space?

For this purpose the ranges of F2 and F3 were selected. F1 was set to a fixed value due to the similarity of the F1 frequencies on the high-vowel continuum between MH and Dutch.

The stimuli in the identification task were generated on the basis of the F2 and F3 ranges in NSD and MH. The results reveal a picture of the high vowel-space of MH. The space seemed to be divided into the two existing vowel categories in the high-vowel space of MH[3] (fig. 3A & 3D). This space as seen in the results is divided approximately equally between the /i/ and the /u/ categories. Between these categories, a transition area is seen and in this area the participants' perception varied. I argue that the results rule out an influence of category size on the perception of the high-vowel space of MH. The stimuli played to the participants in the perception experiment contained both vowel tokens in the range area of MH /i/ and /u/ and ones which are not; the vowel tokens which were not in the range areas were assimilated into the closest category in MH. I claim that these sounds are treated as L2 sounds according Flege's SLM model in which non-native sounds that are phonetically similar to native sounds will be assimilated into the closest native category (Flege,1995, 1988).

As for the goodness rating of the vowel tokens heard by the MH listeners, they seemed to correspond to the production ranges of /i/ and /u/, hence in these ranges the goodness rating is the highest rated in the experiment. In the NSD /y/ production range, the goodness ratings were much lower and ranged between 2 and 3 for both the /u/-identified vowels and the /i/-identified vowels. Considering the fact that the /y/ is approximately in the middle of the MH perceptual space, the goodness ratings are not surprising. Best (1995) reports that non-native vowel which were assimilated into a native vowel category were rated as more or less 'Good' vowels; the rating in this study shows a different pattern: the goodness of the vowel tokens in the NSD /y/ range were rated as 'Bad' and 'intermediate'. Since the /y/ is in the middle of the high-vowel space of MH it might be a good idea to check if /y/ could be considered by MH listeners as a 'new' category. Planning an experiment in which the participants are asked to identify uncommitted[4] space could shed light in this matter.

The results and arguments answers the first research question and supports the hypothesis that the space is divided into the two MH high vowel categories and the two vowels occupy approximately the same space. The finding suggests that every non-native vowel which is

[3] This is of course according to the options given to the participants in the perception experiment.

[4] Uncommitted space meaning the vowel tokens in that space cannot be committed to an existing category in the native language of the listeners.

acoustically somewhere between the /i/ and the /u/ will be perceived by MH listeners with some difficulties. As Flege (1987, 1988 and 1995) claims a non-native vowel with spectral properties similar to those of the L1 will be categorized into the closest category. Now that the mapping of the high-vowel space of MH is clear, can the influence of the spectral cues explain it? This leads us to the rest of the research questions.

The second research question was: how are the F2 and F3 acoustic cues influencing the perception of the high vowel space of MH listeners?

According to the results of the logistic regression, the F2 has the largest influence on the MH listener response; although F3 has less influence, it is an important cue in the perception of the high-vowel space. An examination of the difference in the odds increase showed that the increase in odds for a certain change in F2 is the third power of the increase in odds for the same change in F3. Cases in which a specific spectral cue is found and considered to be a main cue for a certain perception were reported before. Hattori and Iverson (2009) reported that the main cue for predicting Japanese identification of liquids as /r/ or /l/ is F3. These findings answer the second research question regarding the cues that influence the perception of MH listeners in the high vowel space, and support the hypotheses that F2 has the main influence and F3 has a secondary influence.

These findings lead to last research question. Now when we know the F3 is a cue which has a secondary influence on the perception of the MH listener, can it be determined that the F3 is a secondary cue, helping the MH listener to perceive the /y/ more as a /u/ when a sound is ambiguous?

Since the influence of the F3 is much smaller but still considerable and significant, the F3 seems to have a secondary affect on the perception. According to the results the border-line between the /i/ and the /u/ categories, crosses in the middle of the /y/ range (which is in the transition area). In this area, the perception of /u/ and /i/ seem to be equal. Looking at the average F2 of NSD /y/, an 11% change in the /i/ perception probability along the vertical view can be seen.

