DIFFERENTIAL HEIGHT SPECIFICATION IN FRONT VOWELS FOR GERMAN SPEAKERS AND TURKISH-GERMAN BILINGUALS: AN ELECTROENCEPHALOGRAPHIC STUDY

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ABSTRACT

Despite similar phonetics, phonological analyses suggest a differential tongue height specification of the vowels /i/ and /e/ in Turkish and German. This was tested by use of the mismatch negativity (MMN), an automatic change detection response of the brain, which was recorded for Turkish-German bilinguals and German listeners. Our results support the predictions about the differential specification of tongue height features, i.e. in Turkish /e/ is specified for [LOW] and not underspecified as in German; whereas /i/ is underspecified for height in Turkish and specified for [HIGH] in German.

Keywords: Vowels, underspecification, FUL-model, mismatch negativity, bilinguals.

1. INTRODUCTION

Neurolinguistic investigations study how language is represented in the brain and whether theoretical claims about linguistic categories are borne out by neural responses. Recently, neurobiological evidence for phonological underspecification has been reported [1,2,12]. Hypotheses on asymmetries in the mapping from the phonetic signal to underlying phonological representation according to the Featurally Underspecified Lexicon (FUL) model [7] could be verified by electrophysiological means. These findings are in conflict with accounts that assume the storage of highly detailed information about sound exemplars [8]. Instead, the results by [1,2, 12] support the notion that lexical representations are underspecified. Underspecification of features follows from general principles (e.g. [CORONAL] is always underspecified, only [HIGH] or [LOW] can be specified, nothing in between) or from language specific contrasts ensuring that entries in the mental lexicon are minimal and abstract with respect to phonetic details such as information about differential realizations of sounds of the same category, different speakers, etc. Turkish and German provide a testing ground for these claims considering vowel height: The vowels /e/ and /i/ are phonetically similar but underlyingly specified differently in each language. In lines of FUL's predictions we expected that Turkish and German listeners' auditory neural responses reflect these differences.

1.1. Specification of phonological height in Turkish and German vowels

Turkish and German vowels differ in their specification of tongue height features. Turkish /e/ is assumed to be specified for [LOW] [3,5]. German /e/ is assumed to be fully underspecified. German /i/ is specified for [HIGH] but underspecified for height in Turkish [3,16]. According to [3] the underspecification of [HIGH] and the specification for [LOW] of Turkish /e/ account for processes of vowel assimilation as well as other phonological processes. Furthermore, epenthetic segments are [HIGH] in Turkish, indicating underspecifiation of [HIGH].

1.2. Underspecification and lexical access

The assumption of underspecification of certain distinctive features is central to the FUL model [7]. FUL makes testable predictions about the way lexical entries are accessed during speech perception. Phonetic surface features are extracted from the signal and compared to the phonological features stored in the mental lexicon via a matching process with three possible outcomes: (a) match: surface and underlying features are the same; (b) no-mismatch: the surface feature is not listed in the lexicon or not conflicting with underlying features; (c) mismatch: surface and specified features are mutually exclusive. Only mismatch leads to a rejection of the lexical candidate. This results in perceptual asymmetries.

For Turkish and German vowels different matching patterns can be assumed for the vowel contrast /e - i/ in respect to tongue height. In comparison, /i – y/ should lead to the same matching pattern in both languages. Our predictions according to the FUL-model are summarized in Table 1. FUL assumes that no surface feature is extracted from mid vowels, which assures a reliable activation of correct lexical height in a three-step system. Furthermore, not only lexical representations but also surface feature extraction is language-specific (for review see [13]). Turkish separates between high, mid and low vowels differently from German and therefore assumably extracts [LOW] from [e].

Table 1: Surface feature extraction and lexical mapping for Turkish and German vowels according to the FUL-model. Phonological features which are common to all stimuli were neglected for the sake of clarity.

