International Journal of Psychophysiology 87 (2013) 8–12

Contents lists available at SciVerse ScienceDirect

International Journal of Psychophysiology

journal homepage: www.elsevier.com/locate/ijpsycho

Phonological processing differences in bilinguals and monolinguals

Henna Tamminen [a,b,c,*], Maija S. Peltola [a,b,c], Heidi Toivonen [a,b], Teija Kujala [d,e], Risto Näätänen [e,f,g]

[a] Department of Phonetics, University of Turku, Finland
[b] Centre for Cognitive Neuroscience, University of Turku, Finland
[c] LAB-lab, Department of Phonetics, University of Turku, Finland
[d] Cicero Learning Network, University of Helsinki, Finland
[e] Cognitive Brain Research Unit, Institute of Behavioural Sciences, University of Helsinki, Finland
[f] Center of Functionally Integrative Neuroscience, University of Århus, Denmark
[g] Department of Psychology, University of Tartu, Estonia

ARTICLE INFO

Article history:
Received 11 July 2012
Received in revised form 6 September 2012
Accepted 6 October 2012
Available online 13 October 2012

Keywords:
Bilingualism
Speech perception
Phonological processing
Mismatch negativity (MMN)

ABSTRACT

The present study examined whether monolinguals and balanced bilinguals perceive speech sounds similarly or whether the two phonological systems in bilinguals interact so that one language is affected by the other. Two groups, monolingual native speakers of Finnish and balanced Finnish–Swedish bilinguals, were tested. We measured mismatch negativity (MMN) responses and used individually selected, native language, stimuli. The results revealed that balanced bilinguals had a significantly longer MMN latency than the monolinguals which suggests slower and weaker preattentive processing in the bilinguals. This implies that the two phonological systems are intertwined which decreases the access of exemplars.

1. Introduction

A variety of linguistic backgrounds may result in bilingualism and the definition may be based on the age and timing of the acquisition of the two languages (from birth simultaneously or later in life consecutively) or the obtained level of competence (Bloomfield, 1962; Grosjean, 1989). This undoubtedly leads to differing, even contradictory, results in studies on bilingual speech perception. For example, it has been shown that the two languages of early, fluent bilinguals are neurally represented in the same brain areas (Chee et al., 1999). In contrast, Klein et al. (1995) showed that this applies also when the languages are learned later in life. Perani et al. (1996) found that languages are represented in separate brain areas in less fluent later bilinguals, whereas Perani et al. (1998) found that the neural activations are similarly distributed in fluent bilinguals (early or late). They suggested that the localisation of cortical representations of the second language is determined more by the attained proficiency than the age of acquisition. A more complex pattern was found by Kim et al. (1997) who showed that, in the frontal lobe, early learners' languages are represented in a shared area while late learners' languages are spatially separated; however, there were no such distinctions in the activations in the temporal lobe. Different learning backgrounds also lead to differences in speech sound representations: new memory traces for non-native speech sounds evolve in cases of immigration (Winkler et al., 1999), but not in classroom (Peltola et al., 2003). Furthermore, these learning contexts result in either separate or intertwined phonological systems: Immigrants (Winkler et al., 2003) seem to have functionally inseparable languages while classroom learning (Peltola & Aaltonen, 2005; Peltola et al., 2012) leads to the development of functionally distinct phonemic systems. These kinds of differences in the results may partly be explained by the use of different methods, varying stimulus selection criteria, and different definitions of bilingualism. The distinction between balanced and dominant bilinguals proposed by Albert and Obler (1978) offers a solution to the problematic definition of bilingualism. Learning background may be one criterion when classifying bilinguals into balanced and dominant ones – balanced having acquired both languages from birth, in a one-language–one-parent setting, and dominants having learned the second language later in life. This dichotomy presupposes that the age of acquisition and proficiency level are natural features of the type of bilingualism.

Speech sound perception is known to be language-specific and mother tongue phonemes are discriminated easily and preattentively on the basis of long term memory traces (Näätänen et al., 1997), and these memory traces and the consequent phonological system develop early in childhood (Cheour et al., 1998). Behavioural (Kuhl, 1991; Liberman et al., 1957) and psychophysiological (Sharma & Dorman, 1999) studies have shown that discrimination sensitivity is highest

* Corresponding author at: Department of Phonetics, FIN-20014, University of Turku, Finland. Tel.: +358 2 333 5305.
E-mail addresses: henna.tamminen@utu.fi (H. Tamminen), maija.peltola@utu.fi (M.S. Peltola), teija.m.kujala@helsinki.fi (T. Kujala), risto.naatanen@helsinki.fi (R. Näätänen).

0167-8760/$ – see front matter
http://dx.doi.org/10.1016/j.ijpsycho.2012.10.003

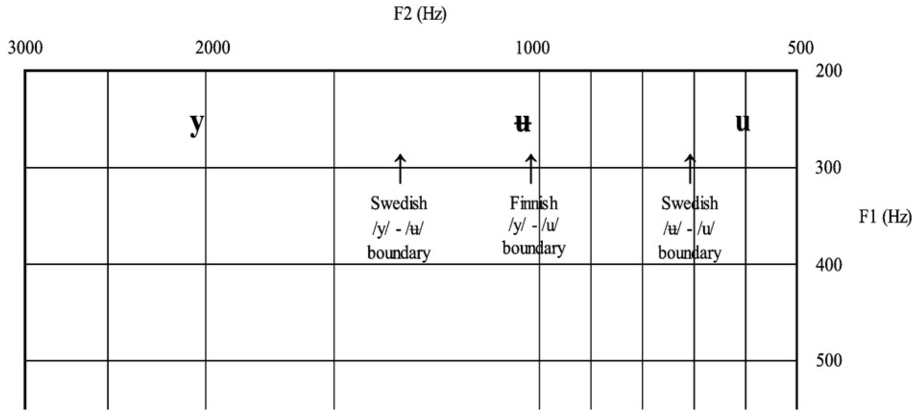

Fig. 1. The closed rounded vowels used in the experiment. The extremes are at 2077 Hz (/y/) and 606 Hz (/u/), and the mid-vowel is roughly placed on the most /ʉ /-like location. The category boundaries are also indicated by arrows.

