The relationship between non-native phoneme perception and the MMN

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Abstract: This study examined the relationship between auditory discrimination at a neurophysiologic level, as reflected by the MMN (mismatch negativity) auditory evoked potential, and the behavioral ability of native speakers of AE (American English) to discriminate and label Hindi consonants contrasted by a feature that is not phonemic in English. Two pair of dental vs. retroflex stop consonants were presented separately; one pair was voiced, the other voiceless. The ability of 12 listeners to label and discriminate the Hindi contrasts was poor; however, the MMN was observed in at least half of the listeners.

INTRODUCTION

The MMN may have clinical applications as a neurophysiologic correlate of speech discrimination ability (1). It is an automatic cortical evoked potential that represents the brain's detection of acoustic change. It is passively-elicited, requiring neither attention to the stimuli nor a behavioral response. The MMN is elicited using an oddball paradigm in which a repeating "standard" stimulus is occasionally and unpredictably replaced by a "deviant" (oddball) stimulus. The listener is instructed to ignore the train of stimuli and is distracted by another task. Responses to standard and deviant stimuli are averaged separately, and a difference waveform is created by subtracting the averaged response to standard stimuli from the averaged response to deviants. The MMN, when present, is evident only in the deviant and difference waveforms.

The MMN has been reported to be evident in response to stimuli that are perceptibly different, but not in response to contrasts that cannot be discriminated behaviorally (2). However, it has also been reported that the MMN reflects acoustic, rather than phonetic, difference detection (3). The purpose of the present study was to determine the relationship between the presence or absence of the MMN, and the ability to behaviorally categorize and discriminate Hindi stop consonants contrasted by a place-of-articulation feature that is not phonemic in English. Of interest was whether the MMN would reflect the detection of differences that were acoustic, but not phonemic, or whether it would reflect a listener's behavioral discrimination of the contrasts.

METHOD

Participants: 12 female college students between the ages of 19.3 and 33.3 years (mean = 23.3) served as listeners. All were native speakers of AE and had normal hearing.

Stimuli: The Hindi consonants used were the voiceless unaspirated dental and retroflex stops [t] and [T] and the voiced unaspirated dental and retroflex stops [d] and [D]. They were produced by a male native speaker of Hindi and presented to listeners in isolated CV syllables with the vowel [a]. Multiple syllables were produced in carrier phrases, recorded on a DAT recorder, and digitized into a Macintosh computer. Four different productions of each CV contrast were selected. A single vowel production was spliced onto each consonant so that the only differences in the syllables were in the consonant productions.

Procedure: The first procedure involved testing each listener on a Macintosh computer through earphones. Listeners were instructed in the articulatory differences between the dental and retroflex place of articulation. Testing was done on one voicing condition at a time. For familiarization, listeners heard 28 examples of the stimuli. Familiarization and testing were done on an interactive Hypercard program. The test consisted of 96 randomized presentations of each contrast. The listener labeled each consonant (heard twice) as either dental or retroflex. No feedback was given. Listeners were also given a 50-item discrimination task for each voicing condition, in which 30 "different" pairs were randomly mixed with 20 "same" pairs and presented to the listener’s right ear through an insert earphone in an audiometric test booth. The listener scored each pair as "same" or "different."
MMN data acquisition and stimulus presentation were accomplished using Neuroscan software. Recording sites were Cz, Fz, and the mastoids, with the nose as reference and the forehead as ground. Eye artifact was recorded with a bipolar electrode montage, using supraorbital and infraorbital electrodes around the left eye. To control for level of arousal and minimize attention to the test stimuli, participants watched a videotaped movie. Videotape audio levels averaged 40 dB SPL (A-weighted scale), at the listener's left ear. Experimental stimuli were presented to the right ear at 72 dB SPL through an insert earphone. As with the behavioral tasks, the presentation order of the voicing conditions was counterbalanced across listeners.

For each listener, ten trial blocks of responses to each of the voicing conditions were collected. Each trial block consisted of 165 events: 25 deviants and 140 standards. Thus approximately 1400 responses to standard stimuli and 250 responses to deviant stimuli were collected for each listener in each voicing condition. Separate averages of responses to standard and deviant stimuli were created from the ten trial blocks. The composite standard waveform was subtracted from the corresponding deviant waveform, creating a deviant-minus-standard difference waveform. The MMN was identified in the difference waveforms as a relative negativity following the N1 component only when (1) the onset latency was less than 235 ms and (2) the area was greater than 225 ms x μV (4).

RESULTS

As expected, performance on the labeling task was poor. Listeners averaged 54.3% accuracy on the voiceless condition and 51.9% accuracy on the voiced condition. Four native speakers of Hindi averaged 96% and 98% accuracy, respectively, on the same tasks. Overall performance on the behavioral discrimination task was also poor. Listeners averaged 37.3% accuracy on the voiceless condition and 29.3% accuracy on the voiced condition.

For each of the voicing conditions, 9 of the 12 listeners (75%) demonstrated relative negativities following the N1 component that met the onset latency criterion. Fewer of these negativities met the stringent area criterion. In most cases, these negativities were considered to be rudimentary MMNs. However, in response to the voiceless condition, five listeners had negativities that were judged to be MMNs; the same was true for three listeners in response to the voiced condition (two listeners had MMNs in both conditions). There appeared to be no relationship between the ability to behaviorally label or discriminate the contrasts and the presence of an MMN.

DISCUSSION

Results lend some support to the hypothesis that the MMN reflects the detection of acoustic differences that are not behaviorally perceptible. Half of the listeners demonstrated MMNs and several others showed rudimentary MMNs, without corresponding evidence of behavioral discrimination. Research is currently underway to evaluate the effects of auditory training on the MMN and behavioral perception. A comparison of pre-training to post-training MMN data may indicate that the MMN has some predictive value with regard to training success, and may provide more information about the relationship between the MMN and phonetic processing.

ACKNOWLEDGMENTS

The authors would like to thank Steven Parker, John Pruitt, and Vikram Gupta for their help with this study. This study was partially funded by the Curry Foundation.

REFERENCES