Along this line, the majority of the listener’s perception is varied from 46% to 57%. The F3 can influence the majority perception from /i/ to /u/ and vice versa. As much as it looks like a change, in these fuzzy transition areas these changes are not that large. Looking at the average point of NSD /y/ (F2 and F3), a 51% probability of perceiving /i/ is seen. In addition, this and the equal perception division in the NSD /y/ range, suggests that the MH listeners can perceive either /i/ or /u/, as opposed to what was found on Ben-Arieh (2008).There are two reason comes to mind, that could explain the difference in the results of this study and the one reported in Ben-Arieh (2008): (1) The stimuli used in the experiment were different. In this study, synthesized vowel tokens were played to the participants, while in Ben-Arieh (2008), natural stimuli were used. This could explain the results and perhaps indicate that some of the natural properties of a sound are not present in the synthesized ones, leading to a different perception by the listeners. Another reason for that could be the number of tokens put into the experiment. The experiment in this study consisted of 2 blocks of 69 vowels, while the experiment in Ben-Arieh (2008) consisted of 36 and 40 (two tasks). The number of tokens and time taken to perform the experiment could have affected the results.

As for hierarchy and ranking that was suggested in this study, the answer to the second research question showed that the F3 has a secondary influence, but due to these findings and insufficient evidence of F3 influencing perception in a specific range when the sounds are ambiguous, the third hypothesis can be only partially supported. After this will be found out, it would be interesting to check what cues are influencing the perception in different languages such as Brazilian Portuguese in which the listeners perceived the French /y/ as their own /i/; do different cues influence the perception of the Brazilian Portuguese listeners.

It seems that although some of the reasons for cross-linguistic perception are being studied and found, there is still a lot more to investigate and discover, generally and specifically for MH.

5. Summary

The aim of this study was to continue and investigate the cross-linguistic perception of the NSD vowel /y/ by MH listeners. The beginning of the investigation was reported in Ben-Arieh (2008) and according to the results of that study, the majority of the MH participants perceived the NSD /y/ vowel as their own /u/, rather than /i/.

In the current study, the reasons for that specific perception have been investigated.
A perception experiment was executed in order to find the influencing cues for the MH perception. A group of 20 MH listeners have listened to 69 synthesized vowels which were

generated in a relevant matrix of F2 and F3 of both MH and NSD. The listeners both identified the vowel they heard as /u/ or /i/ and rated the goodness of the vowel.

Results show that the high-vowel space of MH is divided into the /i/ and /u/ categories approximately equally. In each category area the perception was high for /i/ and /u/ respectively. Between the two categories, a small transition area was shown.

Statistical analysis show that the influencing cues in the MH high vowel space are both the second and third formants, and that the increase in odds for a certain change in F2 is the third power of the increase in odds for the same change in F3, i.e. the F2 is apparently the main cue for the perception and the F3 seems to be a secondary cue.

In the NSD /y/ production range, a minor influence on the perception of /i/ or /u/ was seen on the average point. However this influence changes the majority of /i/ perception from 46% to 57%, averages which does not show clear perception of /i/ or /u/.

According to findings reported in this study, the high-vowel space of the MH was examined for the first time by a perception experiment and the category dispersion across the space was revealed. It is argued that the F2 and the F3 are the influencing cues to the perception of the MH listeners and that the F3 plays a role of a secondary cue.

The question of whether the F3 plays a role in taking over when a sound is ambiguous was not answered fully and should be further investigated. The division of the high-vowel space of MH and the perception in the average point of the NSD /y/ showed different results from what was reported in Ben-Arieh (2008).