at the native language phoneme boundaries and weakest near the native speech sound category prototypes. In behavioural discrimination this is reflected, e.g., in shorter vs. longer reaction times and in preattentive neural processing native-likeness is connected with responses having shorter latencies and larger amplitudes (Kujala & Näätänen, 2010). This is problematic in bilingual speech perception: balanced bilinguals' discrimination sensitivity peaks at the category boundary of one language while this boundary may be near a prototype of the other language which impedes discrimination. For example, within the closed vowel continuum Finnish distinguishes between three categories (/i/ – /y/ – /u/) while Swedish has four vowels (/i/ – /y/ – /ʉ / – /u/). Therefore, the category boundary between the Finnish /y/ and /u/ is located within the Swedish category /ʉ /. For balanced Finnish–Swedish bilinguals this means that the same acoustic distinction may be easy or difficult to discriminate depending on whether they rely on the Finnish or Swedish phonology.

The goal of the present study was to determine whether Balanced Finnish–Swedish bilingual speech processing is different from Monolingual Finnish perception. We aim to find out if the co-existence of two phonological systems results in different kinds of perceptual processings in bilinguals, compared to monolinguals who have only one native language, and how this potential difference is manifested in preattentive memory trace retrieval. Memory trace activations can most conveniently be studied by using the mismatch negativity (MMN) component of the event-related potential (ERP) since the MMN allows us to measure how fast (latency) and strongly (amplitude) memory traces are accessed, strong memory traces being reflected in short-latency and large-amplitude MMNs (Kujala & Näätänen, 2010). Our hypothesis is that speech processing may be different in bilinguals in comparison with monolinguals because bilinguals have a more extensive repertoire of phonological categories, some of which overlap between languages. Nevertheless, an acoustic distinction relevant for the Finnish phonology should result in a native-like MMN response, high in amplitude and short in latency, in both groups. However, if the dual phonological role (phonemic or non-phonemic depending on the language) has an effect on memory trace activation, this could be seen as divergent latency and/or amplitude in the Balanced bilinguals.

2. Materials and methods

Two groups of voluntary, right handed (tested with Edinburgh Handedness Inventory (Oldfield, 1971)), normally hearing (tested with an audiometer with perceptually relevant frequencies 250 Hz, 500 Hz, 1000 Hz, 2000 Hz, and 4000 Hz), and neurologically healthy subjects participated in this study. The first group consisted of 10 (mean age 26.7 years, 7 females) native speakers of Finnish (Monolinguals) and the second group consisted of 12 (mean age 20.3 years, 7 females) Finnish–Swedish bilinguals (Balanced bilinguals). The Balanced bilinguals were from the same Finland–Swedish dialectal area, they had acquired Finnish and Finland–Swedish from birth (one-language–one-parent), and none of them had ever lived in Sweden. They reported a high proficiency in both languages and they continued using both languages equally often in their daily lives. The socioeconomic status of these languages in Finland is equal as they are official languages and all public services are provided with both languages which enable concurrent use of both. The bilingual subjects and their data are the same as in Peltola et al. (2012) study. Prior to testing, a written consent was obtained from the subjects, and the experiments were conducted according to the guidelines defined by the ethical committee of the University of Turku.

The behavioural identification test (forced choice) consisted of 18 synthetic (HLsyn software, version 1.0. Sensimetrics, Inc.) isolated vowels from the closed rounded vowel continuum which is divided into two categories in Finnish, /y/ – /u/, and three in Swedish, /y/ – /ʉ / – /u/. The values for the second formant (F2) ranged from 606 Hz (703 Mel) to 2077 Hz (1553 Mel) in steps of 50 Mel while the other formants were kept constant (F1 = 250 Hz, F3 = 2600 Hz, and F4 = 3500 Hz). Fig. 1 shows an illustration of the continuum and roughly the category boundaries in question. It should be noticed that, the Finland–Swedish and Sweden–Swedish closed vowels are somewhat different, especially the close central /ʉ / has a lower F2 in Finland–Swedish (which is the one in question in this study) than in Sweden–Swedish (Asu et al., 2009). To imitate natural speech, the fundamental frequency (F0) contour was set at 112 Hz at the onset of the stimuli then reaching the maximum 132 Hz by 100 ms and finally descending to 92 Hz at the end. The stimuli contained a 30 ms ramp both at the onset and at the offset during which the amplitude was smoothened. The duration of the stimuli was 350 ms.

In the EEG recordings we used an individually selected stimulus pair for each subject (the stimuli always being 100 Mels apart) to ensure that the stimulus contrast had a phonological status in one of the participant's languages (Finnish), but not in the other (Swedish). This may not have necessarily been the case, if we had used group average stimuli, since the acoustic area of the closed vowels is quite vast. The stimulus pair was chosen on the basis of identification experiments carried out prior to the MMN registrations. In these ID-tests we located the /y/ – /u/ category boundary for Finnish (from both groups) as well as the /y/ – /ʉ / and /ʉ / – /u/ boundaries for Swedish (from Balanced bilinguals) individually for each subject and ensured that the Finnish boundary was located within the Swedish category /ʉ /. The