National Aeronautics and Space Administration

Vibration penalty estimates for indoor annoyance caused by sonic boom

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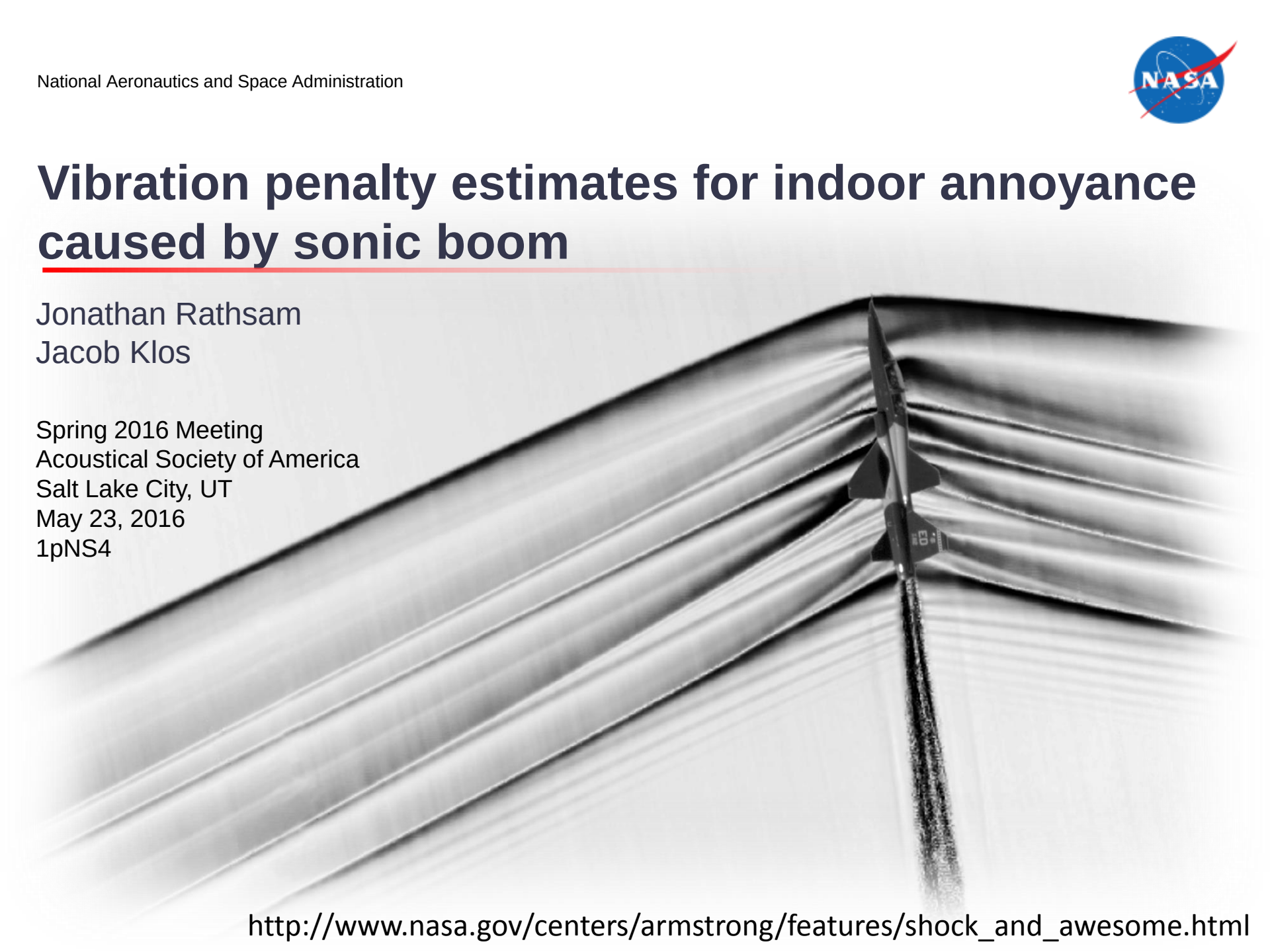
1pNS4



http://www.nasa.gov/centers/armstrong/features/shock_and_awesome.html

Acknowledgments

- NASA Commercial Supersonic Technology Project
  - Alexandra Loubeau, Jerry Rouse, Kevin Shepherd

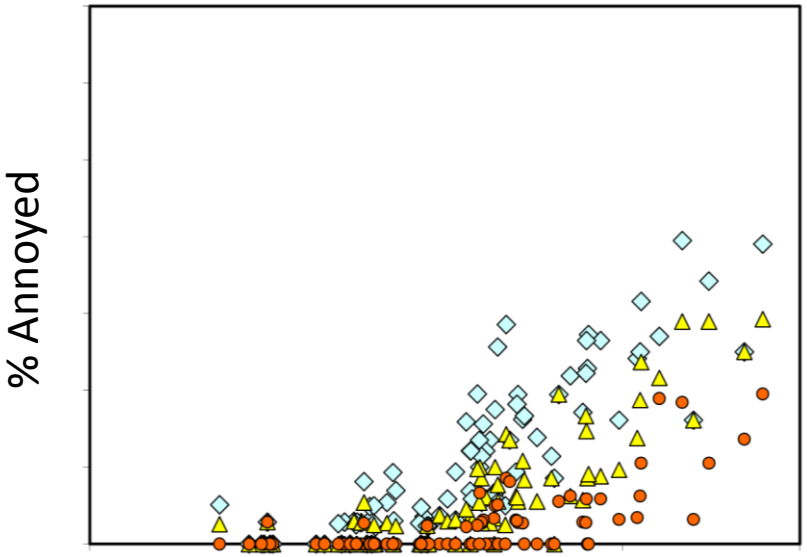
Outline

1. Motivation
2. Simulated vibration method
3. Test matrix
4. Test method
5. Results and conclusions

Motivation

- Aircraft noise regulators (FAA, ICAO) considering allowing commercial supersonic flight

