Phonetic Content of Auditory Representations

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Summary

Varying standards is argued to enforce a **phonological** memory trace.
Question: is variation on an acoustic dimension **unrelated** to the standard-oddball contrast **sufficient** to enforce a phonological memory trace?
Results: We observe a mismatch effect to a within-category contrast in two conditions: one with varying standards and one without.
Conclusion: Variation on an acoustic dimension unrelated to phonological category membership does not enforce a phonological category representation.

Background

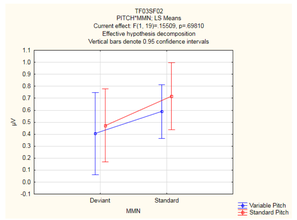
Mismatch Negativity (MMN) is a measure of neural 'surprise'. The auditory systems is entrained to a series of **standards** interrupted by a **deviant** which contrasts with the standard sounds in some way. The MMN is an indication that the auditory system has created a **memory trace** of the standard sounds and used that memory trace to make a prediction about incoming sounds. The mismatch is a result of a **failed** prediction.

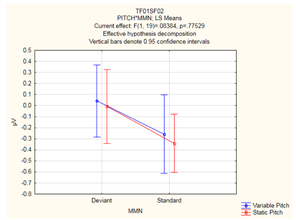
Many studies have used a 'varying standards' paradigm to enforce a **phonological** memory trace. Varying the acoustic properties of the standard sounds causes the auditory system to recruit a more abstract representation – a phonological category representation – to make predictions.

Studies have used:
- ❑ Different speakers[1,2]
- ❑ Variation in F0 formant frequency[3]
- ❑ Variation in VOT[4,5,6]

We vary a single acoustic parameter (pitch) unrelated to the standard-deviant contrast (VOT) to determine whether this variation is sufficient to enforce a phonological category memory trace.

Results



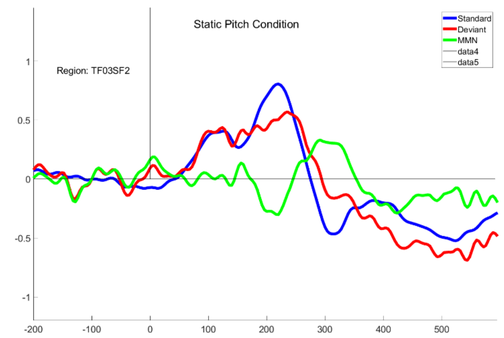


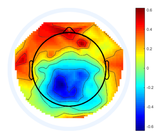
Mean voltage values were compared in a repeated-measures ANOVA with two factors: PITCH (two levels: Variable Pitch and Static Pitch) and MMN (two levels: Standard and Deviant).

ANOVA results showed a significant effect of MMN at TF03SF02 ($F = 6.139$; $p = .023$*) but no significant effect of PITCH ($F = 1.534$; $p = .231$), and no significant interaction ($F = .155$; $p = .698$).

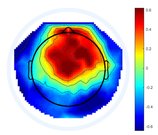
The ANOVA revealed similar results at TF01SF02. There was a significant effect of MMN (actually a **positivity**) at TF01SF02 ($F = 16.73$; $p = .001$*), no significant effect of PITCH ($F = .52$; $p = .478$) or interaction ($F = .08$; $p = .775$).

The lack of a significant effect of PITCH or PITCH*MMN interaction indicates that the neural response to both conditions (Variable vs Static Pitch) are the same. This indicates that a similar memory trace was used in both conditions.

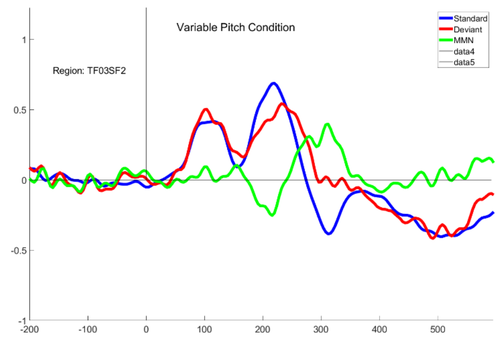


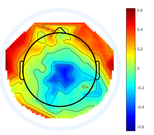


TF03: 184-232ms

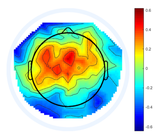


TF01: 268-336ms





TF03: 184-232ms



TF01: 268-336ms

We observed a mismatch negativity in an early time window typical of MMN (TF03SF02: 184-232ms), as well as a later positivity at the N2 (TF01SF02: 268-336). There was no difference between Variable and Static Pitch conditions.

Because the contrast is within-category, the only way for the auditory system to register a difference between standard and deviant is through an evaluation of **phonetic** properties. A mismatch should be impossible with a phonological memory trace. These results indicate that the memory trace retained phonetic information in both conditions (with or without variation unrelated to the contrast).

Methods

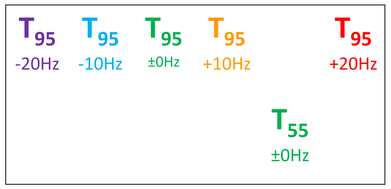
Subjects: 23 UD undergrads (ages 18-26).

Stimuli: synthesized CV syllables /tæ/
- Standard: 95ms VOT
- Deviant: 55ms VOT
- Pitch ranged from 116-97Hz over the syllable

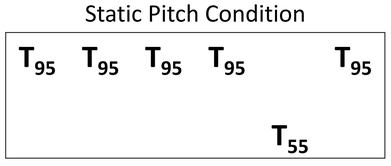
Design: 2 conditions
- ❑ Static Pitch Condition
  - All standards have identical pitch
- ❑ Variable Pitch Condition
  - One standard had baseline pitch
  - Four other standards had their pitch contour shifted ±10Hz or ±20Hz

Both conditions had a within-category contrast (voiceless).

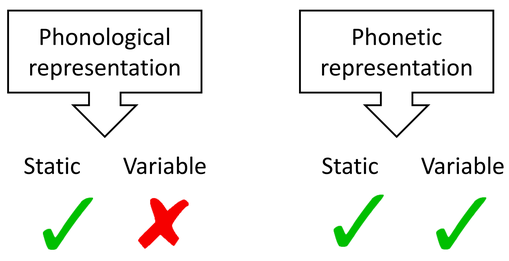
Variable Pitch Condition



Static Pitch Condition

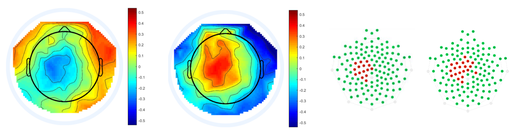


Prediction:
If **any** variation can enforce a phoneme representation, then there should be an MMN effect in the Static Pitch Condition, but **no MMN** effect in the Variable Pitch Condition.
If phonetic information is retained despite this variation, there should be an MMN effect in **both** conditions.



PCA

A principle components analysis was performed to find temporal/spatial regions that contributed the most to the overall variance.
The PCA was conducted on the main MMN effect.
The variable/static pitch conditions were collapsed. A standard-deviant difference was computed.
The PCA found two temporal factors corresponding to a typical time course of the MMN.



From left: topoplot of TF03 (184-232ms), topoplot of TF01 (268-336ms), ROI for TF03, ROI for TF01.

Conclusion

We tested the hypothesis that varying standards enforces phonological representations. We were interested in the lower limits of this claim: is **any** kind of variation sufficient? We observed a mismatch to a within-category contrast in two conditions: with and without simple variation in pitch.
The lack of a difference between these conditions indicates that this variation (unrelated to the within-category contrast in VOT) is **not** sufficient to enforce a phonological memory trace.

References

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