An unnatural test of a natural model of pitch perception:

The “tritone paradox” and spectral dominance

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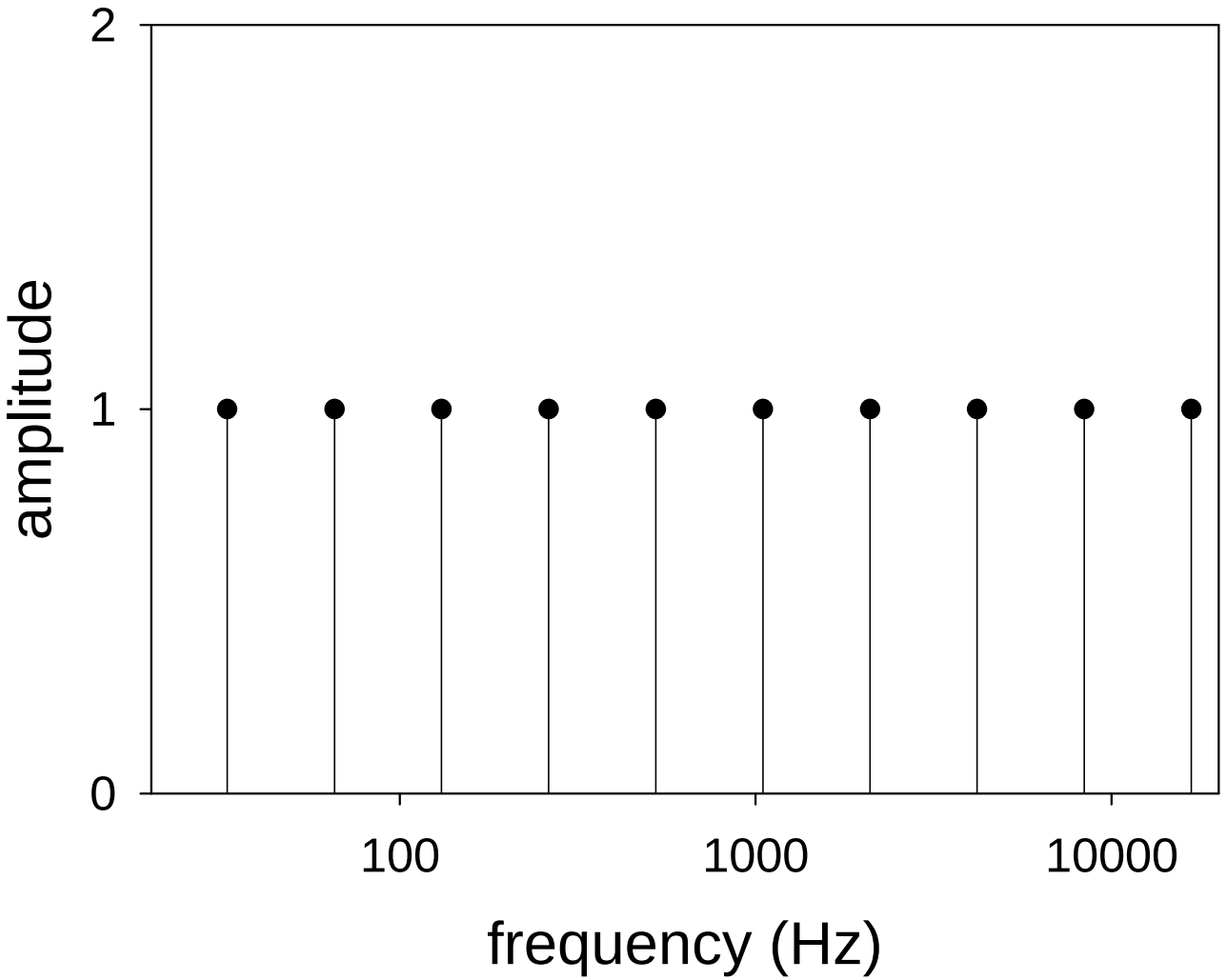
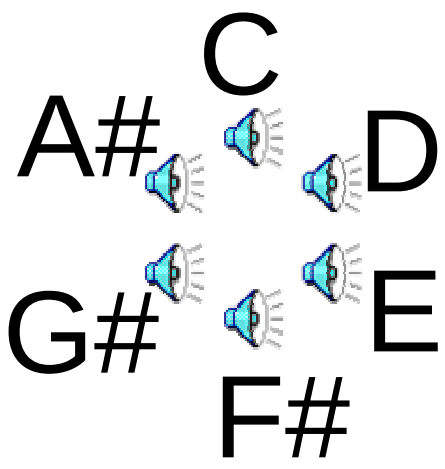
Octave-complex tone (OCT) on C



Sound demonstrations

OCTs:

