Developmental Systems Neuroscience: Language and the Infant Brain

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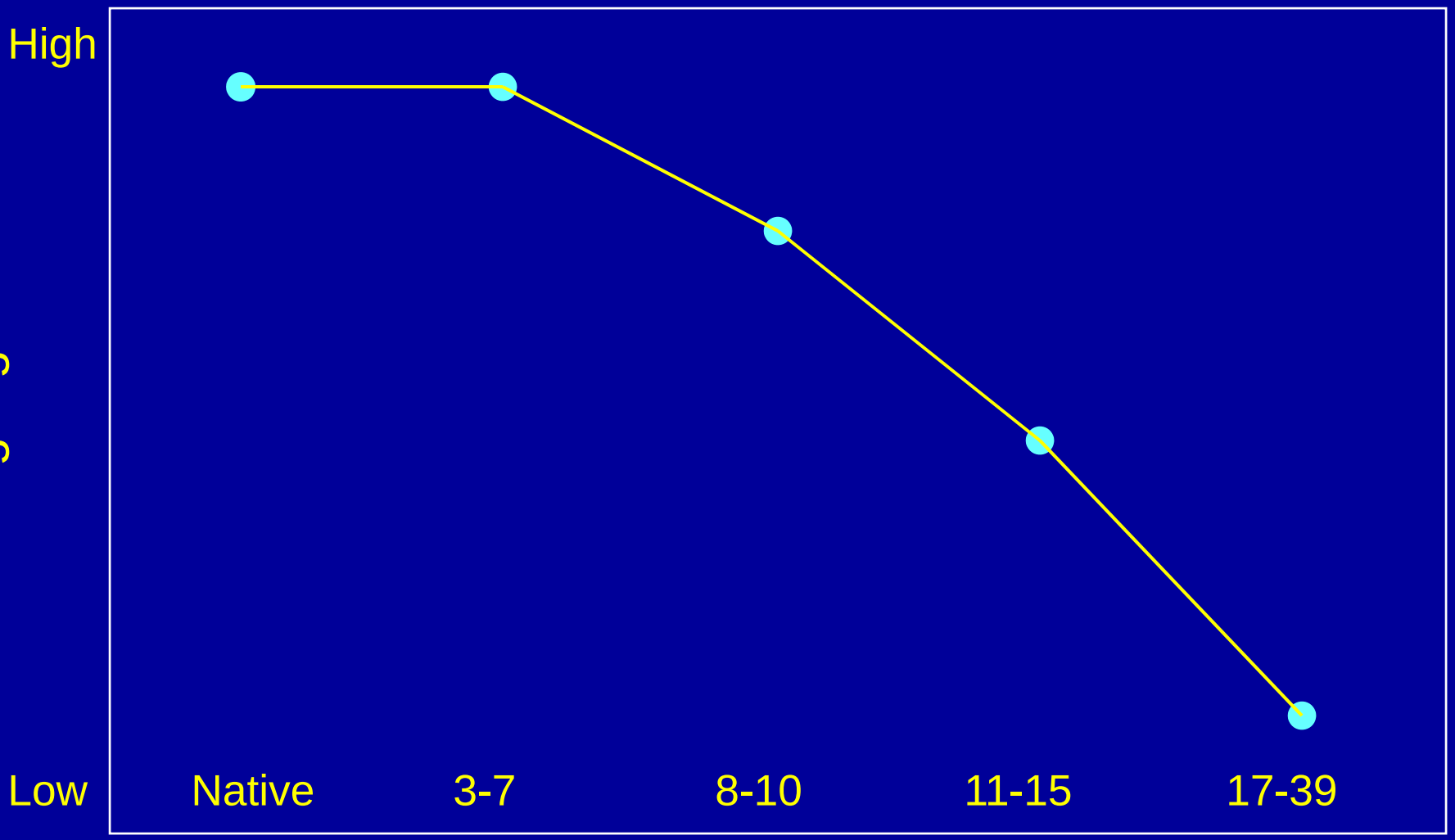
Director, NSF Science of Learning Center (LIFE)
Bezos Family Endowed Chair in Early Childhood Learning

