Phase Effects in Pitch Discrimination

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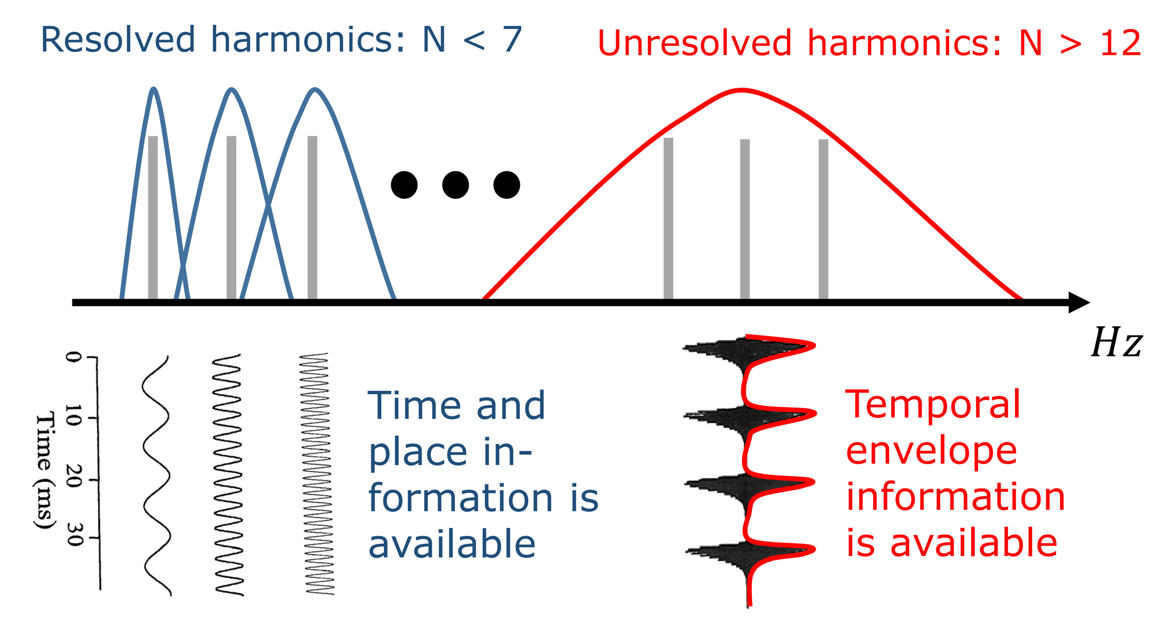
1. Introduction

Harmonic resolvability decreases with increasing harmonic number (N), i.e., when the harmonics of a complex tone interact on the basilar membrane[1]. Pitch discrimination between complex tones deteriorates in case of unresolved harmonics (N>12), for which only the temporal envelope of the signal conveys pitch cues.

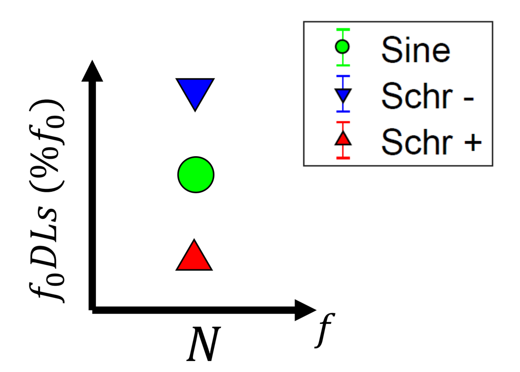


Modified from Plack[1]