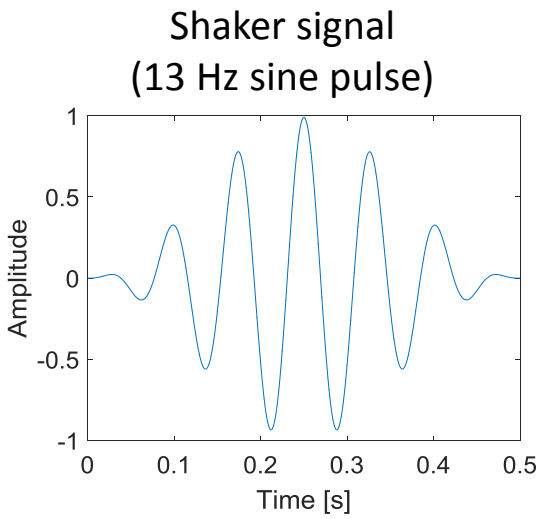
- Community annoyance prediction model
  -Link predicted booms to community annoyance
  -Support new regulations
  -Support aircraft designers



[Fidell, et al. 2012]

Laboratory Study

- Is there a vibration penalty?
  - increment in sound level that yields same annoyance increment as realistic vibration
- If so, how great?

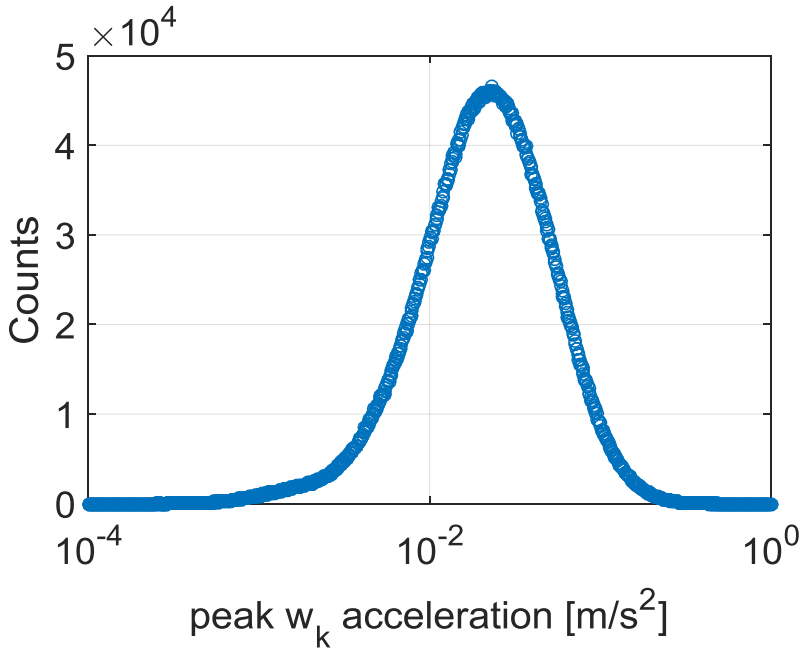


Test Matrix

Signature	Exterior PL [dB]	Peak w_k acceleration [m/s^2]	
Small Airliner	75		
Large Airliner	76		
X-plane (A)	76		
Business Jet (A)	77		
Business Jet (B)	79		
X-plane (B)	80		
X-plane (C)	84		

Simulated Vibration Data

- Vibration predicted across 6000 virtual buildings
- Lognormal distribution fit to data



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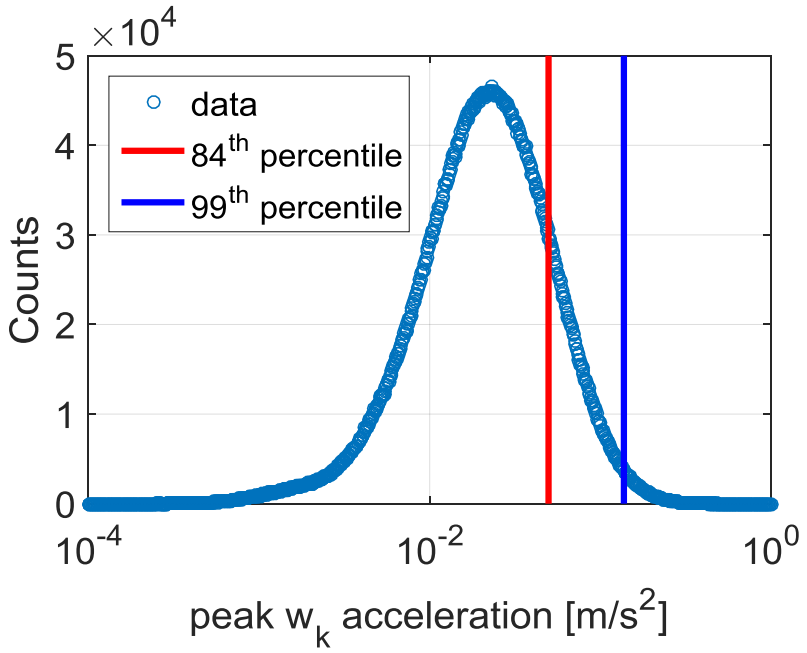