Language Exhibits a ‘Critical Period’



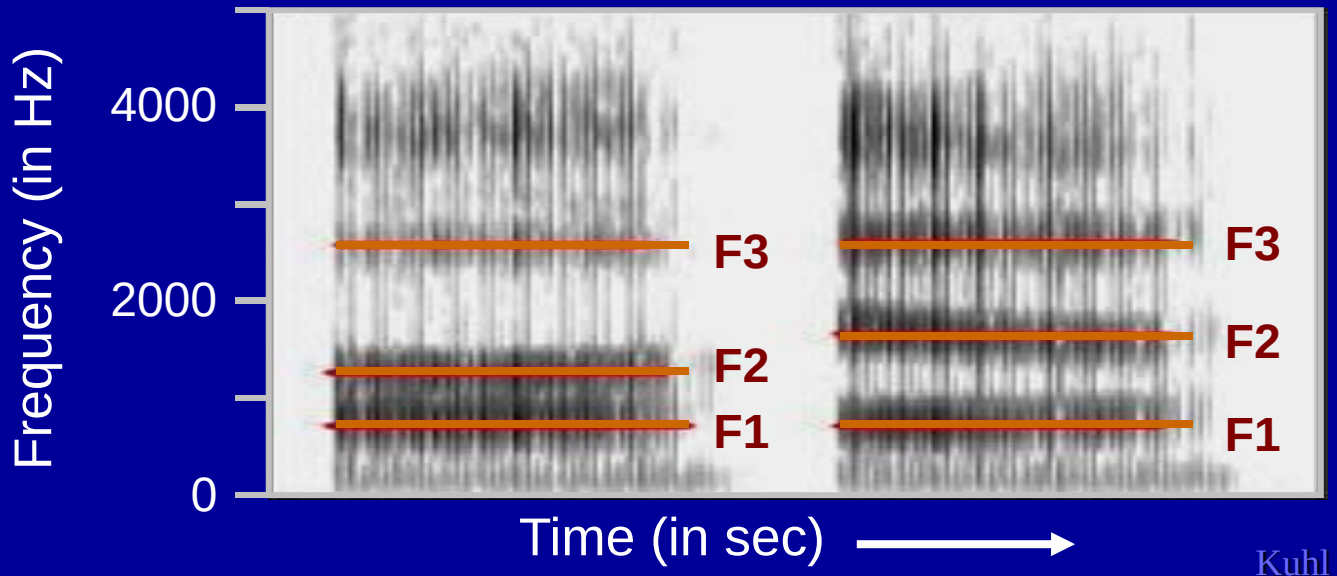
Johnson & Newport, 1989

How Speech is Produced

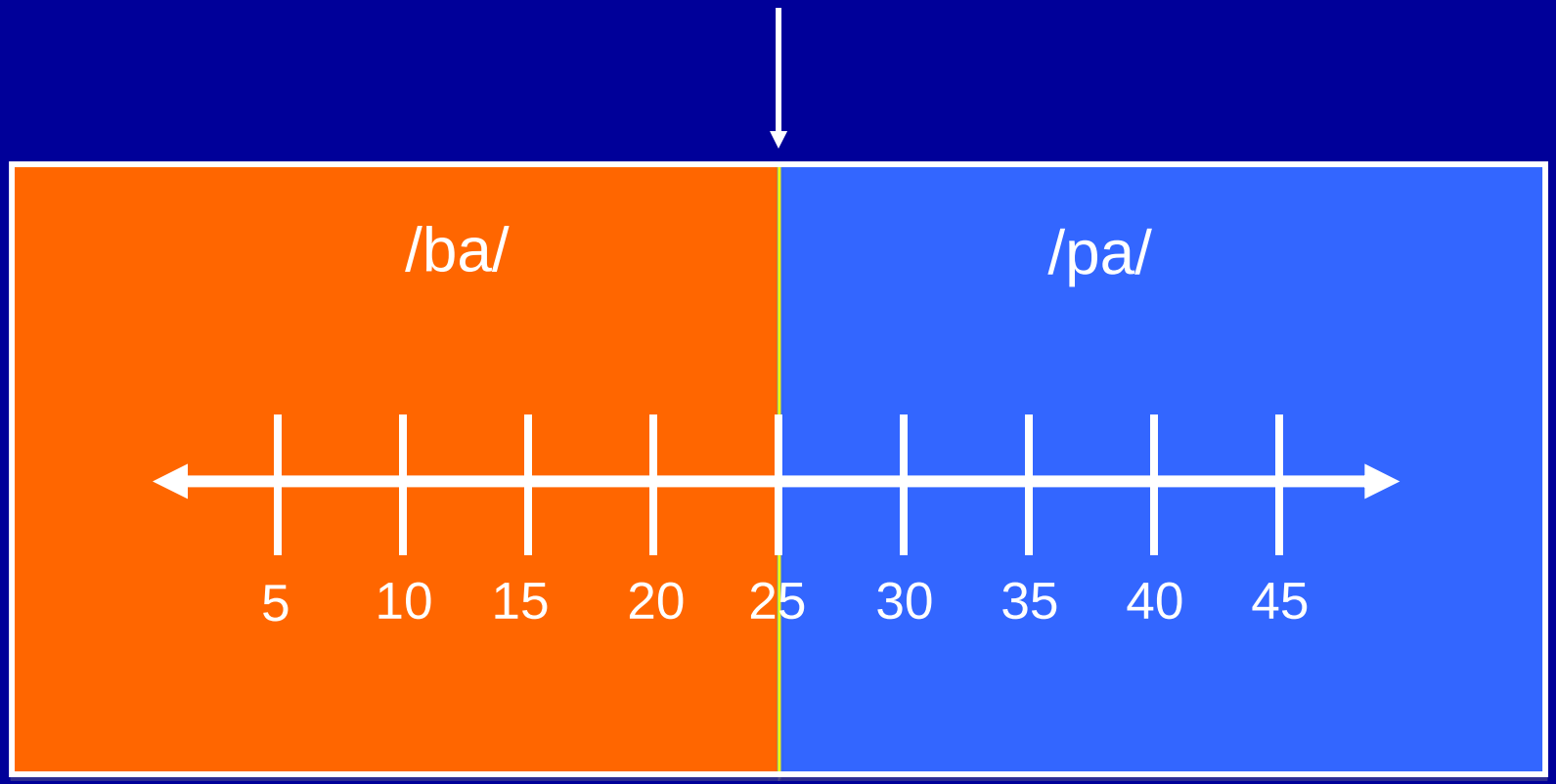