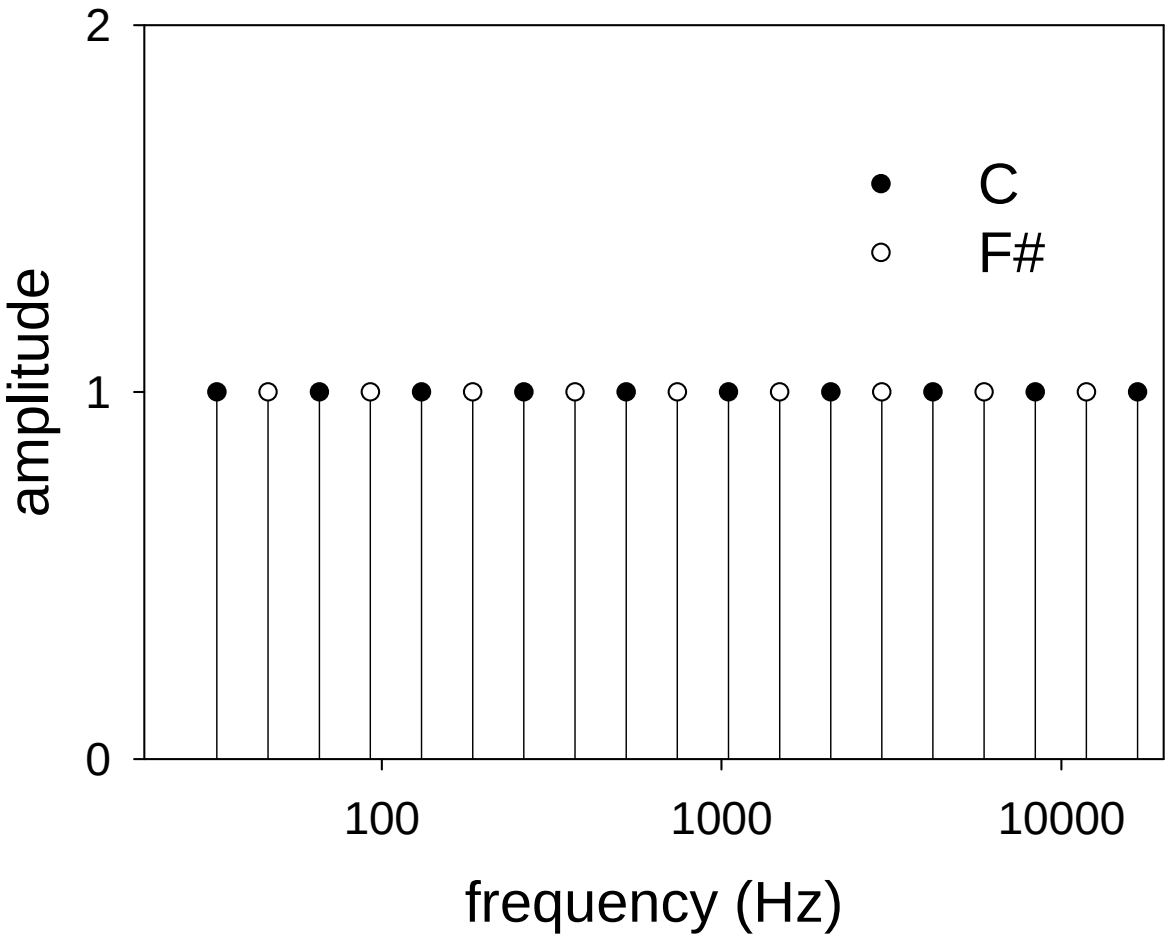


pure tones:

F#2 G#2 A#2 C3 D3 E3 F#3 G#3 A#3 C4 D4 E4

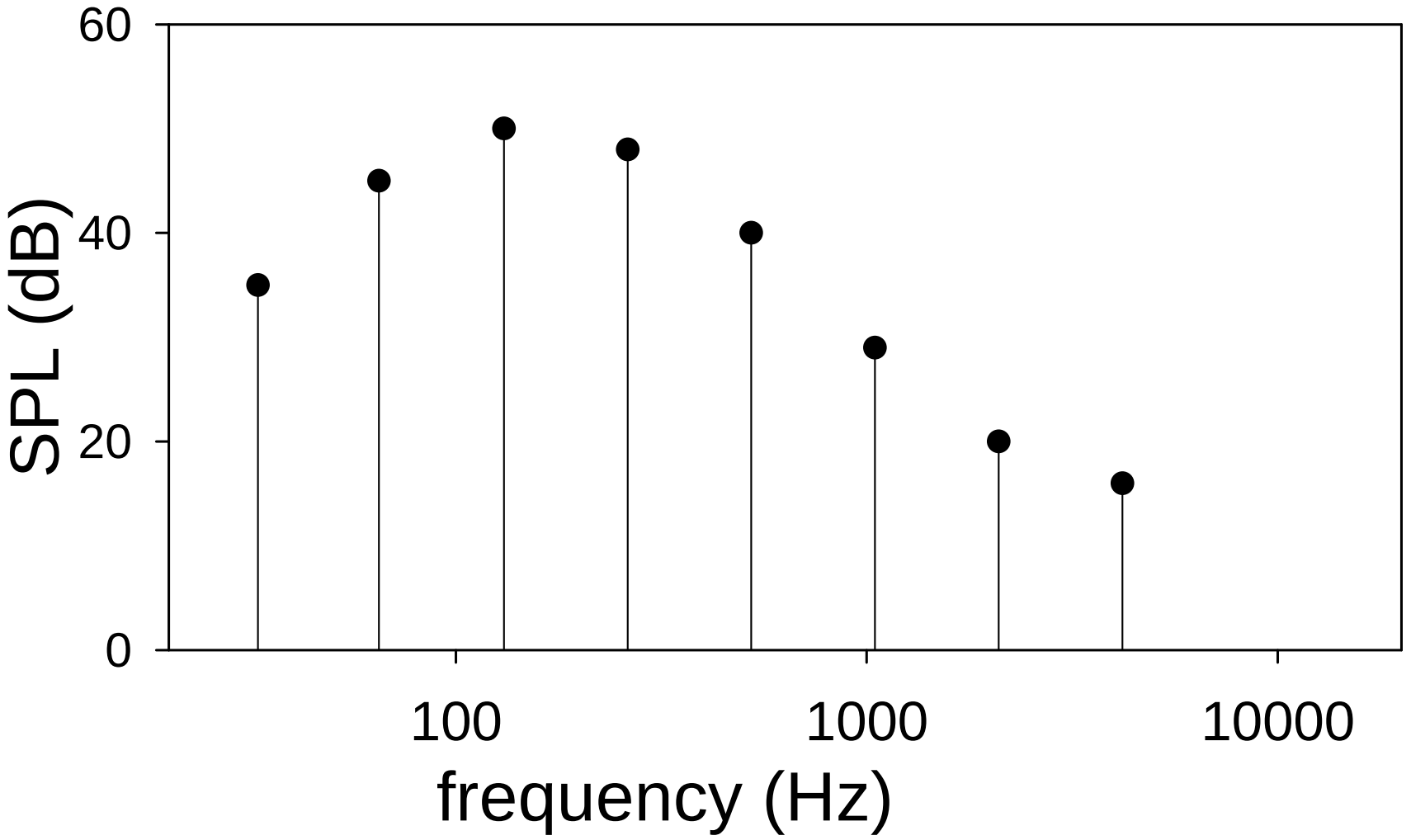
F#4 G#4 A#4 C5 D5 E5 F#5 G#5 A#5 C6 D6 E6