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6. Appendix

6.1 Praat vowel synthesis script

Fig. 1.

```
# Generate synthetic vowels with duration, F1, F2 and F3 steps possibilities
# Stores resulting sounds in specified directory

form Generate vowels (cascade mode) with duration, F2 and F3 steps
    positive Initial_F0_(Hz) 150
    positive Final_F0_(Hz) 100
    sentence Directory_to_write_to D:\Studies\Thesis\Experiment\Test
    positive Minimum_duration_(ms) 200
    positive Maximum_duration_(ms) 250
    positive Number_of_duration_values 1
    positive Minimum_F1_(Hz) 350
    positive Maximum_F1_(Hz) 350
    positive Number_of_F1_values 1
    positive Minimum_F2_(Hz) 800
    positive Maximum_F2_(Hz) 2800
    positive Number_of_F2_values 9
    positive Minimum_F3_(Hz) 1800
    positive Maximum_F3_(Hz) 3800
    positive Number_of_F3_values 9
endform


# calculate duration steps
if number_of_duration_values > 1
   logrange = log10(maximum_duration / minimum_duration)
   logstep = logrange / (number_of_duration_values - 1)
   for i to number_of_duration_values
        d'i' = minimum_duration * 10^((i-1)*logstep)
   endfor
else
   d1 = minimum_duration
endif

# calculate F1 values
if number_of_F1_values > 1
    maxmel = hertzToMel(maximum_F1)
```

```
    minmel = hertzToMel(minimum_F1)
printline 'maxmel'
printline 'minmel'
    melrange = maxmel - minmel
    melstep = melrange / (number_of_F1_values - 1)
    for i to number_of_F1_values
        melvalue = minmel + (i-1) * melstep
        first'i' = melToHertz(melvalue)
    endfor
else
    first1 = minimum_F1
endif


# calculate F2 values
if number_of_F2_values > 1
    maxmel = hertzToMel(maximum_F2)
    minmel = hertzToMel(minimum_F2)
    melrange = maxmel - minmel
    melstep = melrange / (number_of_F2_values - 1)
    for i to number_of_F2_values
        melvalue = minmel + (i-1) * melstep
        second'i' = melToHertz(melvalue)
    endfor
else
    second1 = minimum_F2
endif

# calculate F3 values
if number_of_F3_values > 1
    maxmel = hertzToMel(maximum_F3)
    minmel = hertzToMel(minimum_F3)
    melrange = maxmel - minmel
    melstep = melrange / (number_of_F3_values - 1)
    for i to number_of_F3_values
        melvalue = minmel + (i-1) * melstep
        third'i' = melToHertz(melvalue)
    endfor
else
    third1 = minimum_F3
endif

# initialize duration and formants table
numsounds = number_of_duration_values * number_of_F1_values * number_of_F2_values * 
number_of_F3_values
Create TableOfReal... params numsounds 5
Set column label (index)... 1 rep
Set column label (index)... 2 f1
Set column label (index)... 3 f2
Set column label (index)... 4 f3
Set column label (index)... 5 dur

# generate sounds & update table
row = 0
```

```
Erase all
Select outer viewport... 0 6 0 6
Axes... hertzToMel(minimum_F2) hertzToMel(maximum_F2) hertzToMel(minimum_F3)
hertzToMel(maximum_F3)
Draw inner box


for d to number_of_duration_values
    dur = d'd'/1000
    for third to number_of_F3_values
        f3 = third'third'
        for second to number_of_F2_values
            f2 = second'second'
            for first to number_of_F1_values
                rep = 0
                f1 = first'first'
                if (f1 >= f2 - 100) or (f2 >= f3)
                    rep = 1
                endif
                select TableOfReal params
                row += 1
                Set row label (index)... 'row' 'first'_'second'_'third'_'d'
                Set value... row 2 f1
                Set value... row 3 f2
                Set value... row 4 f3
                Set value... row 5 dur

                if rep = 1
                   Set value... row 1 rep
                   Draw circle... hertzToMel(f2) hertzToMel(f3) 12
                endif
                call generate
                if rep = 0
                    Write to WAV file... 'directory_to_write_to$'\'first'_'second'_'third'_'d'.wav
                    Paint circle... 0.7 hertzToMel(f2) hertzToMel(f3) 12
                endif
                !Remove
            endfor
        endfor
    endfor
endfor
Marks left... 9 yes yes yes
Marks bottom... 9 yes yes yes
Text left... yes F3 (Mel)
Text bottom... yes F2 (Mel)


select TableOfReal params
!to binary file... 'directory_to_write_to$'\vowelparams.TableOfReal
!Write to headerless spreadsheet file... 'directory_to_write_to$'\vowelparams.txt



procedure generate
```

```
# Create voice source signal

# Creating the source signal
# name is 'sound', 200 ml duration, 10 formants

Create KlattGrid... sound 0 dur 10 1 1 6 1 1 1
Add pitch point... 0 initial_F0
Add pitch point... dur final_F0
Add voicing amplitude point... 0 0
Add voicing amplitude point... 0.005 90
Add breathiness amplitude point... 0.1 30
Add aspiration amplitude point... 0.1 0


# Define values of some extra formants to get a flatter spectrum.
f4 = max (3500, f3 + 400)
f5 = max (4000, f4 + 600)
f6 = f5 + 1000
f7 = f6 + 1000
f8 = f7 + 1000
f9 = f8 + 1000
f10 = f9 + 1000

#for-loop be used for multiple formants
for i to 10
Add oral formant frequency point... 'i' 0.1 f'i'
Add oral formant bandwidth point... 'i' 0.1 f'i'/10
endfor

To Sound

#Cleaning the object list
select KlattGrid sound
Remove

select Sound sound
Scale... 0.99

endproc
```

