VOWEL IDENTIFICATION IN BALANCED BILINGUALS

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ABSTRACT

The native language affects non-native languages in such a way that the phoneme categories formed in infancy impede the perception of sound contrasts within the native language categories. Balanced bilinguals form in this respect an interesting group: do the two languages affect each other on the perceptual level, or can the two systems be kept apart in a behavioral attention-demanding task? In order to study vowel perception in balanced bilinguals, a behavioral identification task was performed. In the light of the obtained results, it seems that bilinguals are behaviorally able to keep the two languages apart, and consciously choose to use one or the other in an attention-demanding identification task.

Keywords: Bilingualism, vowel perception, identification, context language.

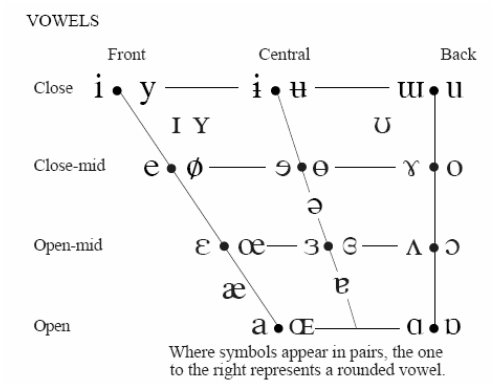
1. INTRODUCTION

The perception of speech sounds is known to be categorical rather than continuous, and discrimination accuracy is better near the category boundaries and poorer within categories [6]. The perception of native language speech sounds is based on the activation of long-term memory traces [7]. According to Kuhl [5], by the age of six months the vowel system has changed as a result of the native language, and this gradually makes second language sound perception more difficult. The native language affects second language learning as the phoneme prototypes of the first language function like magnets drawing the nearby sounds towards the centre, thus impeding sound discrimination near the prototype [4]. Second language speech sounds are therefore perceived through the filter of the mother tongue.

Bilinguals form one shared or two separate sound systems depending, e.g., on the amount of language input, the age of acquisition, and the language environment [1]. Different researchers have defined bilingualism as anything varying from a second language learner speaking a foreign language [9] to a person with a native-like proficiency in two or more languages [1]. The subjects of this study had acquired both languages from infancy, thus they cannot be considered second language learners.

Finnish and Swedish (the Finnish dialectal variant) vowel systems differ in the way the closed vowel continuum is phonologically divided. In Finnish, the continuum is divided into three categories, whereas in Swedish there are four categories. In addition to the front vowels /i/ and /y/ and the back vowel /u/, the Swedish system contains the central vowel /ʉ/ (see Fig. 1).

Figure 1: The closed vowel continuum /y - u/ used in the experiment, in relation to the chart of international vowels (International Phonetic Alphabet, IPA) [3]. The central closed vowel /ʉ/ forms a category in Swedish, but does not have a phonological status in Finnish.



The aim of this study was to find out how the Finnish-Swedish bilinguals categorize the vowels of the /y/ – /u/ continuum both in Finnish and in Swedish. If the bilinguals are not balanced, the dominant language should have an effect on the identification performance of the weaker language, causing perhaps more hesitation. If the two languages of the bilinguals are equally strong and two vowel systems with separate category boundaries exist, the labeling of the sounds according to both languages should be possible in an attention-demanding task. The subjects of the present study can be considered balanced, but it remains unclear, whether the two languages can be kept separate in an attention-demanding task or whether they affect each other.

A control group of monolingual native Finnish speakers was also tested in order to obtain the standard Finnish results. Monolingual Swedish speakers (the Finnish dialectal variant) were not tested, because it is nearly impossible to locate Swedish speaking monolinguals from the area, especially in the desired age group.

It has been suggested that the two phonological systems are neurally intertwined in bilinguals [2,8,10]. Despite this, the bilinguals may still be able to keep the two systems apart on the behavioral level.