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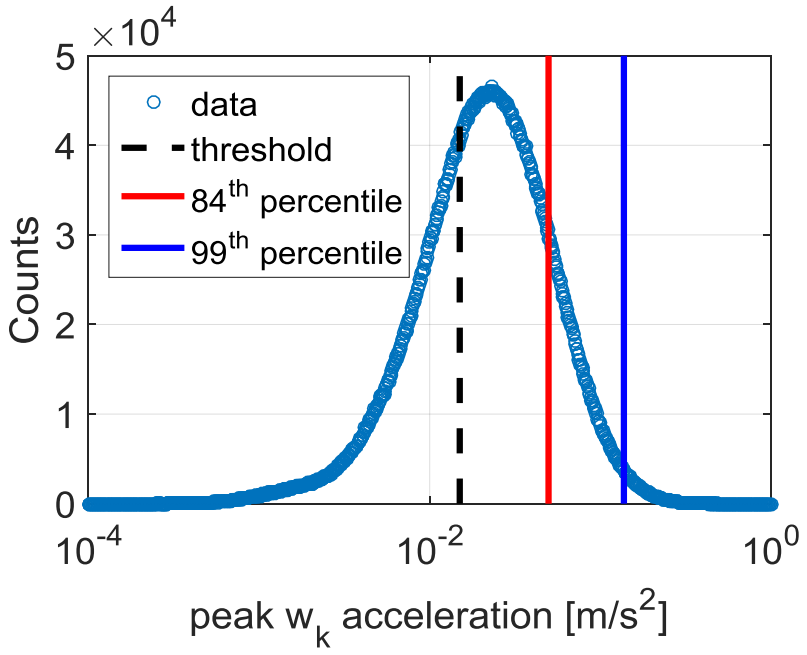


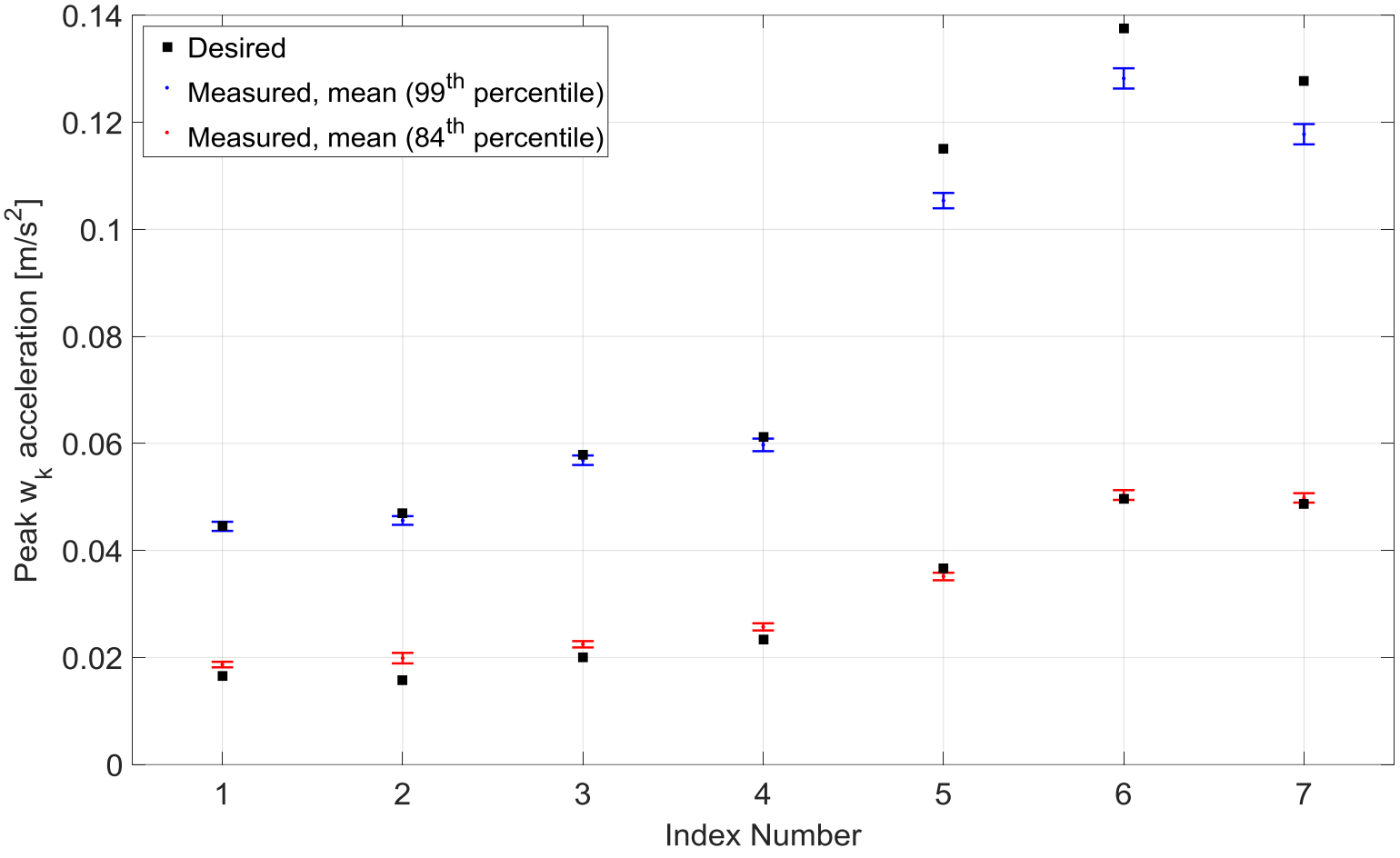
Test Matrix

Signature	Exterior PL [dB]	Peak w_k acceleration [m/s^2]	
		84th percentile	99th percentile
Small Airliner	75	0.017	0.045
Large Airliner	76	0.016	0.047
X-plane (A)	76	0.020	0.058
Business Jet (A)	77	0.023	0.061
Business Jet (B)	79	0.037	0.115
X-plane (B)	80	0.050	0.138
X-plane (C)	84	0.050	0.128

Comparison with Previous Lab Research

	Acoustics		Vibration		
	Frequency (Hz)	Level	Frequency (Hz)	Level (m/s^2)	Level (VDV) $m/(s^{1.75})$
Current Study (Quiet Sonic Booms)	1 – 2000 (impulsive, peak ~10 Hz)	61 – 69 (dB, ASEL)	13 Hz (impulsive)	0.02 – 0.16	0.008 – 0.065
Leatherwood 1979 (Aircraft Cabin Noise)	63 – 2000 (octave band noise)	76 – 94 (dBA, SPL)	3,6,9,12 Hz	1.04 – 3.14 (at 12 Hz)	
Howarth and Griffin 1991 (Railway noise)	20 – 3000 (pink noise)	52.5 – 77 (dB, ASEL)	10 – 60 Hz		0.056 – 0.4