Lang-uage	Dir-ection	Surface and lexical features	Mapping result
Turkish German	[e] → /i/	[low] → /__/ [__] → /high/	no-mismatch no-mismatch
Turkish German	[i] → /e/	[high] → /low/ [high] → /__/	**mismatch** no-mismatch
Turkish German	[y] → /i/	[lab, high] → /__/ [lab, high] → /high/	no-mismatch no-mismatch
Turkish German	[i] → /y/	[high] → /lab/ [high] → /lab, high/	no-mismatch no-mismatch

1.3. Phonological and electrophysiological mismatch

The mismatch negativity component (MMN) of the auditory event-related potential was used as a dependent variable. The MMN indexes change detection between the sensory memory trace of repeated standard stimuli and infrequent deviant sounds. The memory trace for standard events is abstracted from the acoustics of single standard stimuli [10]. Detected differences between the deviant and the standard sound representations elicit the MMN at a latency around 100 to 250 ms after change onset. Linguistic experience modulates the MMN because the memory trace for the standard partly corresponds to long-term memory representations (for review see [10]).

Recently, it was found that the MMN is sensitive to phonological representations [1,2,12], corroborating results from behavioral research [6,15]. For example, when investigating the German contrast [o] and [ø] in a MMN-paradigm a conflict situation arises when the feature [CORONAL] is extracted from the deviant sound [ø] and mapped onto the standard representation of [o] which is specified for [DORSAL]. The reversal with [ø] being the standard and [o] being the deviant does not lead to a conflict because [CORONAL] is underspecified, [11]. [1] found a higher MMN amplitude and shorter MMN latency for conflicting than for non-conflicting situations.

In our study, a phonological mismatch is only expected as Turkish listeners map deviant [i] onto their representation of standard /e/, resulting in a conflict between [HIGH] extracted from [i] and the representation of [LOW] for /e/ (Table 1).

2. METHODS AND MATERIALS

2.1. Subjects

15 Turkish-German bilinguals (8 males, mean age: 26, range: 21-33) with Turkish as their first language and 16 native German subjects (8 males, mean age: 25, range: 22-30) participated. All were students at the University of Konstanz. German subjects had no command of Turkish. Turkish subjects had learnt Turkish as their first language from their parents which they addressed almost exclusively in this language. Turkish subjects were fluent in Turkish and German and used both languages daily. Their language history and usage was assessed through a detailed questionnaire, based on [14]. Ten Turkish subjects began learning German by 2-4 years, the rest had lived in Turkey up to puberty or early adulthood and were exposed to German in school by the age of 10 to 11 years. All subjects were paid for participation.

2.2. Stimuli

Production and perception data was assessed in both languages. Synthetic vowels [e, i, y] were created using source-filter-synthesis in Praat 4.4.07 (duration = 150 ms) based on F1 and F2 values within the production range of Turkish and German male speakers. Two 11-step continua were created from [e] to [i] and from [i] to [y]. The perceptual boundary between these vowels was tested in an identification task with 5 Turkish and 5 German listeners. The point of a 50% response did not differ significantly between listener groups ($F = .89$, $p > .1$). Three items per vowel category were chosen. Stimuli were delivered through headphones (Sennheiser HD 215) at ca. 75 dB.

2.3. EEG recording and analysis

To provide a Turkish language setting for the Turkish bilinguals a bilingual Turkish-German experimenter spoke exclusively Turkish to them during the experiment. German subjects were tested by a German experimenter. Between experimental blocks, subjects fulfilled a small task in their first language.

The EEG was recorded continuously using an EEG amplifier (Twente Medical Systems) at a sampling rate of 512 Hz from 64 locations with Ag-AgCI electrodes. Impedances were kept below 5 kO. Data were filtered offline (0.3 - 30 Hz) and averaged off-line from 200 ms before stimulus onset and 700 ms after stimulus onset (baseline correction: -200 to 0 ms). Eye artifacts were corrected, epochs exceeding 60 µV and standard stimulus epochs immediately following a deviant stimulus were excluded from further analysis. The criterion to include subjects in the final data analysis was a minimum of 70% of artifact-free responses in each condition. Artifact-free epochs were averaged for standard and deviant stimuli for each subject and block. Difference waves were obtained by subtracting responses to standard sounds from those to deviants of the same phonetic category, (e.g. standard [e] - deviant [e]). MMN was measured at the Fz electrode referenced to linked mastoids where it reached maximum amplitude. The MMN amplitude was quantified by calculating the mean in a 40 ms window centered over the grand average peak of the difference wave for the respective conditions.