2. METHODS

2.1. Subjects

The bilingual group consisted of 12 subjects (mean age 20.3 years, range 16-31, 7 females) who were native speakers of both Finnish and Swedish. All these subjects had one of the parents speaking Finnish and the other Swedish from infancy. The control group consisted of 10 native monolingual Finnish speakers (mean age 26.7 years, range 17-42, 7 females). All the subjects were right-handed (Edinburgh Handedness Inventory) and they all had normal hearing (tested prior to participation).

2.2. Stimuli

The subjects were presented with 18 synthesized (HLSyn software, version 1.0 Sensimetrics, Inc.) vowels from the /y/ – /u/ continuum. The duration of the vowels was 350 ms. The values for the second formant ranged from 703 Mel (606 Hz) to 1553 Mel (2077 Hz) in 50 Mel steps. The first, third, and fourth formant values were set at 344 Mel (250 Hz), 1748 Mel (2600 Hz), and 2019 Mel (3500 Hz), respectively (see Table 1). The amplitude was smoothly ramped for a 30 ms period both at the onset and the offset. The fundamental frequency started at 112 Hz, reached 132 Hz at 100 ms, finally descending to 92 Hz.

Table 1: The F2 values changed in 50 Mel steps, while F1, F3, and F4 were set at fixed values.

	F1	F2	F3	F4
Hz	250	606 - 2077	2600	3500
Mel	344	703 - 1553	1748	2019

2.3. Procedure and analysis

The bilingual subjects performed the identification test twice; in the Finnish test all the instructions were given in Finnish, and in the Swedish test the instructions were given in Swedish. The instructor varied according to the language context. The order of the two test situations was counterbalanced between the subjects. The control group performed the test only in Finnish (/y/ or /u/) with Finnish instructions.

As the vowel continuum in question is divided into two categories in Finnish, and three categories in Swedish, the subjects were asked to label the 18 vowels (each repeated 10 times) into two (/y/ or /u/) or three (/y/, /ʉ/ or /u/) categories according to the language of the test situation. Altogether, one test session consisted of 180 vowel stimuli presented in a pseudo-randomized order.

The test situations were otherwise identical, but the instructions were given in the language which the subjects were informed to hear. They were instructed to label the vowel sounds by pressing marked buttons on a keyboard. The stimuli were delivered binaurally through headphones (Sennheiser HD 25) and were set at a comfortable level. The stimuli were presented and data recorded by using Presentation PC –based software.

The category boundary locations and steepness values of the boundaries were calculated by submitting the categorization results to logit transformation using SPSS software. The category boundary location and steepness values of the bilingual group were separately subjected to a Paired Samples t-test, whereas when comparing the results of the control group and the Finnish results of the bilingual group the values were subjected to an Independent Samples t-test.

3. RESULTS

Figures 2 and 3 present how the bilingual subjects labeled the same vowel continuum into two Finnish and three Swedish categories.

Figure 2: The /y – u/ continuum divided into two categories by the balanced bilinguals in the Finnish language context.

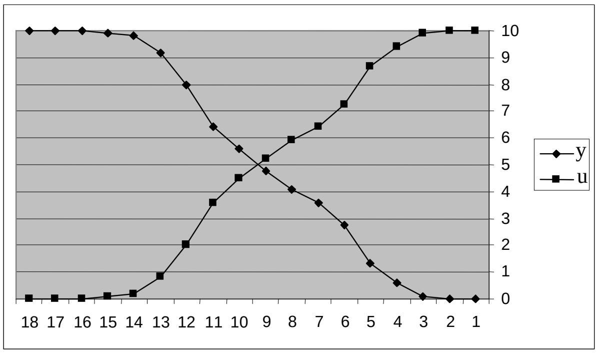
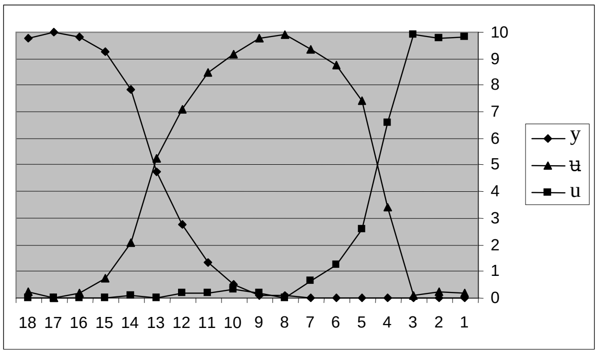


Figure 3: The /y – u/ continuum divided into three categories by the balanced bilinguals in the Swedish language context.