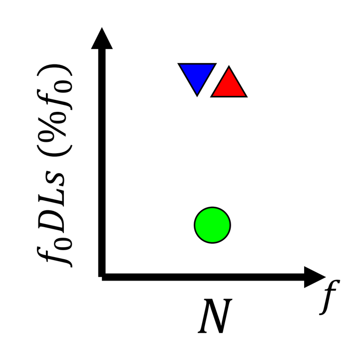
In case of unresolved harmonics, the phase relation of the harmonics plays a key role to generate either a peaky of a flat temporal envelope. Houtsma & Smurzinsky (1990) suggest that these phase effects create differences in pitch-discrimination performance[2,5]. Complex tones consisting of components added with a Schroeder negative phase (Schr-) relation have a periodic upwards frequency sweep in the time domain[6]. In contrast, Schroeder positive phase (Schr+) relations yields a periodic downwards sweep. By stimulating the basilar membrane (BM) with a Schr- complex tone, the interaction between the harmonic phases and the BM phase curvature will yield a flat "internal envelope". The flat envelope will make phase locking harder, thus decreasing pitch discrimination. The opposite effect is expected for Schr+ complex tones, where the internal envelope will have sharp peaks. For sine phase complex tones, a moderately peaky envelope can be observed. By comparing pitch discrimination performance for different phase configurations, this study aims at clarifying what phase alterations occur on the BM.

2. Hypothesis

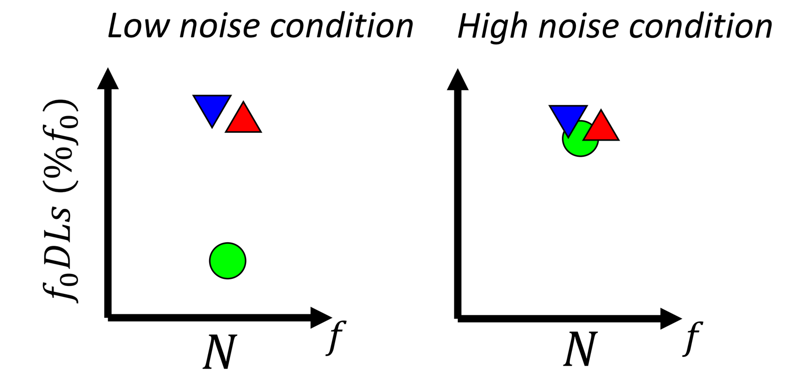
Three possible hypothesis are developed and investigated



1) Phase effects are present, independent of noise level[2]. Sharply peaked temporal envelopes gives rise to increased pitch discrimination due to better phase locking.



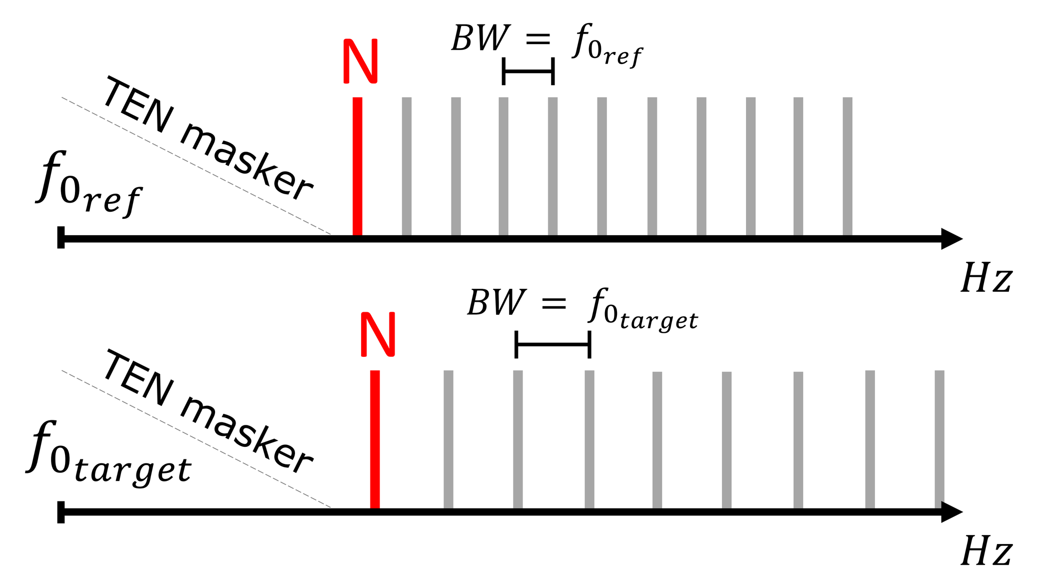
2) Phase effects are not present at high frequencies, independent of noise level[3]. Both the Schroeder phase signals will be hard to phase lock on, as the absence of BM phase effects will leave their temporal envelopes unaltered, thus flat.