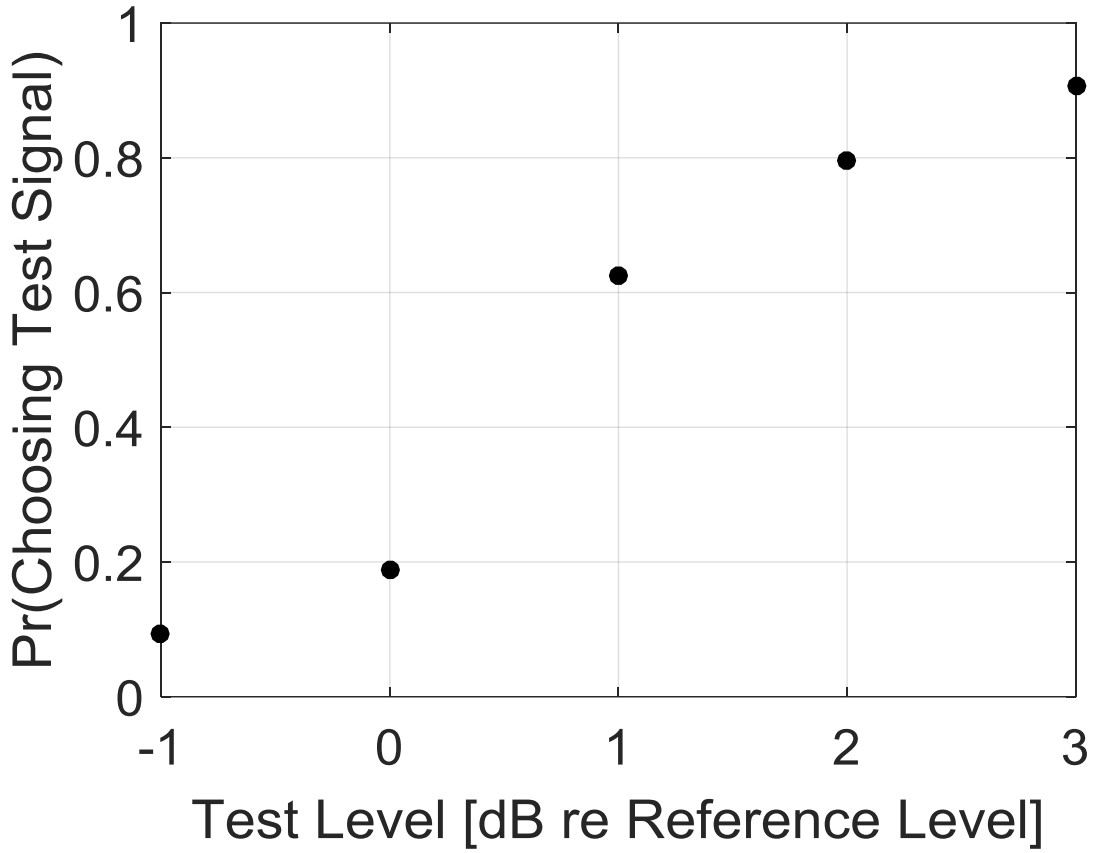
Measured Chair Acceleration



Error bars indicate standard error of the mean

Test Method

Reference contains sound *and* vibration
Test contains sound alone



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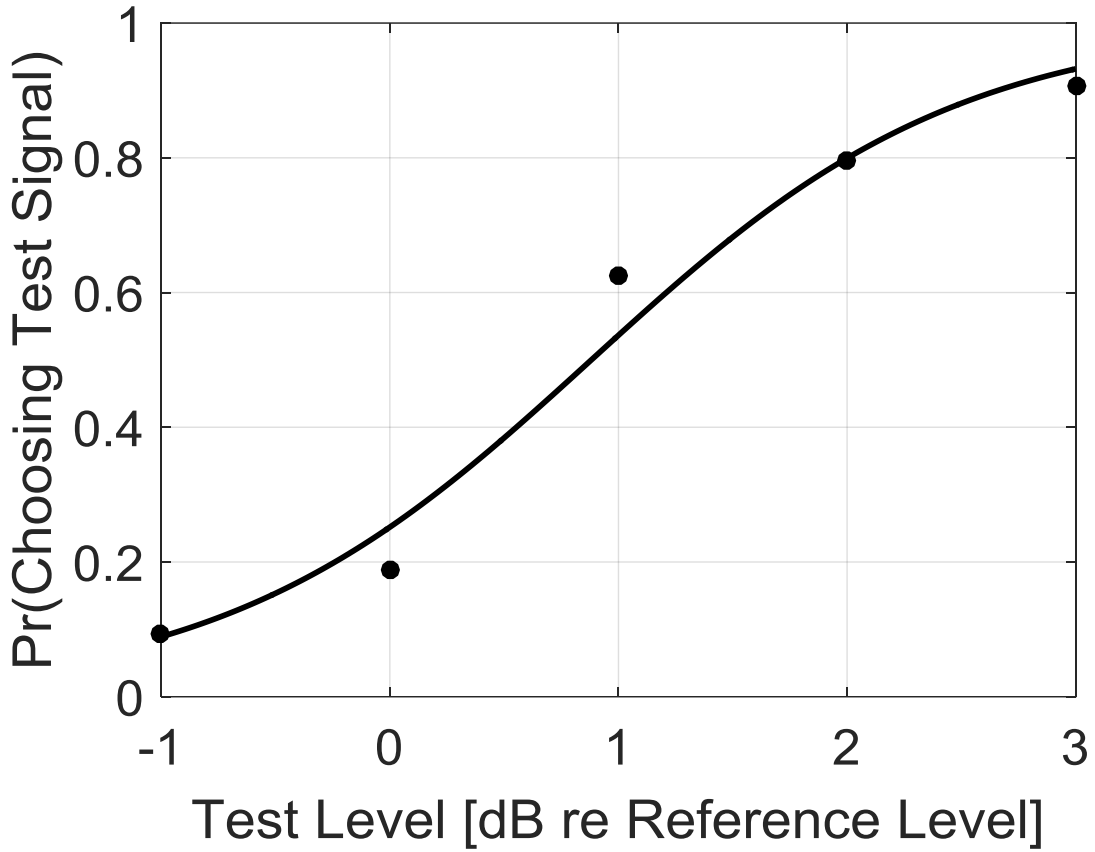