Octave-complex tones (OCTs) on C and F#



Shepard tone on C

with bell-shaped amplitude envelope



Studies by Deutsch and by Repp

Perceived direction of tritone depends on:

Sound:

- Absolute frequency
- Spectral envelope
- Previous context

Listener:

- Analytic versus synthetic hearing
- Bias toward rising or falling
- Culture, language or dialect

Diana Deutsch (1987)

The tritone paradox: Effects of spectral variables. *Perception & Psychophysics.*

„...the form of the relationship between pitch class and perceived height can be surpisingly robust in face of substantial differences in both the relative amplitudes of the sinusoidal components of the tones and their overall heights“

Bruno Repp (1997)

Spectral envelope and context effects in the tritone paradox. *Perception.*

- Lower pitch ~ center of spectral envelope
- Big individual differences in envelope dep.
- Big context effect

Two different „paradoxes“

1. *Inter*-individual paradox:

Some listeners consistently hear tritone rise, others consistently hear it fall.

2. *Intra*-individual paradox:

The same listener hears the same tritone rise or fall on different occasions.

Terhardt‘s pitch theory

Spectral pitches ~ audible partials

SP salience depends on:

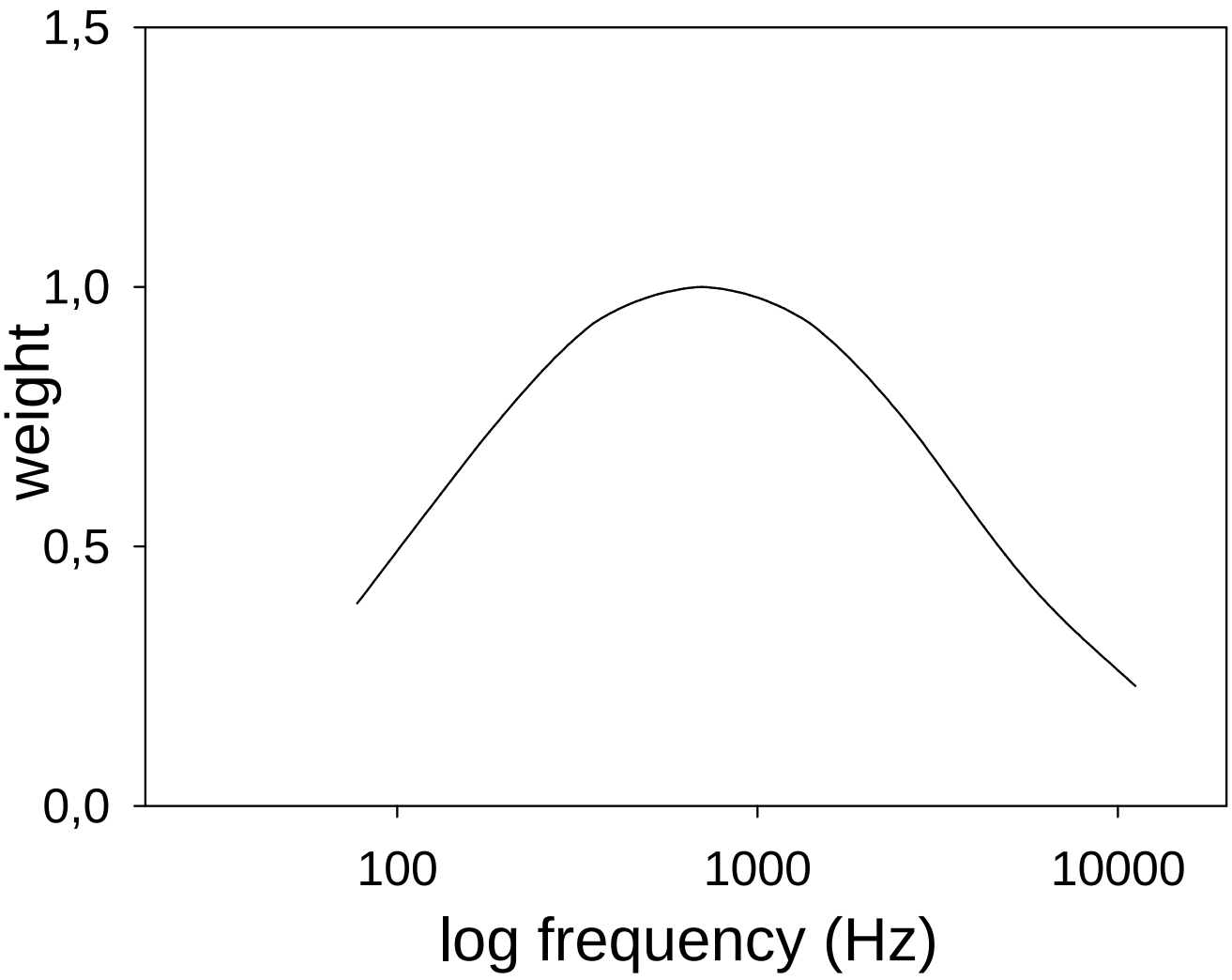
- level above masked threshold (saturation)
- spectral dominance (prox. to 700 Hz)

Virtual pitches ~ fundamentals of harmonic patterns of spectral pitches

VP salience depends on:

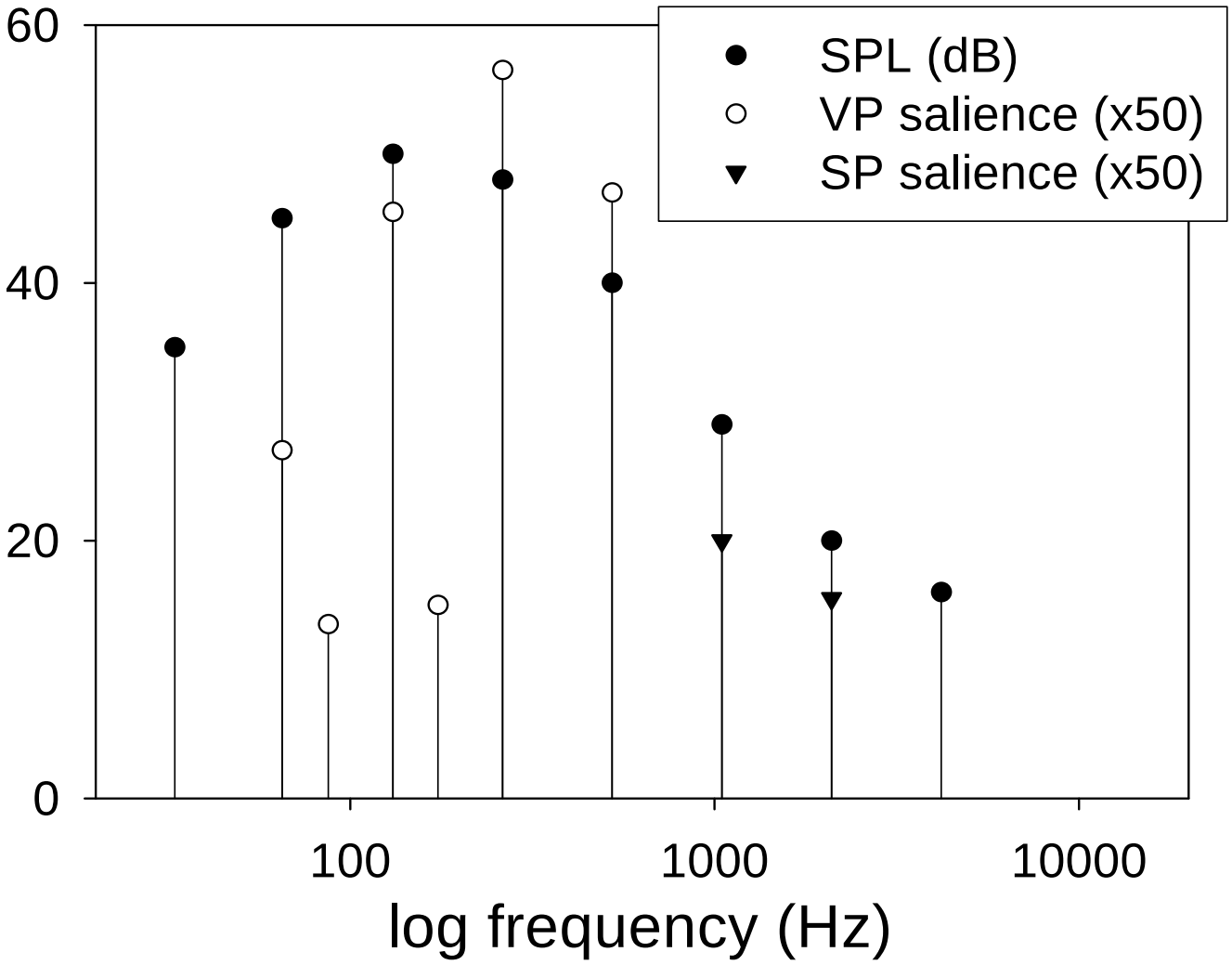
- goodness of fit (harm. template, spectrum)
- harmonic number (the lower the better)

Terhardt‘s spectral dominance region



Shepard tone on C

Predictions of Terhardt‘s pitch algorithm



Ernst Terhardt (1991)

Music perception and sensory information acquisition. *Music Perception.*

Pitch(es) of an octave-complex tone:

- usually virtual
- typically near 300 Hz (D4)

Their saliences:

- depend on spectral dominance function
- VP: almost indep. of spectral envelope

Aims of our experiment

- Determine the octave register of the perceived pitch of each tone
- Use this to predict perceived direction of tritone

Assumptions

1. Pitch, like frequency, is **one-dimensional**

2. If listeners hear e.g.:

   C – F#, D – G# and E – A# as rising

   then they hear:

   C as the lowest, A# as the highest

3. Pitch of pure tones is clear

   of complex tones is **ambiguous**

=>**register** of OCT by comparison with pure

Experiments

1. Direction („tritone paradox“ paradigm)

Stimulus: harmonic tritone of OCTs

Response: up or down

2. Height (new)

Stimulus: isolated OCT

Response: 1 = very low to 5 = very high

3. Distance (new)

Stimulus: OCT then pure, same pitch class

Response : 1 = very close to 5 = very far

Listeners

- 10 male, 10 female
- 19-40 years, mean 23
- mostly undergraduates, mostly psychology

Equipment

- Standard PC and software
- Audiocard Soundblaster 16
- BeyerDynamic DT 100 headphones

Stimuli

Octave-complex tones (OCTs):

- all tones, partials: ET whole-tone scale
- 10 partials per OCT, 20 – 20 000 Hz
- equal amplitude before amplification

Pure comparison tones:

- Same amplitude as partials of OCTs

Duration of all tones and pauses: 250 ms

Design

Each experiment:

- A few practice trials with feedback
- Main trials determined by symmetrical combination of IVs
- Different random order for each $\Rightarrow$ listener

Grouping of listeners

based only on Expt 1

- Does C sound lower or higher than F#?
- Combine data from 2 orders; t-test
- Repeat for D-G# and E#-A#

- Groups: RRR (N=5), URR (3), UUU (3), RUU (2), RFF (2), 7 others (1) *(R = rising, F = falling, U = unsure = diff. not sig)*
- Combine RRR, URR, RUU, UUR