3) Phase effects are not present. Distortion cues helps to discriminate pitch for the sine phased signals at low noise levels. However, at high noise levels, the cues will be masked by additional noise[4].

3. Method

- Phases conditions: Sine, Schroeder -, Schroeder +
- 16 subjects (7 musicians and 9 non-musicians)
- Random presentations of 512ms of complex tones in two intervals separated by 500ms of silence, presented only on the right ear.
- 2AFC method to determine the interval with higher pitch
- The reference fundamental frequency, $f_{0_{ref}}$, is 200 Hz
- Lowest Harmonics number, N, tested: 16th and 25th.
- Threshold Equalizing Noise (TEN) per ERB was used:
  - Signal/Noise of 29/10 dB SPL (Low noise condition)
  - Signal/Noise of 65/55 dB SPL (High noise condition)



Subjects are presented with two complex tones, both lacking the fundamental frequency. N denotes the lowest presented harmonic, and is followed by 10 additional harmonics. A roving technique, that shifts the lowest N (±1), is employed to avoid subjects to listen for the spectral edges. The temporal order of the tones are random with equal probabilities.

4. Results

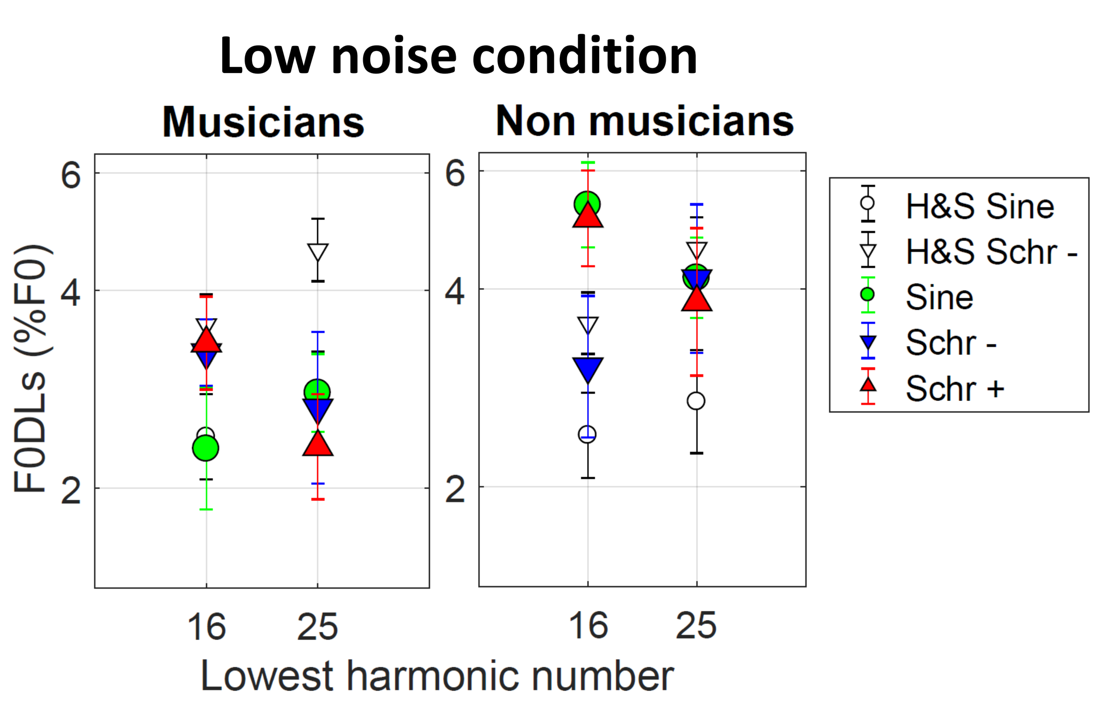
16 subjects were tested in their ability to discriminate pitch in three different phase conditions. 7 subjects were classified as musicians, based on a criterion of more than 4 years of musical experience, and 9 as non musicians. All subjects were tested in two different noise conditions, and tested 3 times per condition.