6.2 Results table processed by Praat script

Stimulus	F2	F3	U	i	u_goodness	i_goodness	u_goodness_average	i_goodness_average
1_1_1_1.wav	493.8679	798.7388	20	0	78	0	3.9	NA
1_1_2_1.wav	493.8679	841.0723	20	0	80	0	4	NA
1_1_3_1.wav	493.8679	883.4059	20	0	79	0	3.95	NA
1_1_4_1.wav	493.8679	925.7394	20	0	80	0	4	NA
1_1_5_1.wav	493.8679	968.0729	20	0	77	0	3.85	NA
1_1_6_1.wav	493.8679	1010.406	20	0	79	0	3.95	NA

1_1_7_1.wav	493.8679	1052.74	20	0	78	0	3.9	NA	
1_1_8_1.wav	493.8679	1095.074	19	1	75	4	3.947368		4
1_1_9_1.wav	493.8679	1137.407	20	0	79	0	3.95	NA	
1_2_1_1.wav	556.3517	798.7388	19	1	69	3	3.631579		3
1_2_2_1.wav	556.3517	841.0723	20	0	79	0	3.95	NA	
1_2_3_1.wav	556.3517	883.4059	20	0	76	0	3.8	NA	
1_2_4_1.wav	556.3517	925.7394	20	0	75	0	3.75	NA	
1_2_5_1.wav	556.3517	968.0729	20	0	75	0	3.75	NA	
1_2_6_1.wav	556.3517	1010.406	20	0	72	0	3.6	NA	
1_2_7_1.wav	556.3517	1052.74	19	1	68	2	3.578947		2
1_2_8_1.wav	556.3517	1095.074	20	0	69	0	3.45	NA	
1_2_9_1.wav	556.3517	1137.407	20	0	75	0	3.75	NA	
1_3_1_1.wav	618.8355	798.7388	20	0	69	0	3.45	NA	
1_3_2_1.wav	618.8355	841.0723	20	0	67	0	3.35	NA	
1_3_3_1.wav	618.8355	883.4059	20	0	65	0	3.25	NA	
1_3_4_1.wav	618.8355	925.7394	20	0	74	0	3.7	NA	
1_3_5_1.wav	618.8355	968.0729	20	0	58	0	2.9	NA	
1_3_6_1.wav	618.8355	1010.406	19	1	59	3	3.105263		3
1_3_7_1.wav	618.8355	1052.74	16	4	42	7	2.625		1.75
1_3_8_1.wav	618.8355	1095.074	18	2	55	4	3.055556		2
1_3_9_1.wav	618.8355	1137.407	19	1	61	3	3.210526		3
1_4_1_1.wav	681.3194	798.7388	20	0	65	0	3.25	NA	
1_4_2_1.wav	681.3194	841.0723	19	1	61	2	3.210526		2
1_4_3_1.wav	681.3194	883.4059	19	1	59	2	3.105263		2
1_4_4_1.wav	681.3194	925.7394	20	0	68	0	3.4	NA	
1_4_5_1.wav	681.3194	968.0729	19	1	54	4	2.842105		4
1_4_6_1.wav	681.3194	1010.406	12	8	29	22	2.416667		2.75
1_4_7_1.wav	681.3194	1052.74	11	9	22	26	2		2.888888889
1_4_8_1.wav	681.3194	1095.074	11	9	29	25	2.636364		2.777777778
1_4_9_1.wav	681.3194	1137.407	16	4	46	8	2.875		2
1_5_1_1.wav	743.8032	798.7388	14	6	28	15	2		2.5
1_5_2_1.wav	743.8032	841.0723	16	4	41	10	2.5625		2.5
1_5_3_1.wav	743.8032	883.4059	14	6	40	15	2.857143		2.5
1_5_4_1.wav	743.8032	925.7394	16	4	43	8	2.6875		2
1_5_5_1.wav	743.8032	968.0729	9	11	23	27	2.555556		2.454545455
1_5_6_1.wav	743.8032	1010.406	9	11	21	33	2.333333		3
1_5_7_1.wav	743.8032	1052.74	1	19	3	53	3		2.789473684
1_5_8_1.wav	743.8032	1095.074	1	19	2	49	2		2.578947368
1_5_9_1.wav	743.8032	1137.407	3	17	6	46	2		2.705882353
1_6_2_1.wav	806.287	841.0723	5	15	13	41	2.6		2.733333333
1_6_3_1.wav	806.287	883.4059	5	15	12	33	2.4		2.2
1_6_4_1.wav	806.287	925.7394	4	16	10	43	2.5		2.6875
1_6_5_1.wav	806.287	968.0729	1	19	1	54	1		2.842105263