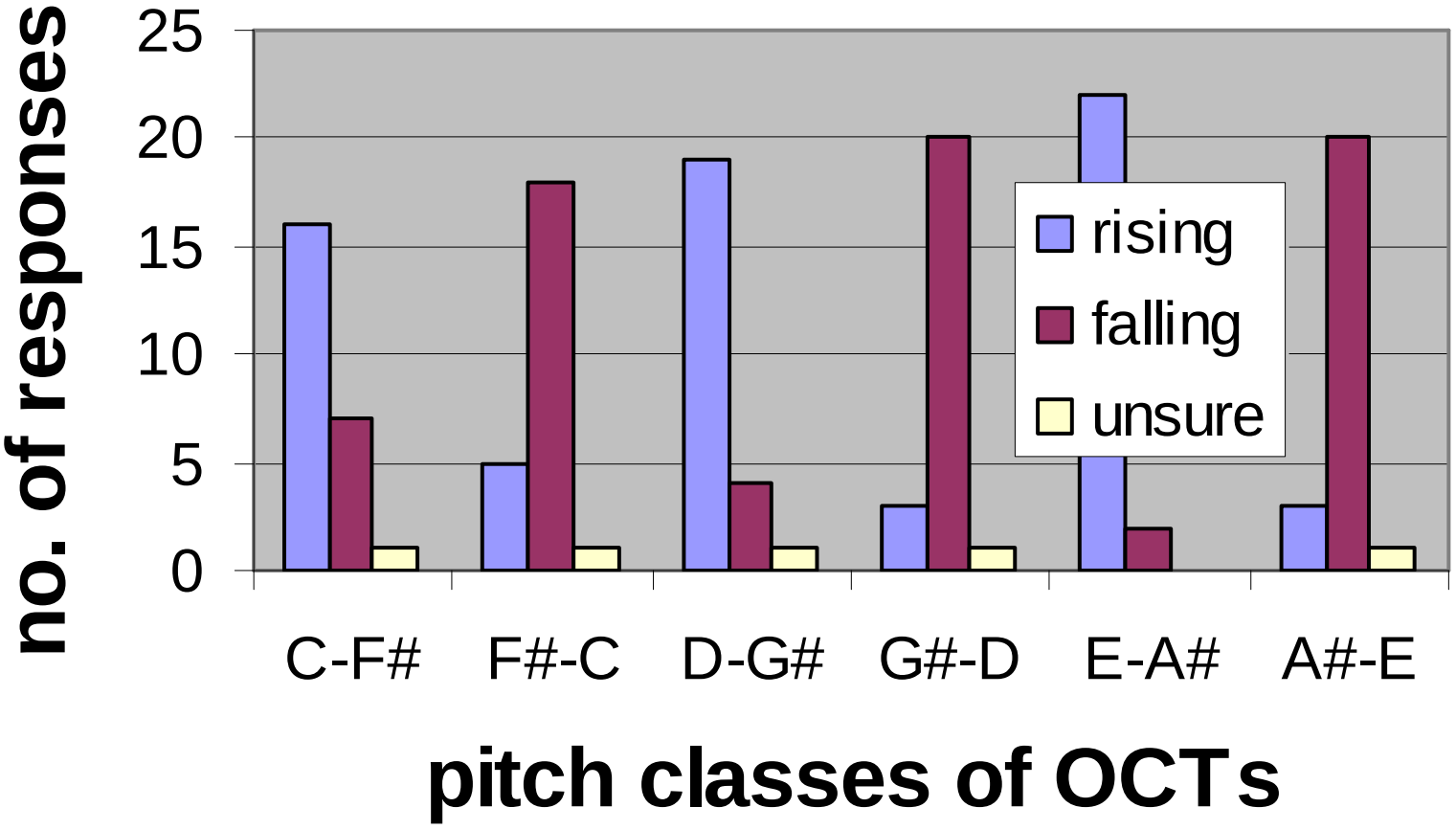
Listener groups

Group	N	C-F#	D-G#	E-A#	low OCT	high OCT
1	11	R (U)	R (U)	R (U)	C	A#
2	3	U	U	U	-	-
3	2	R	F	F	G#	F#
4	1	F	R	R	D	C
5	1	U	F	F	G#	E
6	1	F	F	R	E	D
7	1	R	U	F	A#	F#