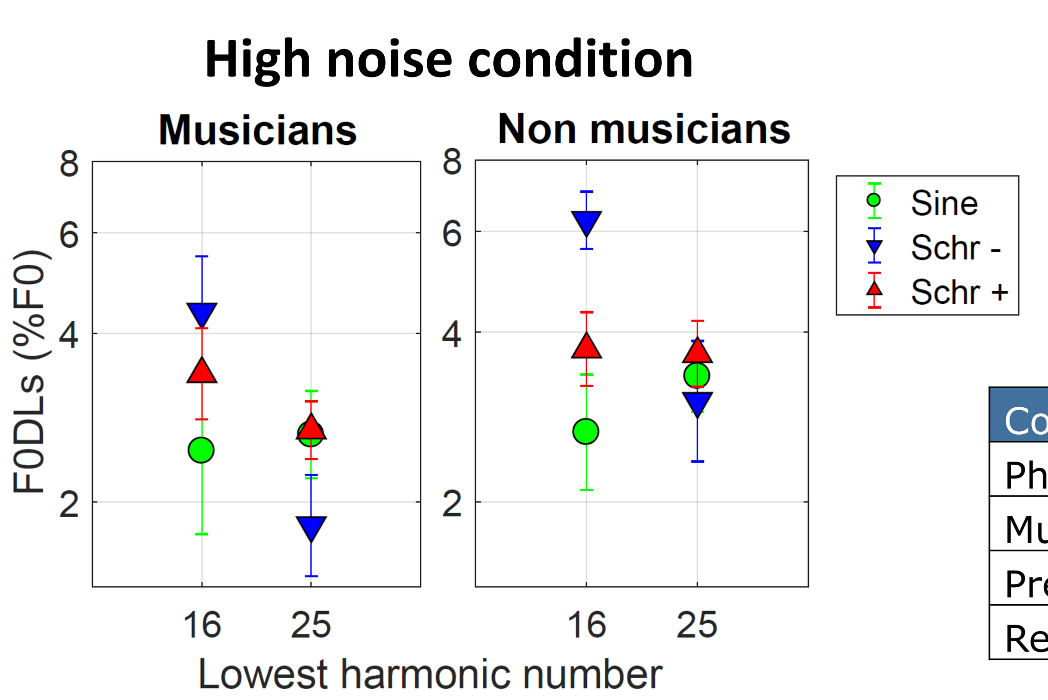
It can be seen from the plots, that no significant phase effects are present in the tested subjects. This is confirmed by a statistical analysis.