The minimum, maximum, mean, and standard deviation values for all category boundaries are presented in Table 2. As can be seen from Table 2, the mean location of the Finnish category boundary differed from both the mean Swedish boundaries. The statistical analysis confirmed that the Finnish category boundary location differed significantly from the Swedish /y – ʉ/ boundary ($t(11)=4.763$, $p=0.001$) and from the Swedish /ʉ – u/ boundary ($t(11)=6.721$, $p<0.001$).

Table 2: The crossover (boundary) values for the Finnish /y – u/ boundary and the Swedish /y - ʉ/ and /ʉ - u/ boundaries.

	min	max	mean	std. dev.
Finnish y-u	5.4	12.7	8.9	2.5
Swedish y-ʉ	10.4	14.7	12.9	1.2
Swedish ʉ-u	3.5	5.9	4.6	0.8

Table 3 presents the minimum, maximum, mean, and standard deviation values for the steepness of the category boundaries. The Finnish category boundary was not as consistent as the Swedish boundaries. When compared, the steepness of the Finnish /y – u/ boundary differed significantly from the Swedish /y – ʉ/ boundary steepness ($t(11)=6.619$, $p<0.001$), and from the Swedish /ʉ – u/ boundary steepness ($t(11)=6.615$, $p<0.001$). Also, the two Swedish category boundaries differed significantly from each other regarding the steepness values ($t(11)=3.763$, $p=0.003$).

Table 3: The steepness (consistency) values for the Finnish /y – u/ boundary and the Swedish /y – ʉ/ and /ʉ – u/ boundaries.

	min	max	mean	std. dev.
Finnish y-u	0.3	2.2	1.2	0.5
Swedish y-ʉ	1.3	3.0	2.0	0.5
Swedish ʉ-u	1.2	4.5	2.7	0.9

Figure 4 presents the identification results of the control group of monolingual Finnish speakers.

Figure 4: The /y – u/ continuum divided into two categories by the native monolingual Finnish speakers.

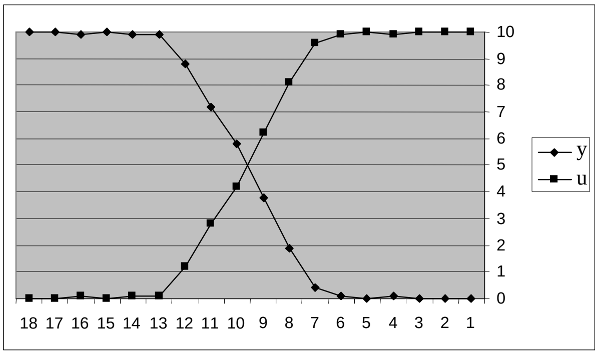


Table 4 presents the minimum, maximum, mean, and standard deviation values for the Finnish category boundary in monolinguals and bilinguals. The statistical analysis showed that the category boundary location did not differ significantly ($t(20)=-1.017$, $p=0.321$). The standard deviation values indicate greater variance in the individual category boundary locations within the bilingual group.

Table 4: The crossover (boundary) values for the Finnish /y – u/ boundary in monolinguals and bilinguals.

	min	max	mean	std. dev.
monolingual y-u	8.8	11.1	9.7	0.8
bilingual y-u	5.4	12.7	8.9	2.5

Table 5 presents the minimum, maximum, mean, and standard deviation values regarding the Finnish category boundary consistency. The statistical analysis confirmed that the two groups did not differ significantly in this respect either ($t(20)=-0.451$, $p=0.657$). Therefore, the slightly less systematic boundary in the results of the bilingual group is not an indication of individual inconsistency, but rather that subjects did not completely agree on the boundary location.