R=rising, F=falling, U=unsure

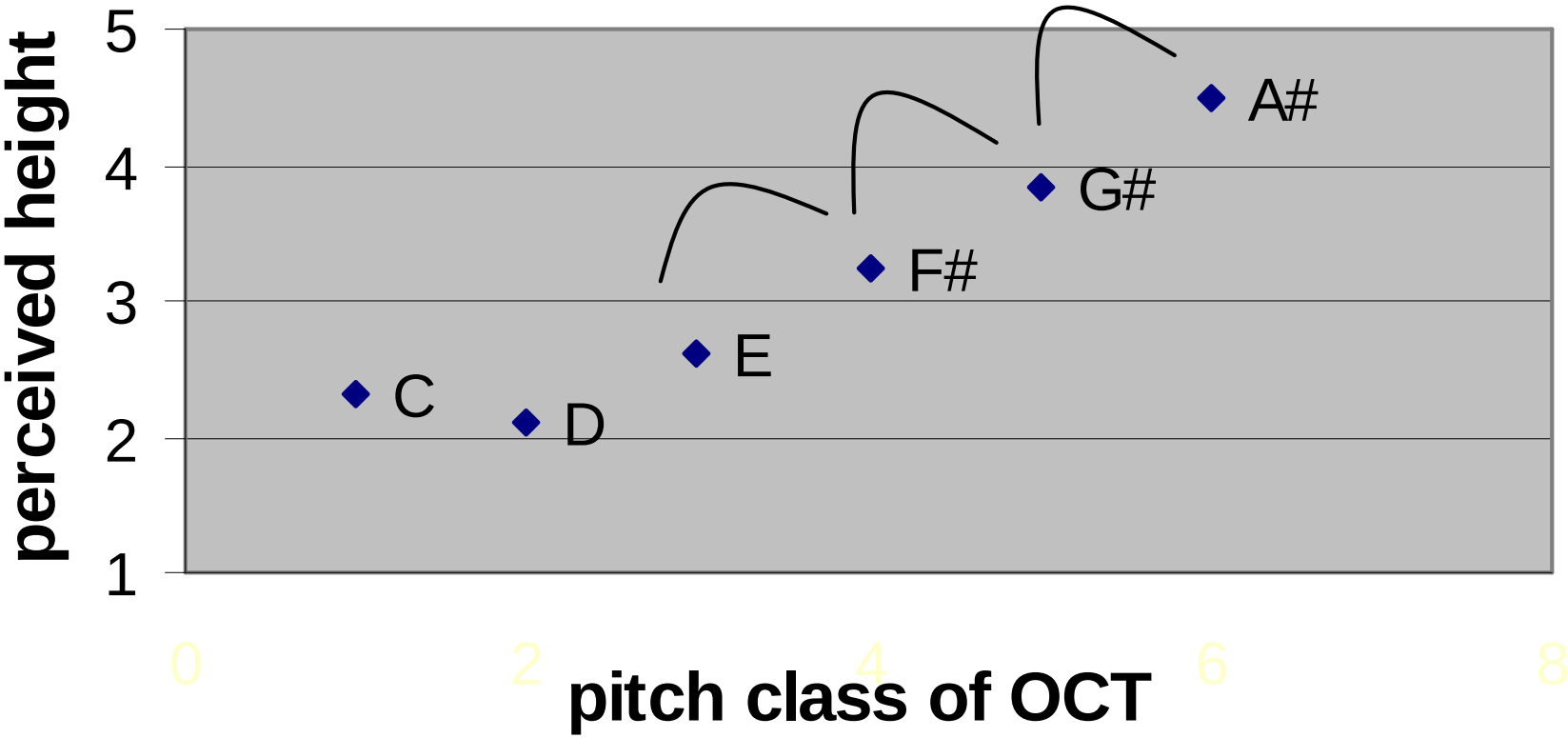
Results: Group 1, Expt 1

Does the melodic tritone rise or fall?



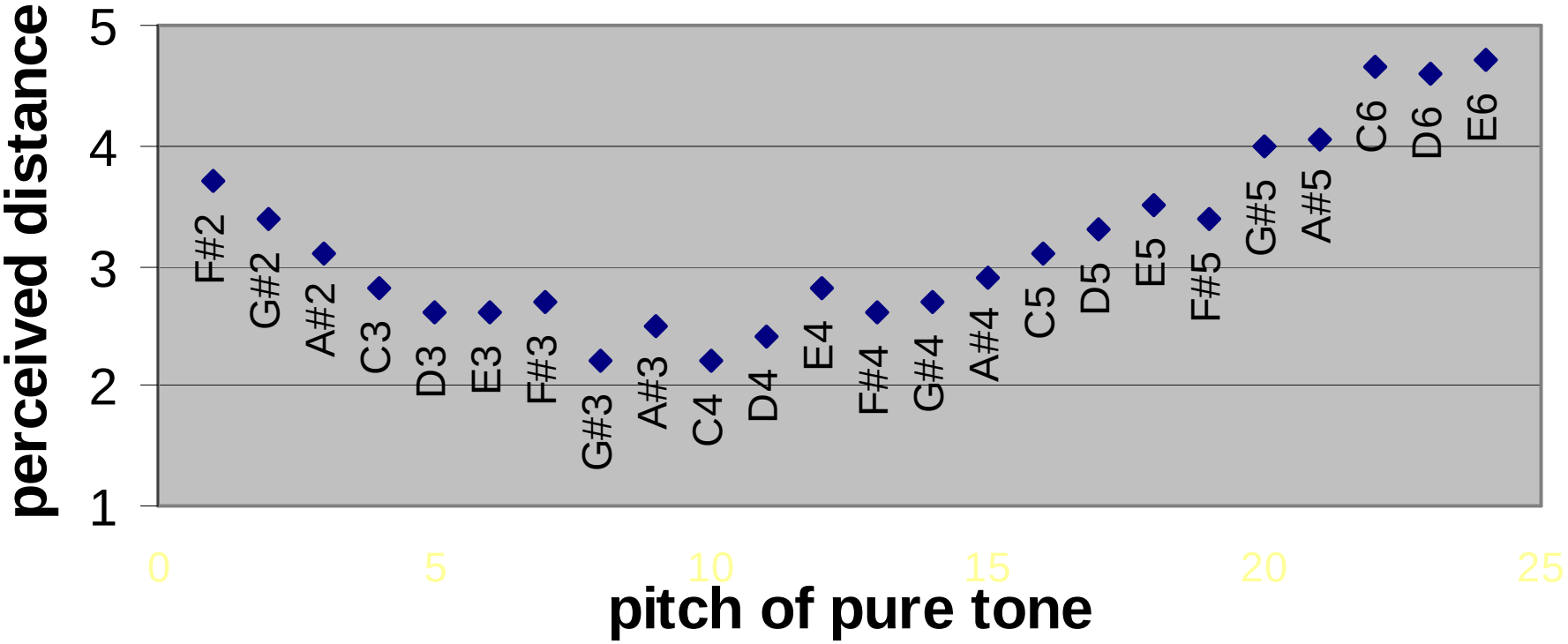
Results: Group 1, Expt 2

How high is the OCT?