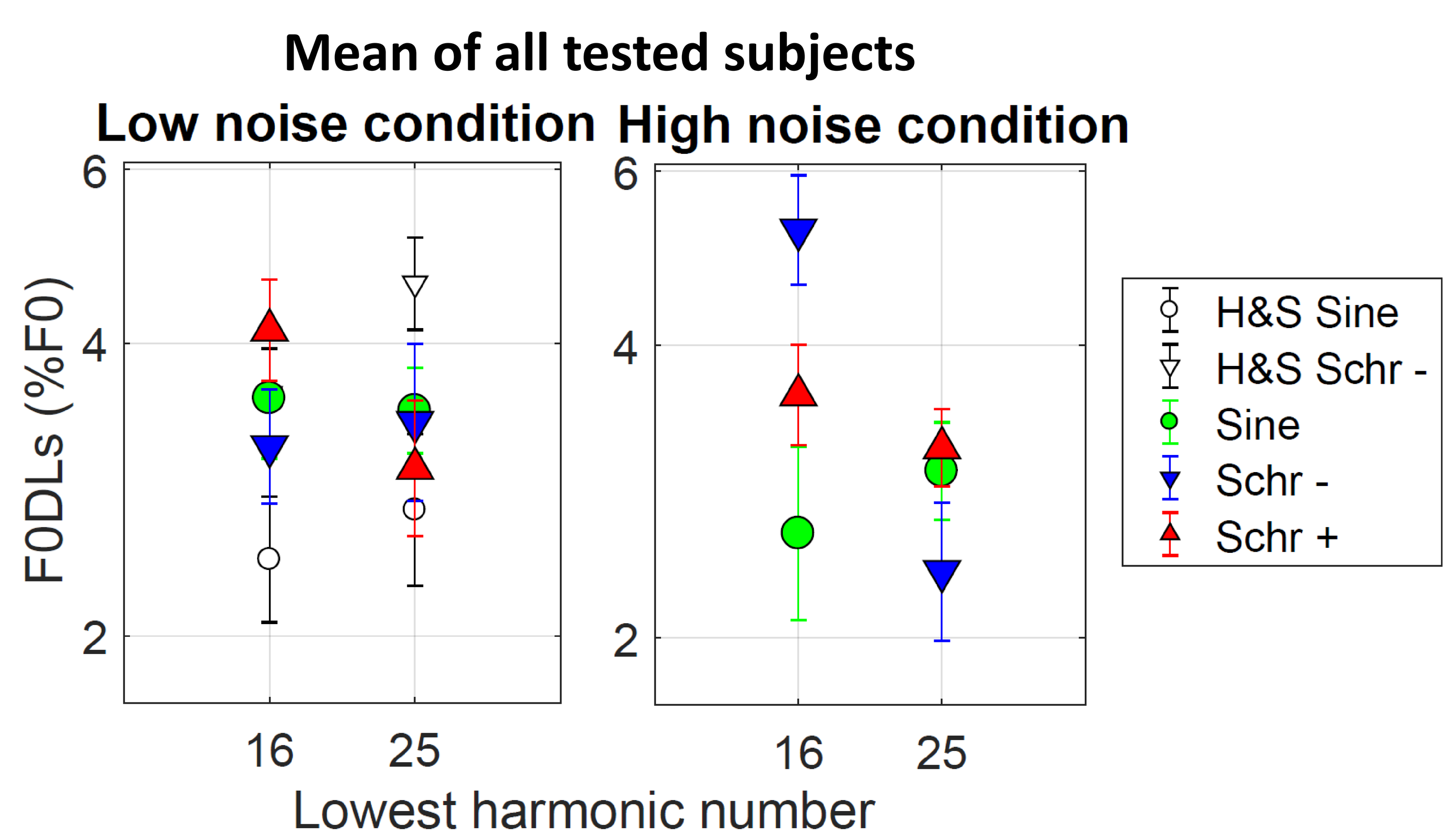
The statistics suggests that being a trained musician will influence the ability to discriminate pitch. As to be expected, the plots, showing musicians vs. non musicians, suggests that musicians are better at discriminating pitch in general.

A significant effect of training is present. This is however to be expected.
Finally, a small significance is seen regarding the presentation level.

Based on the collected data, none of the aforementioned hypothesis' can be used to draw a final conclusion.







The results are presented as difference limens in percentage of the fundamental frequency, f_0, for each condition, with a corresponding standard error (SEM). For the low noise conditions, the data of Houtsma & Smurzinsky are plotted alongside the measure results, for reference.

Conditions of statistical significance (found using ANOVA*)

Condition	Degrees of freedom	F (D.F, Error)	Probability > F	Conclusion
Phase condition	2	0.13	0.878	**Insignificant**
Musicianship	1	16.4	0.0001	Significant
Presentation level	1	4.03	0.0452	Significant
Repetition / training	2	3.6	0.0279	Significant

*Total error of degrees of freedom: 549

5. Discussion

- Too small sample size, consisting only of highly trained subjects were used in Houtsma & Smurzinsky's (1990) research.
- Differences between the collected data and Houtsma & Smurzinsky's research may be attributed to the differences in initial frequency step size (0.6 Hz vs. 0.2 Hz), and the total number of reversals used in the 2AFC method to establish a threshold (6 vs. 10 reversals).
- Sensation level was not personalized, but kept at a constant level across all subjects.

6. Conclusion

Based on the collected data, it can be concluded that phase effects play no significant role in pitch discrimination among both musicians and non musicians.

The statistics reveal that presentation level has a significance effect on pitch discrimination, though only marginally accepted. This will have to be further investigated.

An observation that should be taken into consideration, is the very significant effect of training. These effects are further reinforced by the differences seen between musicians and non musicians. For both groups, the thresholds strongly depend on the corresponding number of repetitions.

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