Table 5: The steepness (consistency) values for the Finnish /y – u/ boundary in monolinguals and bilinguals.

	min	max	mean	std. dev.
monolingual y-u	0.9	2.5	1.3	0.5
bilingual y-u	0.3	2.2	1.2	0.5

4. DISCUSSION

The balanced bilinguals were able to label the identical stimuli from the /y – u/ continuum into two Finnish (like native monolinguals) or three Swedish categories. They were able to place a category boundary of one language inside a category of the other language, and were also able to ignore a boundary of one language and form a category of the other language in the same acoustic area. In other words, in an attention-demanding behavioral task, the two languages do not affect each other.

The vowel continuum /y – u/ is divided into three categories in Swedish and two in Finnish. This diminishes the size of the Swedish categories, since three categories, instead of two, are imposed into the same acoustic area. This might partly explain why the Swedish category boundaries are sharper than the Finnish one. There was also greater variance in the location of the Finnish boundary location by bilinguals; some subjects showed greater area for /y/ and some for /u/, the category boundary, nevertheless, being inside the area of the Swedish vowel /ʉ/. This might also partly explain the relatively inconsistent Finnish category boundary.

There was a general difference in the consistency of the end vowels of the continuum: /u/ was labeled consistently regardless of the language. The /y/ -end, however, was labeled more consistently in Finnish. This might contribute to the difference in steepness values between the two category boundaries in Swedish.

To conclude, despite the fact that, e.g., Hernandez et al. [2], Winkler et al. [10], and Peltola et al. [8] have shown that bilinguals (early learners, immigrants, or balanced bilinguals) might have neurally intertwined systems, the balanced bilingual subjects appear to be able to keep the two phonological systems apart, when an attentive behavioral method is used. This seems only natural, because in everyday life the balanced bilinguals communicate with both Finnish and Swedish speaking people without the two phonological systems being mixed on the behavioral level. It could be concluded that the two phonological systems are balanced, but behaviorally separate.

5. ACKNOWLEDGEMENTS

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6. REFERENCES

[1] Albert, M.L., Obler, L.K. 1978. *The Bilingual Brain: Neuropsychological and Neurolinguistic Aspects of Bilingualism*. New York: Academic Press.

[2] Hernandez, A.E., Dapretto, M., Mazziotta, J., Bookheimer, S. 2001. Language Switching and Language Representation in Spanish-English Bilinguals: An fMRI Study. *NeuroImage* 14, 510-520.

[3] IPA vowel chart. http//www.arts.gla.ac.uk/IPA/vowels visited 6-Mar-07

[4] Kuhl, P.K. 1991. Human adults and infants show a “perceptual magnet effect” for the prototypes of speech categories, monkeys do not. *Perception & Psychophysics* 50: 93-107.

[5] Kuhl, P.K. 1992. Speech Prototypes: Studies on the Nature, Function, Ontogeny and Phylogeny of the “Centers” of Speech Categories. In: Tohkura, Y., Vatikiotis-Bateson, E., Sagisaka, Y. (eds), *Speech perception, production and linguistic structure*. Tokyo: Ohmsha, cop. 239-264.

[6] Liberman, A.M. 1957. Some results of research on speech perception. *Journal of the Acoustical Society of America* 29, 117–123.

[7] Näätänen, R., Lehtokoski, A., Lennes, M., Cheour, M., Huotilainen, M., Iivonen, A., Vainio, M., Alku, P., Ilmoniemi, R.J., Luuk, A., Allik, J., Sinkkonen, J., Alho, K. 1997. Language-specific phoneme representations revealed by electric and magnetic brain responses. *Nature* 385, 432-434

[8] Peltola, M.S., Tamminen, H., Lehtola, H., Aaltonen, O. 2007. Balanced bilinguals have one intertwined phonological system. This volume.

[9] Weinreich, U. 1953/1963. *Languages in contact*. London: Mouton.

[10] Winkler, I., Kujala, T., Alku, P., Näätänen, R. 2003. Language context and phonetic change detection. *Cognitive Brain Research* 17, 833-844.