Pre-attentive perception of speech-like contour patterns: A Mismatch Negativity (MMN) study.

David I Leitman[12*], Sophie Molholm[1], Manuel Gomez-Ramirez[1], Pejman Sehatpour[1], Jeannette Piesco[1], Marina Shpaner[1], Daniel C. Javitt[1] and John. J. Foxe[12].

[1]Cognitive Neurophysiology Laboratory / Program In Cognitive Neuroscience and Schizophrenia, Nathan Kline Institute for Psychiatric Research, Orangeburg, NY. [2] Program In Experimental Cognition The City College Of the City University Of New York, NY, NY.

INTRODUCTION

- The perception of meaning in speech relies on a kaleidoscope of factors, including the ability to segment and interpret changes in stress, rhythm, and pitch in the speech utterance.This 'prosodic' ability allows us to appraise speech utterances in terms of the emotional intent (happy or sad) as well as semantic meaning (a statement or a question) of the speaker.
- Integral to this process is the ability to recognize and distinguish fundamental frequency (f_0) changes within speech that signal affect as well as semantic meaning (Majesky and Bladsdell, 1969; Pell, 1998; Lakshminarayanan, et al., 2003).
- Our ability to recognize prosodic cues begins at an early developmental stage, preceding formalized language acquisition. (Davis, MacNeilage et al. 2000). Further, Fernald et al. (1989) have shown that prosodic cues – particularly exaggeration of pitch contour changes – are among the most salient to infants in conveying affect in mothers' speech.
- The early acquisition of prosodic comprehension, and its extensive integration within speech in conveying affective meaning, suggests a degree of automaticity in the recognition of prosodic cues.
- MMN has already been shown to be elicited to tonal patterns (e.g., Nordby & Roth, 1988) as well as to abstract changes in pitch and duration (e.g., Saarinen, 1992). Within language specifically, MMNs have been elicited to phonemic change (e.g., Rinne et al., 1999).
- We hypothesized that such supra-segmental analysis of speech-like contours might occur early in processing, at a preattentive level which can be indexed using MisMatch Negativity (MMN).
- In the current preliminary study, we tested the hypothesis that tonal phrases which physically approximate declarative and interrogative semantic distinctions elicit an MMN. Using source analysis procedures, we assessed the underlying neural generators of this MMN.

METHOD

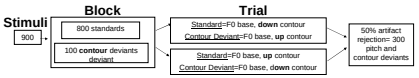
Stimuli:

- The stimuli, adapted from Pell (1998), consisted of short tonal phrases consisting of 4 pure tones strung together.
- The fundamental frequencies of the stressed vowels were extracted from a semantically neutral sentence with either a declarative or an interrogative prosodic intent (see Table 1 below for acoustic properties).
- These phrases were presented in a standard oddball paradigm illustrated in the figure below.

Description of Stimuli Characteristics (adapted from Pell 1998)

phrase	(Robert)		(Read)		(let-)		(-ter)		
Contour	HZ	msec	HZ	msec	HZ	msec	HZ	msec	Duration
Interrogative	227	104	211	60	183	117	**320**	100	381
Declarative	227	104	211	60	183	117	**162**	100	381

Experimental Paradigm



METHOD- (continued)

Measurements and analyses:

- High-density event-related potentials (ERP) were acquired from 128 scalp electrodes. Trials were epoched (–200 ms pre-stimulus to 700 ms post-stimulus) and then averaged separately for each condition.
- Analyses were confined to the MMN and N1 components, which were examined within a 20 ms window centered at the estimated peak latency for each component.
- 3D renderings of scalp topography and source analysis were performed in Brain Electrical Source Analysis (BESA, Ver 5.0) multimodal neuroimaging analysis software package (MEGIS Software GmbH, Munich, Germany).

CONCLUSIONS/SPECULATIONS

- The presence of MMNs to speech-derived tonal phrases that physically approximate declarative and interrogative distinctions suggest that the processing of pitch patterns salient to prosodic recognition and discrimination may occur at a preattentive level
- The presence of changing hemispheric dominance observed during the time course of the MMN and the presence of a frontal dipole located approximately in Broca's area is provocative given that these tonal phrases are based on actual prosodic utterances and the finding of LH predominance for MMN phonemes (Rinne, 1999).
- Further work will seek to incorporate our findings within a general framework for hemispheric function, such as those suggested by Zattore (1992, 2002), Patel (1998), and others.

RESULTS

- ERP analysis revealed significant MMNs to interrogative and declarative contours.

  The MMN to the interrogative contour had earlier onset latency (398 vs. 408 milliseconds), a higher peak amplitude (3.6μ vs. 2.4μ), and a shorter duration (102 milliseconds vs. 128 milliseconds) than the declarative contours.
- 3D voltage topography of subtraction waveforms suggested a stronger left hemisphere (LH) predominance during early portions of MMN activity with a switch to right hemisphere (RH) predominance during the later portion of the activity (see 3D voltage maps below)
- Min Norm estimates and subsequent source localization revealed at least two phases of activity in the subtraction wave for both contours (interrogative shown at left).
- In the first phase LH showed activity in temporal auditory regions as well as dorsalateral prefrontal activity, roughly corresponding to Broca's area. Conversely, RH activity was limited to auditory regions alone.
- Source analysis during the first phase (max = 420 msec) revealed the following 3-dipole solution: Two generators in the left hemisphere a more active dorso-frontal dipole and a less active dipole in auditory cortex. In contrast, RH has a single dipole moderately active in auditory cortex
- In the second phase, the activity of the LH auditory dipole increases while the left dorsofrontal dipole decreases.

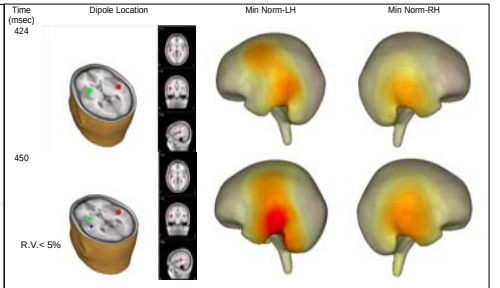
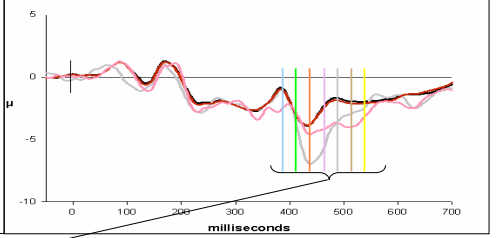


Figure 2: MMN wave forms at Electrode 'Fz"



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