3. RESULTS

A MMN response was elicited by all vowel contrasts for all subjects, except for one Turkish subject in for [e]/i/, two Turkish and one German subject in for [y]/i/. MMN was largest in amplitude at the frontal Fz electrode and reversed in polarity at the mastoids. Figure 1 displays MMN waveforms for each condition and group. Mean MMN amplitudes are summarized in Table 2.

Table 2: Mean MMN amplitudes (µV, with SEM) at Fz in a 40 ms window centered over MMN peak.

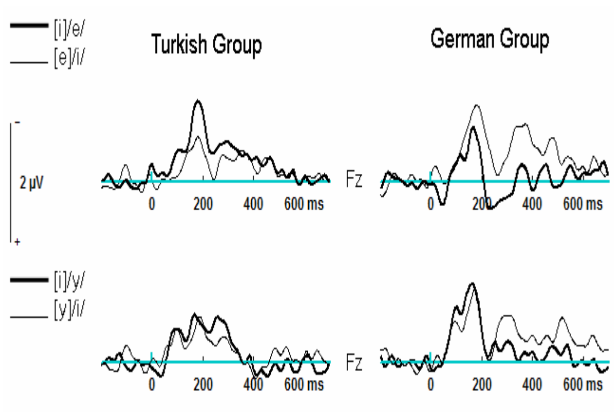
	[e] → /i/	[i] → /e/	[y] → /i/	[i] → /y/
Turkish	-1.4 (0.4)	-2.8 (0.4)	-1.5 (0.4)	-1.6 (0.3)
German	-1.9 (0.3)	-1.6 (0.3)	-1.6 (0.3)	-2.2 (0.5)

2x2 ANOVAs were performed separately for /i/ vs. /e/ and /i/ vs. /y/ including the variables MMN amplitude, language and direction of change. The model for /i/ vs. /e/ showed a significant interaction effect for language*direction of change ($F = 6.28$, $p < .05$). For /i/ vs. /y/ no significant effects were obtained.

One-way ANOVAs for MMN amplitude were calculated for each contrast pair and language group separately. For /i/ vs. /e/ no significant effect of direction of contrast was obtained for the German group ($F = .90$, $p > .1$). A significant difference between /i/[e] and /e/[i] emerged for Turkish subjects ($F = 5.39$, $p < .05$).

The effect of direction of contrast for /i/ vs. /y/ was insignificant in both groups (Turkish: $F = .07$, $p > .1$; German: $F = .97$, $p > .1$).

Figure 1: MMN waveforms for Turkish (left) and German subjects (right) at Fz.



4. DISCUSSION

The MMN results supported the notion of a differential specification of phonological features in the underlying mental representations of Turkish bilinguals and German subjects. Mapping the extracted feature [HIGH] onto the underlying representation of /e/ that is specified for [LOW] in Turkish elicited significantly stronger MMN responses for the Turkish subjects than when the phonetic information extracted from deviant [e] was mapped onto the standard representation of /i/ which is fully underspecified. There is no phonological conflict for these vowels in German. Accordingly, no asymmetry in MMN amplitudes between [i]/e/ and [e]/i/ was found for the German group.

The vowel pair /i - y/ served as a control condition. It was expected that no interaction arises for language group and direction of change. This, in fact, was found for MMN amplitude. The control condition was crucial since there was a certain limitation in providing equally phonetic material for both languages. Turkish does not differentiate between tense and lax vowels. The vowels in our material were more tense than usual in Turkish.

Our findings do not support the notion of a fully specified lexicon or a highly detailed memory. Instead, they speak in favor of underspecified lexical entries which evoke perceptual asymmetries.