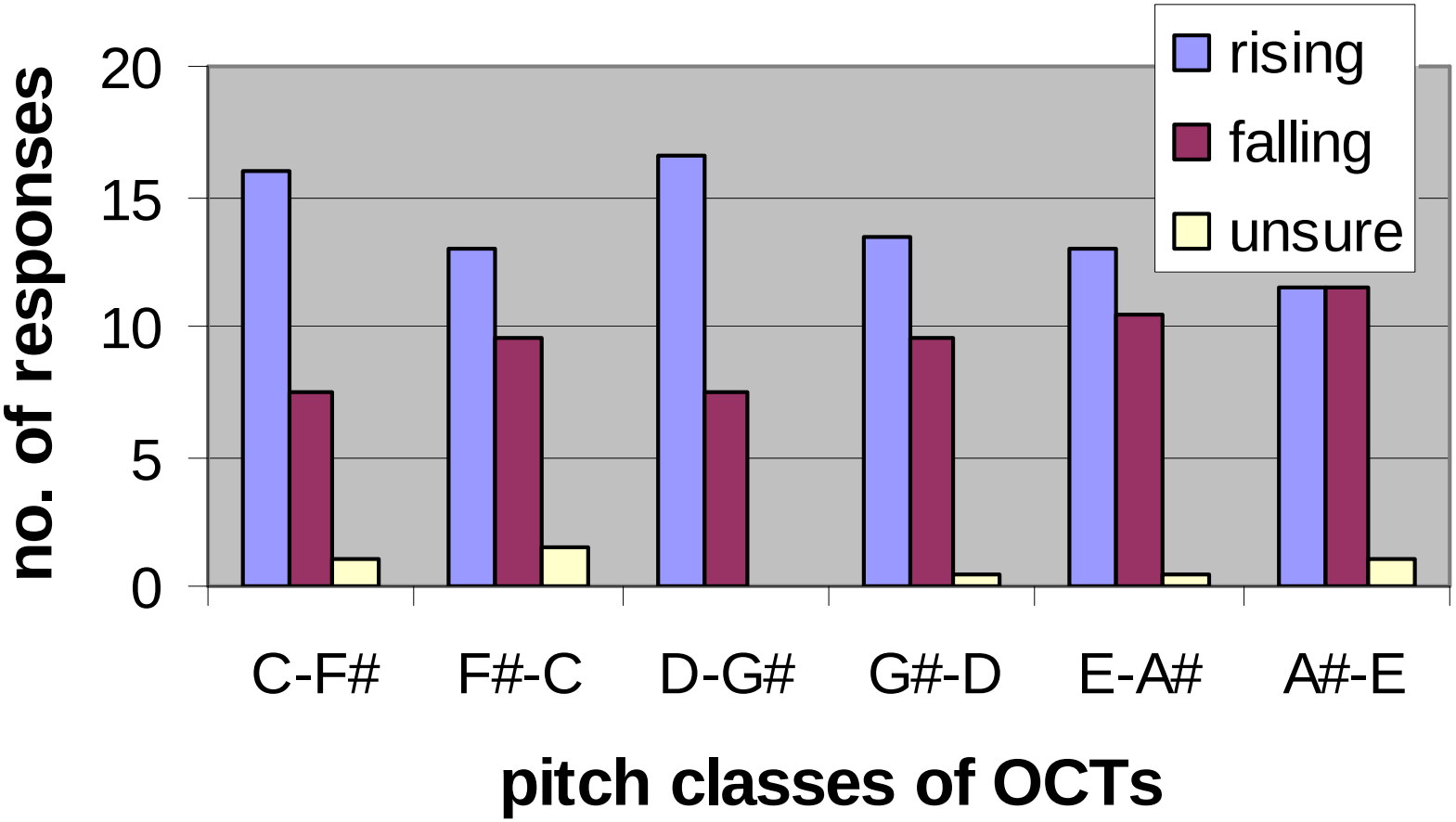
Results: Group 1, Expt 3

Perceived distance between OCT and pure comparison tone



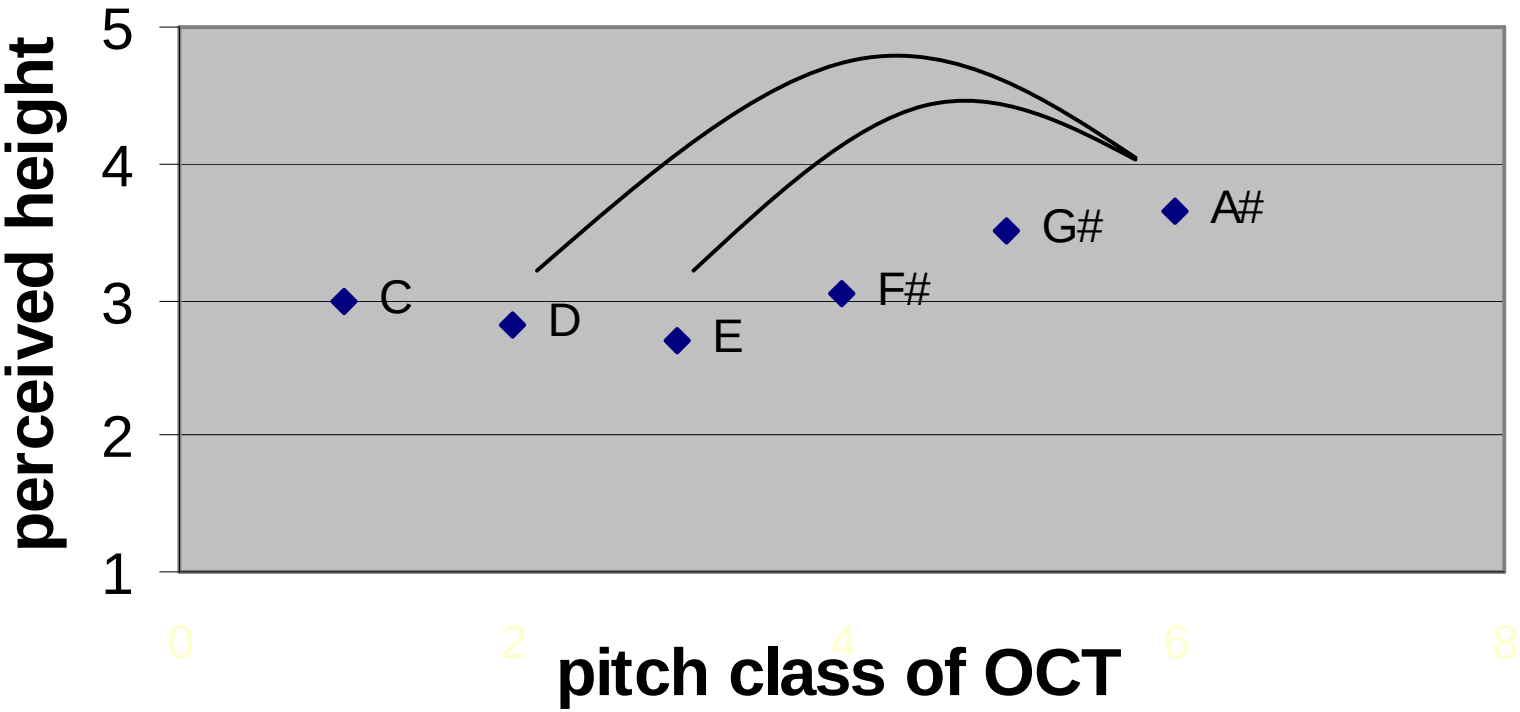
Results: Group 2, Expt 1

Does the melodic tritone rise or fall?



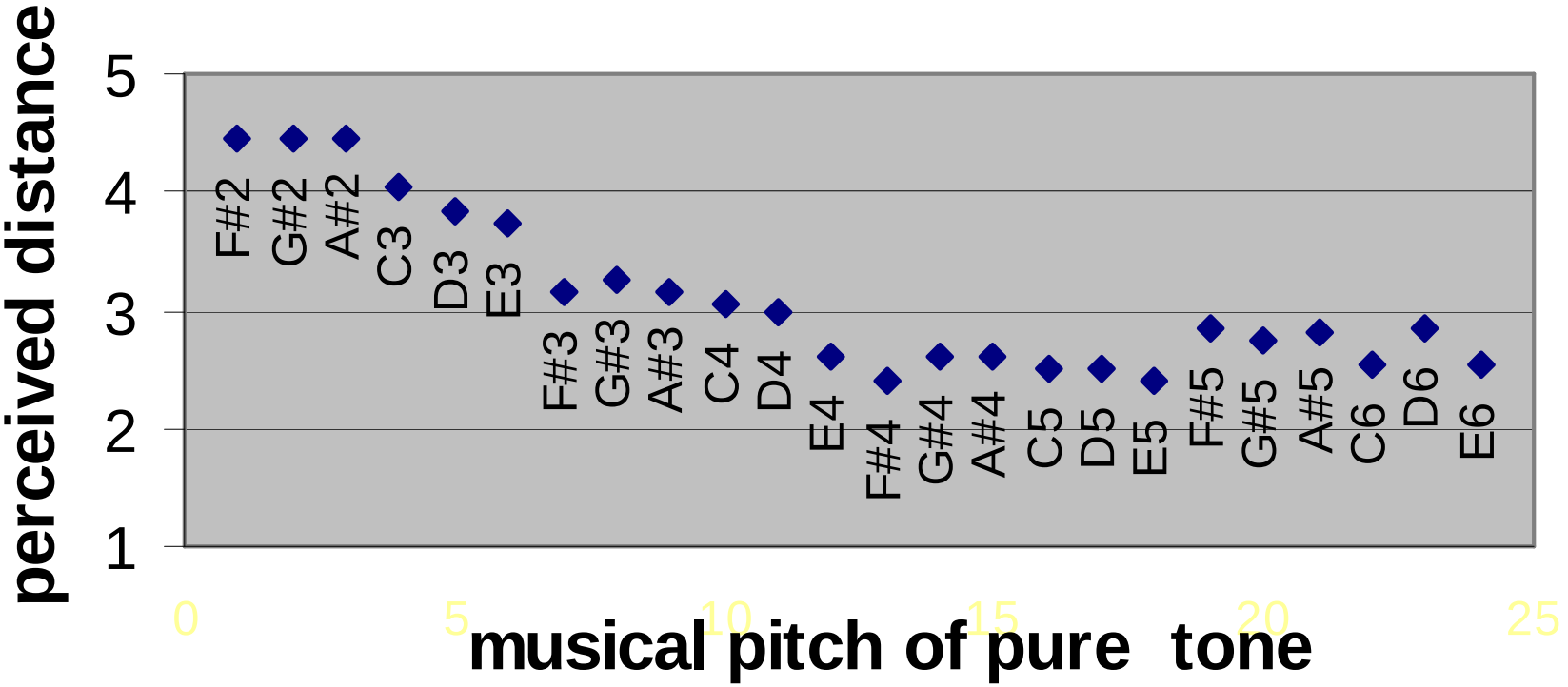
Results: Group 2, Expt 2

How high is the OCT?



Results: Group 2, Expt 3

Perceived distance between OCT and following pure tone



Summary data for all groups

group no.	N	lowest & highest OCTs		register of OCTs	assume listener type
		Expt 1	*Expt 2*	*Expt 3*	
1	11	C - A#	D – A#	3, 4	holistic
2	3	-	-	4, 5, 6	analytic
3	2	A# - F#	-	3, 4	holistic
4	1	D -C	E – A#	3, 4, 5	mixed
5	1	G# - E	-	5?	mixed
6	1	E - C	F# - D	4	holistic
7	1	A# - F#	-	4?	mixed

Conclusions

Holistic listeners (Group 1, N=11):

- hear virtual pitch in registers 3 and/or 4
- pitch register predicts tritone direction

Analytic listeners (Group 2, N=3):

- hear spectral pitches in registers 4-6
- tritone direction unclear
- tendency to hear all intervals rise

Paradox? What paradox?

1. **Some listeners consistently hear tritone rise, others consistently hear it fall.**

Interindividual differences in centre and shape of spectral dominance region or of relationship between spectral and virtual pitch

2. **The same listener hears the same tritone rise or fall on different occasions.**

The pitch of ALL complex tones is ambiguous relative to a 1-D pitch scale

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