Changes in Automaticity of Speech Processing of Japanese Phonetic Contrasts in Second-Language Learning: An MEG study.

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Abstract

This project examined the effect of amount and intensity of L2 experience on automaticity of L2 speech perception using the neurophysiological method magnetoencephalography. The mismatch field (MMF) discriminative component was used to test L2 speech discrimination in three groups of L2 learners of Japanese. The design allowed determination of whether changes in performance are most strongly related to the number of contact classroom hours, or the intensity of hours. We used a visual attention task on a Japanese vowel duration contrast (tado-taado). Results showed that the most experienced L2 learners had the largest MMF, and that more classroom hours are necessary to see clearer improvement in L2 discrimination.

1 Introduction

Studies of second language (L2) learning have established that late (adult) learners of an L2 generally show poorer perception and production of L2 phonological contrasts than early (child) L2 learners, even after considerable experience and seemingly high proficiency. Increased experience with an L2 can result in improvements in L2 phonology, but rarely to a native-like level. First language (L1) listeners develop automatic and efficient selective perception routines (SPRs) (Hisagi et al., 2010; Strange & Shafer, 2008; Strange, 2011), as described by Strange's automatic selective perception model. A benchmark for native-like L2 speech perception is the achievement of automaticity of SPRs.

The phonemic inventories of American English (AE) and Japanese (JP) differ greatly in the relevance of spectral vs. temporal cues in differentiating categories. Studies show that in contrast to native JP listeners, AE L2 learners of Japanese show poorer discrimination and categorization of temporally-cued speech contrasts differing in duration (e.g., Tajima et al., 2003; Hirata et al., 2007; Tajima et al., 2008), particularly when the stimuli were more variable, or the tasks more difficult (Hisagi & Strange, 2011). A previous study suggested that experience with the L2 leads to a more robust discrimination of its phonemic contrasts, but that these representations (or SPRs) are still less robust than in L1 listeners, and that attention modulates these findings (Hisagi et al., in prep). The current study examined whether additional experience leads to more native-like levels of automaticity for these temporal cues. The amount of experience necessary for AE listeners to establish new SPRs for JP temporal contrasts is unknown.

Present Study: This study examined the effect of *amount* (total hours) and *intensity* (hours per week) of L2 experience on automaticity of L2 speech perception using the neurophysiological method magnetoencephalography (MEG). The event related field (ERF) component of interest for this study is the mismatch field (MMF), the magnetic counterpart of the event related potential mismatch negativity (MMN). MMN/MMF typically peaks between 160 and 220 ms (Luck, 2005). The MMF discriminative component was used to test L2 speech discrimination in three groups of L2 learners of JP, all native speakers of AE: (a) students enrolled in a second semester college level JP course taught at a typical rate (standard-rate courses, or SRC1); (b) students enrolled in an accelerated-rate course (very fast track, or VFT) as their second semester of JP; (c) students enrolled in a fourth semester of JP, who had learned JP in standard-rate classes and were at an intermediate level (SRC2). The study allowed determination of whether changes in performance are most strongly correlated with the total number of classroom hours (SRC1 vs. SRC2), or the number of hours per week (SRC1 vs. VFT).

2 Method

Subjects: 21 AE native speakers (6 VFT, 3 female; 6 SRC1, 5 female; and 9 SRC2, 3 female) were recruited from the foreign languages department at MIT. VFT and SRC1 were tested twice, at the beginning (Time 1: before) and end (Time 2: after) of semester 2. SRC2 were tested at the end of semester 4. The subjects were 18-29 years old with normal hearing (at 500-4000 Hz at 20 dB HL).

Design: The overall material and method were the same as in Hisagi et al. (2010) (see details in Hisagi, 2007). Two JP nonsense word forms were created: a long vowel word form, /taado/, served as the standard, and a short vowel, /tado/, as the deviant. Four tokens were created for each word type. A visual attention task was used to direct the subjects' attention away from the auditory stimuli: four different sizes of pentagon and hexagon shapes (orange with a black background) were used to construct an oddball visual discrimination test.

Magnetoencephalography (MEG) Recording: MEG was recorded using an Elekta Triux system (306-channel probe unit with 204 planar gradiometer sensors and 102 magnetometer sensors) at a sampling rate of 1,000 Hz, filtered between 0.03 and 330 Hz. Raw data were preprocessed using spatiotemporal filters (maxfilter software, Elekta, Stockholm).

Data Analysis: The continuous MEG was processed off-line, using Brainstorm software (Tadel et al., 2011). MMF was estimated from signals localized at the primary auditory cortex (transverse temporal gyrus) using minimum-norm imaging (Darvas et al., 2004). MMF responses are potentials evoked by auditory stimuli typically calculated by subtracting the averaged ERF of the standard stimuli from that of the deviant stimuli. To examine group differences, we performed a repeated measures ANOVA on the amplitudes from the subtraction (deviant – standard) waveforms. Depending on the effect of interest, we used different factors, including Group as a between-subjects factor and Stimulus (standard, deviant), Hemisphere (left, right) and Interval (six 40-ms intervals: 120–160; 160–200; 200–240; 240–280; 280–320; and 320–360 ms) as within-subject factors. A significance level of 0.05 was used.

3 Results

Figure 1 shows subtracted waveforms (MMF) for each group before (SRC1 and VFT) and after (SRC1, VFT, SRC2) JP classroom experience. First, a two-way ANOVA was conducted to determine whether MMF was significantly present in each time point. Each group was then examined separately to identify whether a stimulus effect (indicating discrimination) was present. Lastly, we conducted further analyses using the subtraction waves (MMF) to study the group interaction.