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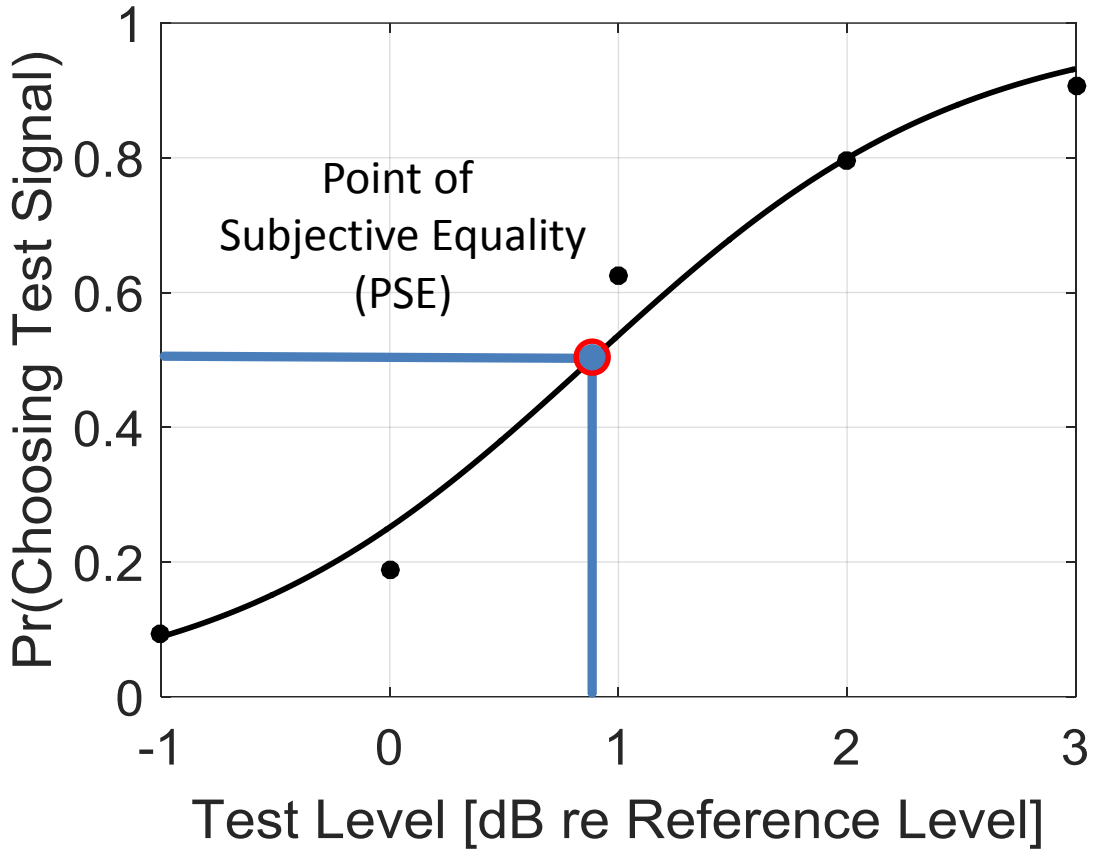

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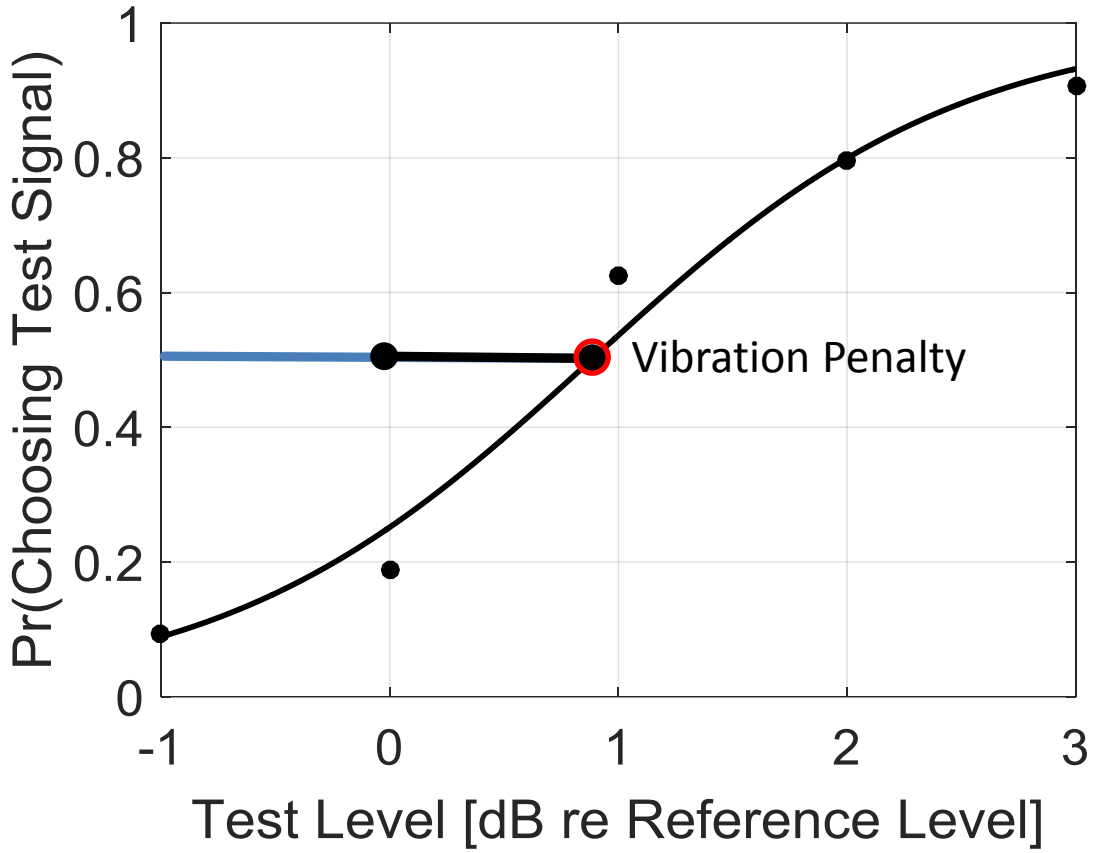