The Turkish-German bilinguals that we tested in this study were fluent in German and had acquired this language at an early age. Turkish was the language that they had first learnt from both of their parents. It has been discussed that bilinguals' two languages interact in perception and production of speech sounds [4,9,14]. Furthermore, it has been proposed that despite such interaction the main language is dominant [9]. Our results indicate that the phonology of the main language, Turkish in our case, affects bilinguals' perceptual processing.

Further research should address the question whether bilinguals are able to activate phonological representations of the other language according to language setting or whether the main language continues to be dominant. Furthermore, it would be of interest to compare bilinguals to monolingual speakers in respect to phonological feature specification.

5. CONCLUSION

In summary, these results indicate that same acoustic stimuli may have different phonological representations crosslinguistically, possibly leading to varying specification in the mental lexicon. The MMN which is sensitive to acoustic differences, was able to tap on to these varying phonological feature representations for German and Turkish vowels in bilinguals.

ACKNOWLEDGEMENTS

We would like to thank Alex Bobrov for his help with the experimental set-up, Melike Birbudak and Robert Hepach for their help with data collection. This study was funded by the German Research Foundation (SFB 471).

REFERENCES

[1] Eulitz, C., Lahiri, A. 2004. Neurobiological evidence for abstract phonological representations in the mental lexicon during speech recognition. *Journal of Cognitive Neuroscience* 16, 577-583.

[2] Friedrich, C., Eulitz, C., Lahiri, A. 2006. Not every pseudoword disrupts word recognition: an ERP study. *Behavioral Brain Functions*, 2, 36.

[3] Kabak, B. 2007. Hiatus resolution in Turkish: An underspecification account. *Lingua* 117/8, 1378-1411.

[4] Kroll, J.F., Tokowicz, N. 2006. Models of bilingual representation and processing: Looking back and to the future. In: Kroll, J.F., De Groot, A.M.B. (eds), *Handbook of Bilingualism: Psycholinguistic Approaches*. Oxford: Oxford University Press.

[5] Lahiri, A. 2000. Phonology: Structure, representation, and process. In: Wheeldon, L. (ed), *Aspects of Language Production*, East Sussex: Psychology Press, 165-225.

[6] Lahiri, A., Marslen-Wilson, W. 1991. The mental representation of lexical form: A phonological approach to the recognition lexicon. *Cognition*, 38, 245–294.

[7] Lahiri, A., Reetz, H. 2002. Underspecified recognition. In: Gussenhoven, C., Werner, N. (eds), *Laboratory Phonology VII,* Berlin: Mouton, 637-675.

[8] Goldinger, S.D. 1997. Words and voices: Perception and production in an episodic lexicon. In: Johnson, K., Mullenix, J.W. (eds), *Talker Variability in Speech Processing*. London: Academic Press, 33-66.

[9] Grosjean, J. 1982. *Life with Two Languages. An Introduction to Bilingualism*. Cambridge, MA: Harvard University Press.

[10] Näätänen, R. 2001. The perception of speech sounds by the human brain as reflected by the mismatch negativity MMN and its magnetic equivalent MMNm. *Psychophysiology* 38, 1-21.

[11] Paradis, C., Prunet, F. (eds), 1991. *The Special Status of Coronals*. London: Academic Press.

[12] Scharinger, M. 2007. *The representations of vocalic features in vowel alternations: Phonological, morphological and computational aspects.* Doctoral Dissertation, University of Konstanz.

[13] Strange, W. 1995. Cross-linguistic studies of speech perception: A historical review. In: Strange, W. (ed) *Speech Perception and Linguistic Experience: Issues in Cross-Language Research*. Baltimore: York Press.

[14] Sundara, M., Polka, L., Baum, S. 2006. Production of coronal stops by simultaneous bilingual adults. *Bilingualism, Language and Cognition* 9, 97-114.

[15] Wheeldon, L., Waksler, R. 2004. Phonological underspecification and mapping mechanisms in the speech recognition lexicon. *Brain and Language*, 90, 401-412.

[16] Wiese, R. 1996. *The Phonology of German.* Oxford: Oxford University Press.