Left hemisphere

Time 1 (before): A main effect of Stimulus [F (1, 10) = 20.71, p = .001] and an interaction of Stimulus × Interval [F (5, 50) = 18.751, p = .000] were found. A main effect of Stimulus: SRC1: [F (1, 5) = 11.680, p = .019]; VFT: [F (1, 5) = 9.03, p = .030] and Interval: SRC1: [F (5, 25) = 22.27, p = .000]; VFT: [F (5, 25) = 9.88, p = .000], and an interaction of Stimulus × Interval: SRC1 [F (5, 25) = 8.84, p = .000]; VFT [F (5, 25) = 10.96, p = .000] were found. A Tukey-post hoc test showed significance in Intervals 3~6 for both groups. Time 2 (after): A main effect of Stimulus [F (1, 18) = 42.745, p = .0000] and an interaction of Stimulus × Interval [F (5, 90) = 27.18, p = .000] were found. A main effect of Stimulus: SRC1: [F (1, 5) = 10.49, p = .023]; VFT: [F (1, 5) = 11.89, p = .018]; SRC2: [F (1, 8) = 27.48, p = .001] and Interval: SRC1: [F (5, 25) = 14.58, p = .000]; VFT: [F (5, 25) = 11.52, p = .000], and an interaction of Stimulus × Interval: SRC1 [F (5, 25) = 6.90, p = .000]; VFT [F (5, 25) = 8.90, p = .000]; SRC2: [F (5, 40) = 15.04, p = .000] were found. A Tukey-post hoc test showed significance in Intervals 3~5 for the SCR1 and VFT groups and in Intervals 3~6 for the SCR2 group. Time 1 vs. Time 2: There was a significant interaction of Before/After x Interval: SRC1 [F (5, 25) = 2.796, p = .039] only for SCR1. A Tukey-post hoc test showed significance in Interval 6. Overall: There was no significant Group interaction in both Time 1 and Time 2.

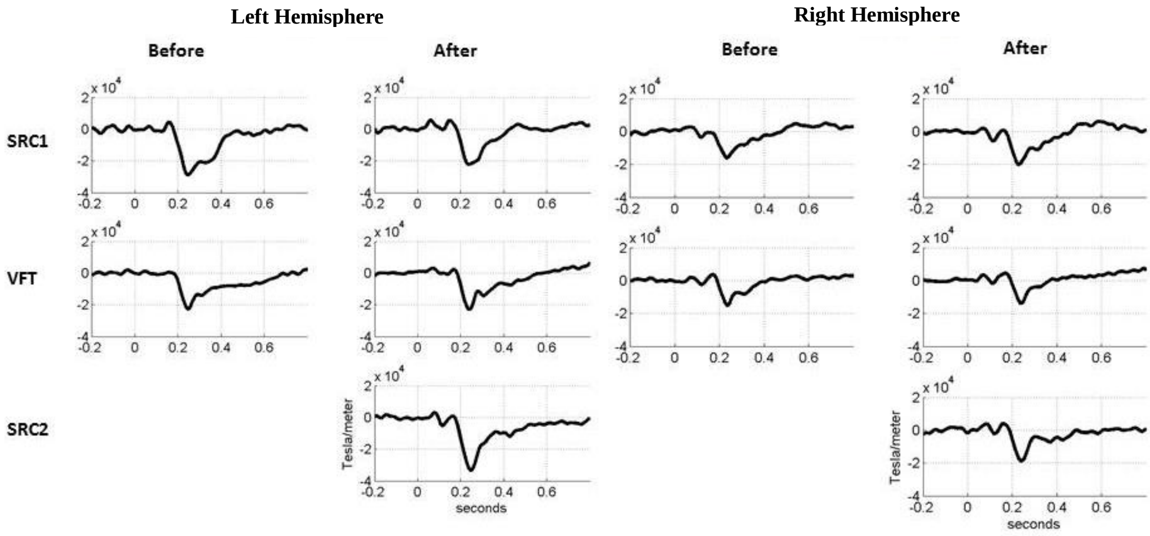
Right hemisphere

Time 1 (before): A marginal main effect of Stimulus [F (1, 10) = 4.337, p = .064] and an interaction of Stimulus x Interval [F (5, 50) = 2.645, p = .034] were found. Time 2 (after): There was no significant main effect of Stimulus, but there was an interaction of Stimulus x Interval [F (5, 90) = 4.76, p = .0006]. There was an interaction of Stimulus x Group [F (1, 10) = 5.55, p = .04] for SCR1 and VFT. A main effect of Stimulus was found only in SRC1: [F (1, 5) = 12.72, p = .016]. A Tukey-post hoc test showed significance in Interval 3 for SCR1. Time 1 vs. Time 2: No significant effect for both groups. Overall: There was no Group interaction in both Time 1 and Time 2.

4 Summary/Discussion

Results showed that the SRC2 had a slightly larger MMF than the other two groups. This is expected since SRC2 had the most experience with JP. Although we expected increases in MMF for the VFT and SRC1 groups, the VFT group showed no change across time and the SRC1 showed a slightly smaller MMF amplitude at Time 2. This may indicate that more time is necessary to see improvement in L2 discrimination. A second possibility is that habituation effects were counteracted by enhanced JP perception. An increase in the sample size will be necessary to determine which explanation is valid.

Figure 1. *Mismatch Field (deviant – standard)*



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