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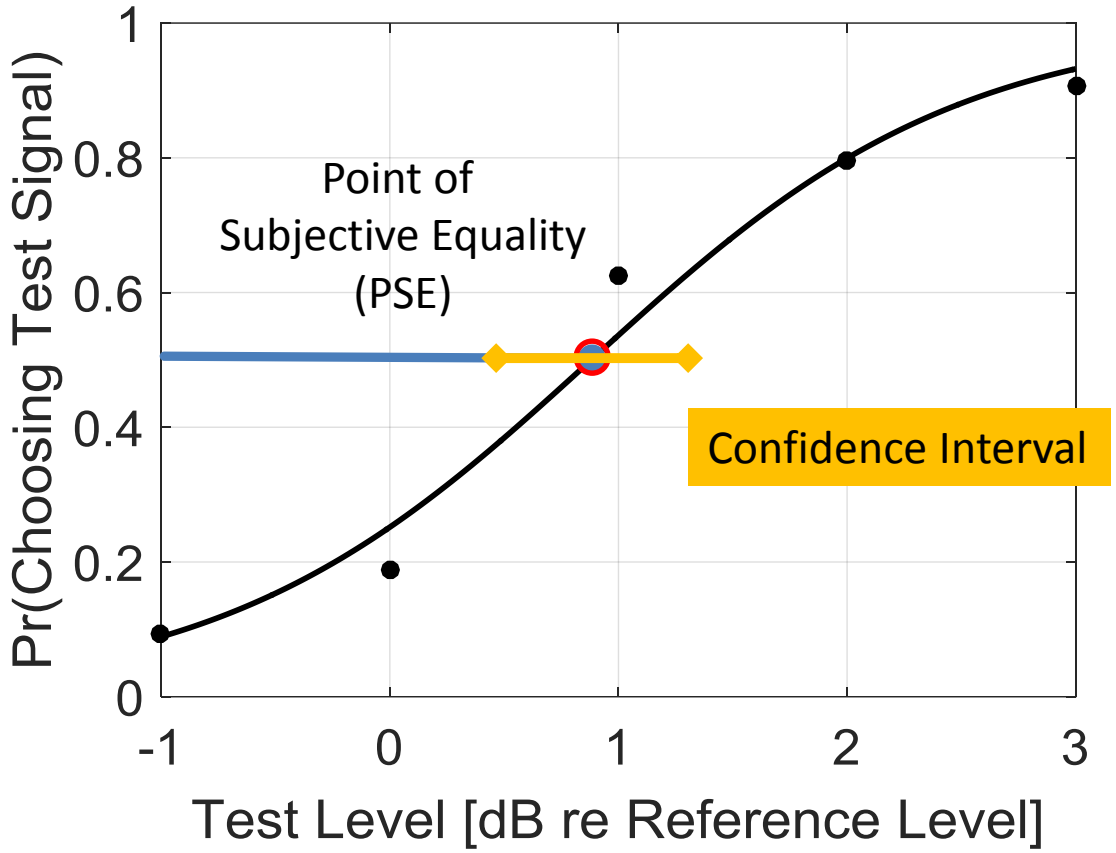
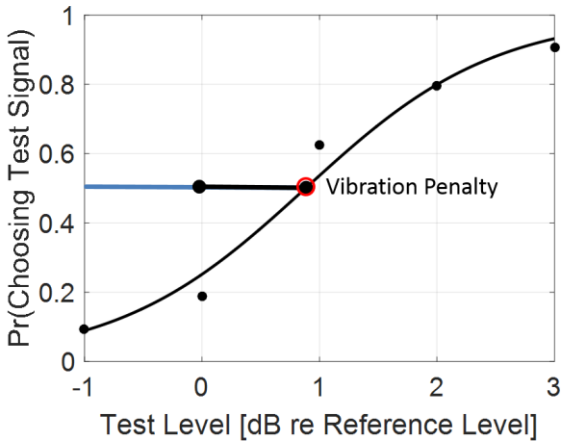
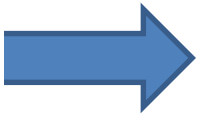
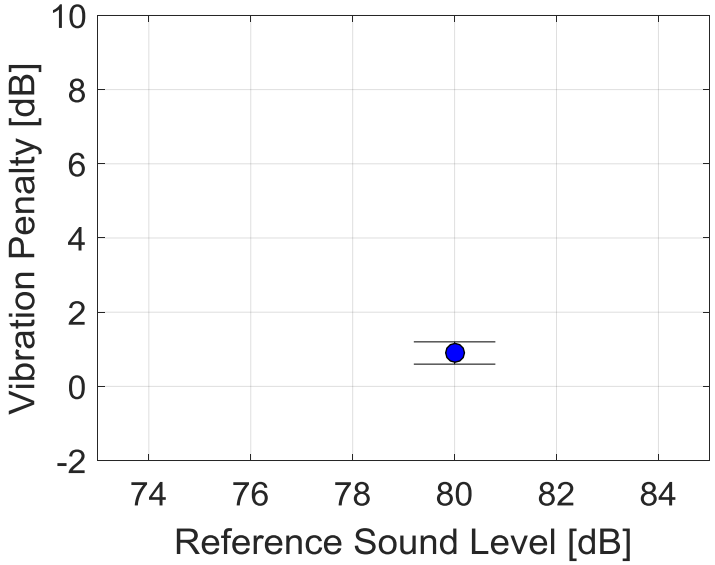