1_6_6_1.wav	806.287	1010.406	0	20	0	61	NA		3.05
1_6_7_1.wav	806.287	1052.74	0	20	0	66	NA		3.3
1_6_8_1.wav	806.287	1095.074	1	19	2	61		2	3.210526316
1_6_9_1.wav	806.287	1137.407	3	17	6	54		2	3.176470588
1_7_3_1.wav	868.7709	883.4059	0	20	0	68	NA		3.4
1_7_4_1.wav	868.7709	925.7394	0	20	0	68	NA		3.4
1_7_5_1.wav	868.7709	968.0729	0	20	0	67	NA		3.35
1_7_6_1.wav	868.7709	1010.406	1	19	4	67		4	3.526315789
1_7_7_1.wav	868.7709	1052.74	0	20	0	75	NA		3.75
1_7_8_1.wav	868.7709	1095.074	0	20	0	66	NA		3.3
1_7_9_1.wav	868.7709	1137.407	0	20	0	67	NA		3.35
1_8_5_1.wav	931.2547	968.0729	0	20	0	82	NA		4.1
1_8_6_1.wav	931.2547	1010.406	0	20	0	79	NA		3.95
1_8_7_1.wav	931.2547	1052.74	0	20	0	79	NA		3.95
1_8_8_1.wav	931.2547	1095.074	1	19	2	69		2	3.631578947
1_8_9_1.wav	931.2547	1137.407	0	20	0	72	NA		3.6
1_9_6_1.wav	993.7385	1010.406	0	20	0	87	NA		4.35
1_9_7_1.wav	993.7385	1052.74	0	20	0	86	NA		4.3
1_9_8_1.wav	993.7385	1095.074	0	20	0	86	NA		4.3
1_9_9_1.wav	993.7385	1137.407	0	20	0	82	NA		4.1

6.3 Logistic Regression results done in Praat

Object id: 15

Object type: LogisticRegression

Object name: Results_RatingAvgFinalTable

Date: Sat Jul 25 21:27:35 2009

Factors:

Number of factors: 2

Factor 1: F2

Factor 2: F3

Fitted coefficients:

Intercept: -31.17584627038073

Coefficient of factor F2: 0.02971567242841897

Coefficient of factor F3: 0.009565078518720689

Ranges of values:

Range of factor F2: minimum 493.8678762632772, maximum 993.7385406259275

Range of factor F3: minimum 798.7387809014285, maximum 1137.4070652209173

Dependent 1: u

Dependent 2: i

Interpretation:

$\ln (P(i)/P(u)) \approx -31.175846 + 0.029716 * F2 + 0.009565 * F3$

Log odds ratios:

Log odds ratio of factor F2: 14.853993

Log odds ratio of factor F3: 3.239389

Odds ratios:

Odds ratio of factor F2: 2824926.540259674

Odds ratio of factor F3: 25.518118552228007

6.4 Logistic regression results SPSS

6.4.1 F2-F3 Model

Logistic Regression

6A. Case Processing Summary

Unweighted Cases[a]		N	Percent
Selected Cases	Included in Analysis	1380	100.0
	Missing Cases	0	.0
	Total	1380	100.0
Unselected Cases		0	.0
Total		1380	100.0

a. If weight is in effect, see classification table for the total number of cases.