Research Question Revisited



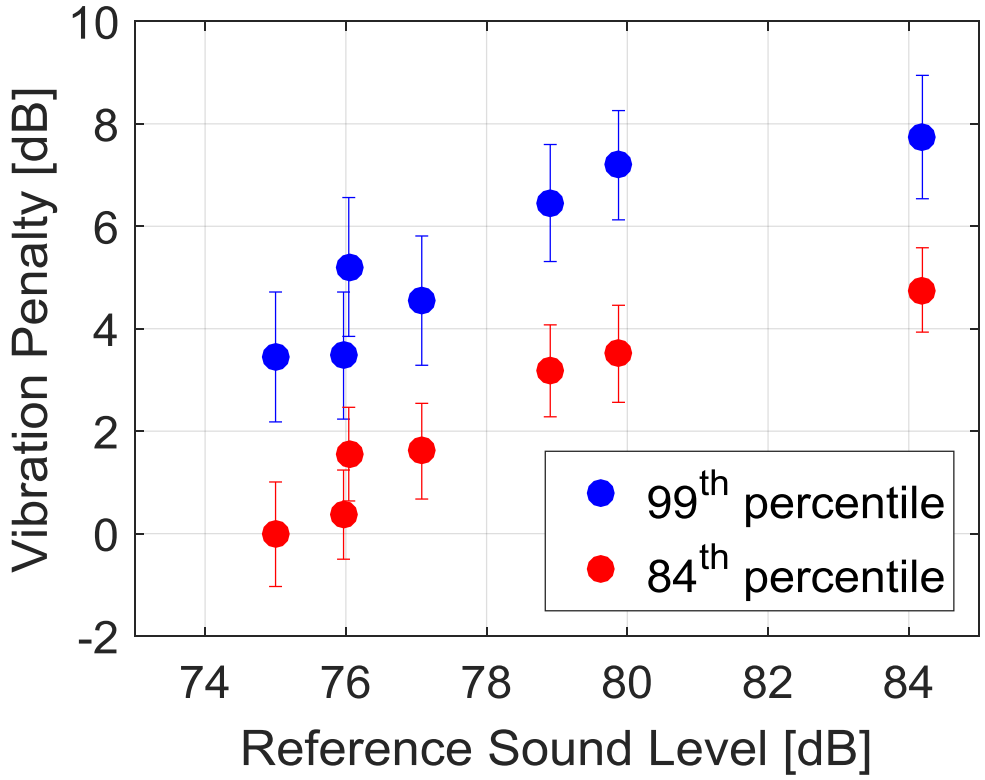




Research Question Revisited

- Is there a vibration penalty? Yes

  0 – 5 dB for lower vibration and 4 – 8 dB for higher vibration



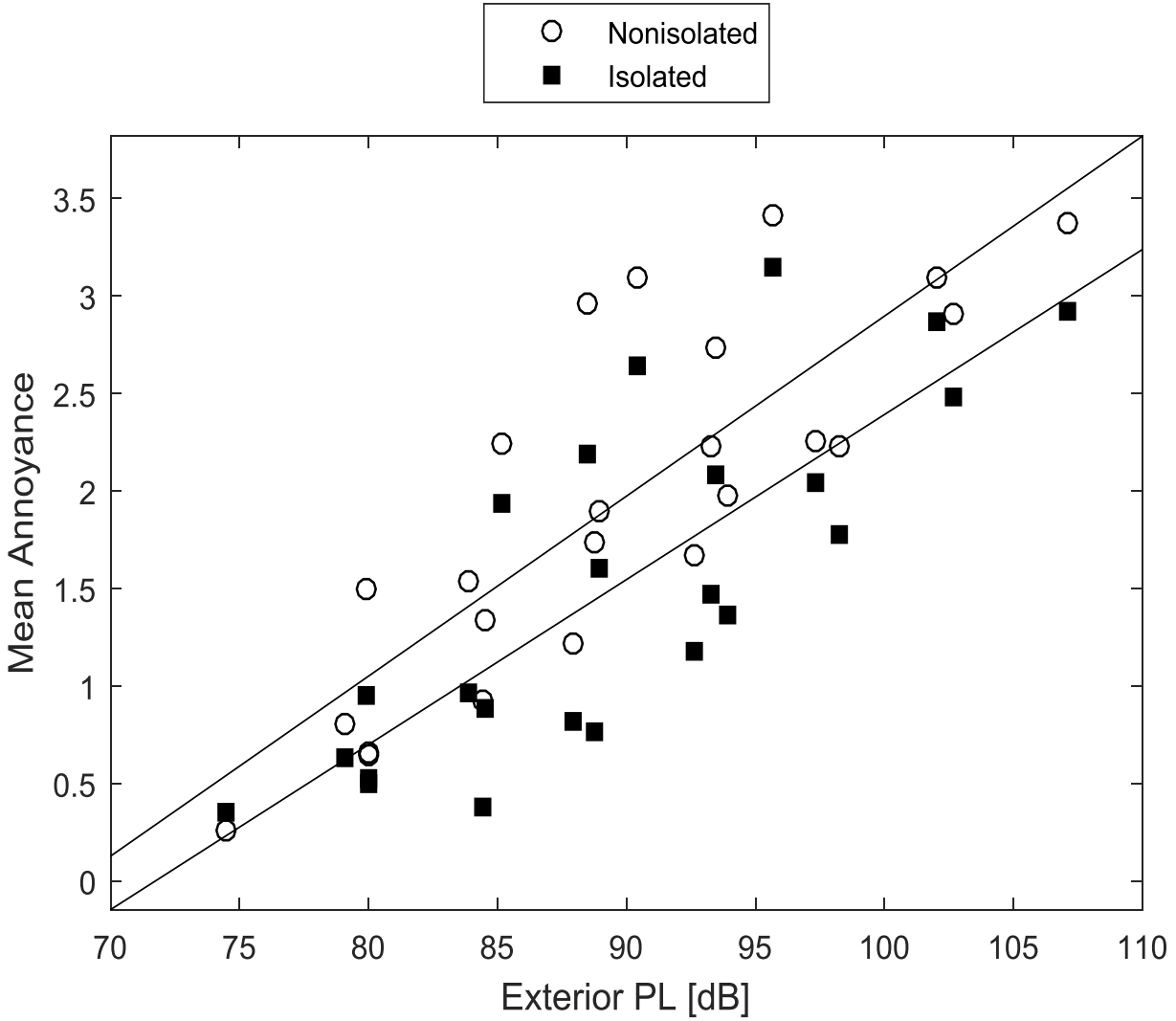
Thank You

References:

- Fidell, S. et al. “Pilot Test of a Novel Method for Assessing Community Response to Low-Amplitude Sonic Booms” NASA/CR-2012-217767 (2012).
- Henne, P.A. “Case for Small Supersonic Civil Aircraft” *Journal of Aircraft* 42 (3) 765-774 (2005).
- Howarth, H.V.C. and M.J. Griffin, “The annoyance caused by simultaneous noise and vibration from railways,” J. Acoust. Soc. Am., 89(5), 2317-2323, (1991).