6B. Dependent Variable Encoding

Original Value	Internal Value
0	0
1	1

6C. Classification Table[a,b]

Observed			Predicted: i 0	Predicted: i 1	Percentage Correct
Step 0	i	0	780	0	100.0
		1	600	0	.0
	Overall Percentage				56.5

a. Constant is included in the model.

b. The cut value is .500

6D. Variables in the Equation

		B	S.E.	Wald	df	Sig.	Exp(B)
Step 0	Constant	-.262	.054	23.344	1	.000	.769

6E. Variables not in the Equation

			Score	df	Sig.
Step 0	Variables	F2	868.468	1	.000
		F3	153.575	1	.000
	Overall Statistics		893.834	2	.000

6F. Omnibus Tests of Model Coefficients

		Chi-square	df	Sig.
Step 1	Step	1312.064	2	.000
	Block	1312.064	2	.000
	Model	1312.064	2	.000

6G. Model Summary

Step	-2 Log likelihood	Cox & Snell R Square	Nagelkerke R Square
1	577.477[a]	.614	.823

a. Estimation terminated at iteration number 8 because parameter estimates changed by less than .001.

6H. Classification Table[a]

Observed			Predicted		
			i		Percentage Correct
			0	1	
Step 1	i	0	736	44	94.4
		1	64	536	89.3
	Overall Percentage				92.2

a. The cut value is .500

6I. Variables in the Equation

		B	S.E.	Wald	df	Sig.	Exp(B)
Step 1[a]	F2	.030	.002	267.332	1	.000	1.030
	F3	.010	.001	71.149	1	.000	1.010
	Constant	-31.176	2.037	234.198	1	.000	.000

a. Variable(s) entered on step 1: F2, F3.

6J. Variables in the Equation

		95% C.I.for EXP(B)	
		Lower	Upper
Step 1[a]	F2	1.026	1.034
	F3	1.007	1.012
	Constant		

a. Variable(s) entered on step 1: F2, F3.

6.4.2 F2 Model

Logistic Regression

6K. Case Processing Summary

Unweighted Cases[a]		N	Percent
Selected Cases	Included in Analysis	1380	100.0
	Missing Cases	0	.0
	Total	1380	100.0
Unselected Cases		0	.0
Total		1380	100.0

a. If weight is in effect, see classification table for the total number of cases.

6L. Dependent Variable Encoding

Original Value	Internal Value
0	0
1	1

6M. Classification Table[a,b]

Observed			Predicted		
			i		Percentage Correct
			0	1	
Step 0	i	0	780	0	100.0
		1	600	0	.0
	Overall Percentage				56.5

a. Constant is included in the model.

b. The cut value is .500

6N. Variables in the Equation

		B	S.E.	Wald	df	Sig.	Exp(B)
Step 0	Constant	-.262	.054	23.344	1	.000	.769

6O. Variables not in the Equation

			Score	df	Sig.
Step 0	Variables	F2	868.468	1	.000
	Overall Statistics		868.468	1	.000

6P. Omnibus Tests of Model Coefficients

		Chi-square	df	Sig.
Step 1	Step	1224.880	1	.000
	Block	1224.880	1	.000
	Model	1224.880	1	.000

6Q. Model Summary

Step	-2 Log likelihood	Cox & Snell R Square	Nagelkerke R Square
1	664.661[a]	.588	.789

a. Estimation terminated at iteration number 7 because parameter estimates changed by less than .001.

6R. Classification Table[a]

Observed			Predicted i 0	Predicted i 1	Predicted Percentage Correct
Step 1	i	0	676	104	86.7
		1	44	556	92.7
	Overall Percentage				89.3

a. The cut value is .500

6S. Variables in the Equation

		B	S.E.	Wald	df	Sig.	Exp(B)
Step 1[a]	F2	.027	.002	303.446	1	.000	1.028
	Constant	-19.974	1.145	304.229	1	.000	.000

a. Variable(s) entered on step 1: F2.

6T. Variables in the Equation

		95% C.I.for EXP(B) Lower	95% C.I.for EXP(B) Upper
Step 1[a]	F2	1.024	1.031
	Constant		

a. Variable(s) entered on step 1: F2.