- Leatherwood, J.D. “Human Discomfort Response to Noise Combined with Vertical Vibration,” NASA Technical Paper 1374 (1979).

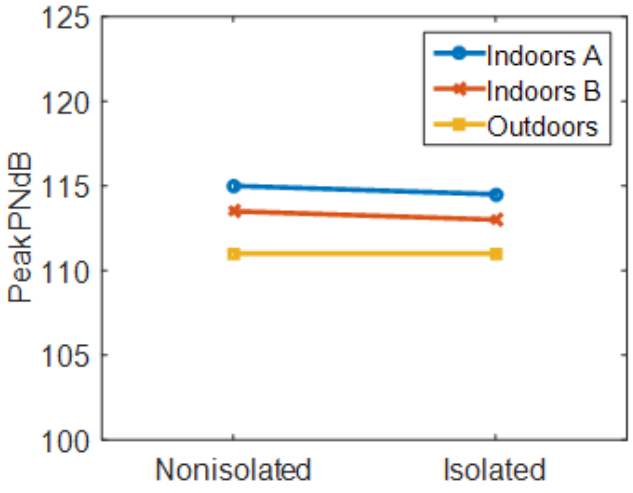
Backup Slides

Motivation (2 of 2)

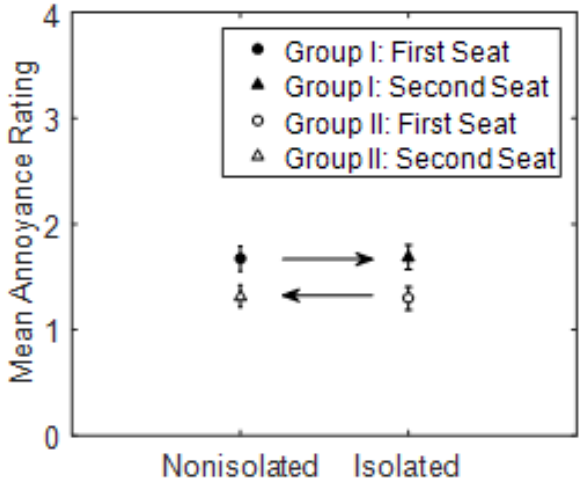


Are vibrations from a sonic boom annoying?

- "…sonic booms experienced inside were less acceptable than those experienced outside presumably because of …the rattling and shaking of items within the structure, and the *actual vibration of the structure itself.*" [Nixon and Borsky 1966]



Kryter, et al. 1968



Rathsam, et al. 2014

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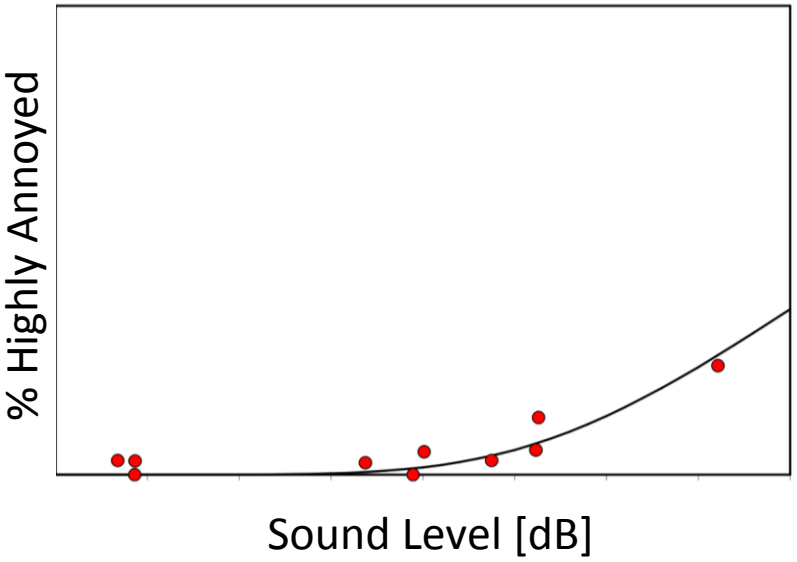

Fidell, et al. 2012

Measured Acceleration