/a/

/ae/

Physics of Sound

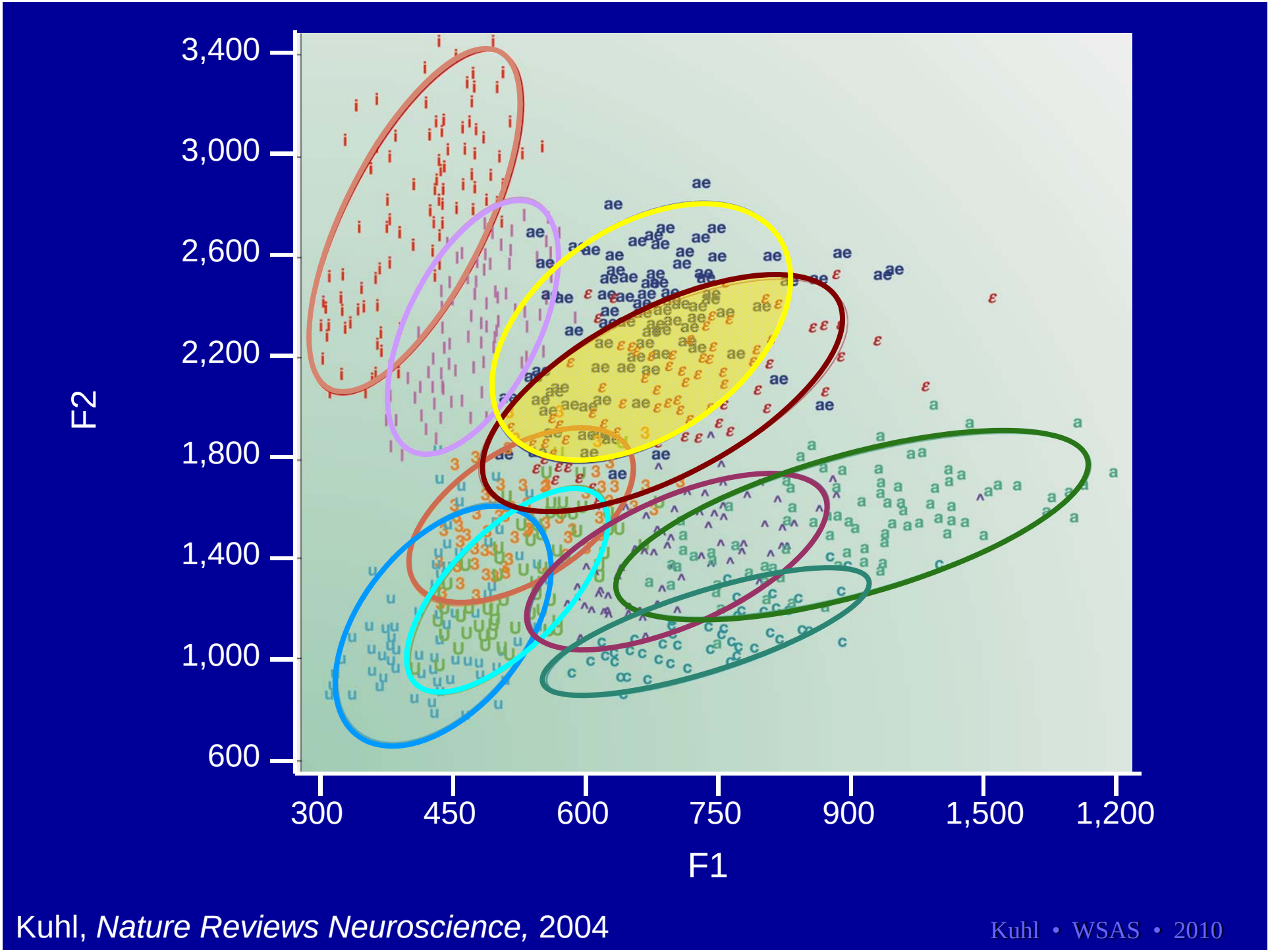


Phonetic Boundary



Critical cue — Voice onset time

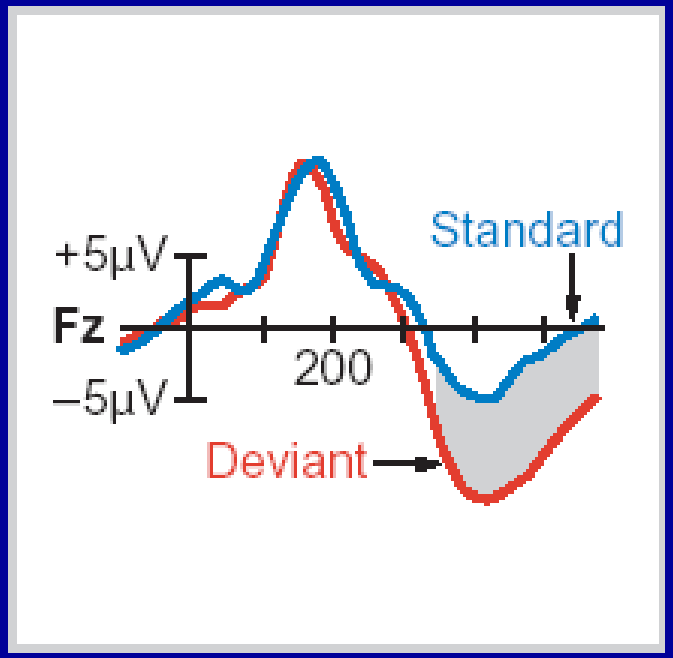
Infant data -- Eimas et al, *Science*, 1971
Animal data -- Kuhl & Miller, *Science*, 1975



Kuhl, *Nature Reviews Neuroscience,* 2004

Brain Measures of Speech Discrimination

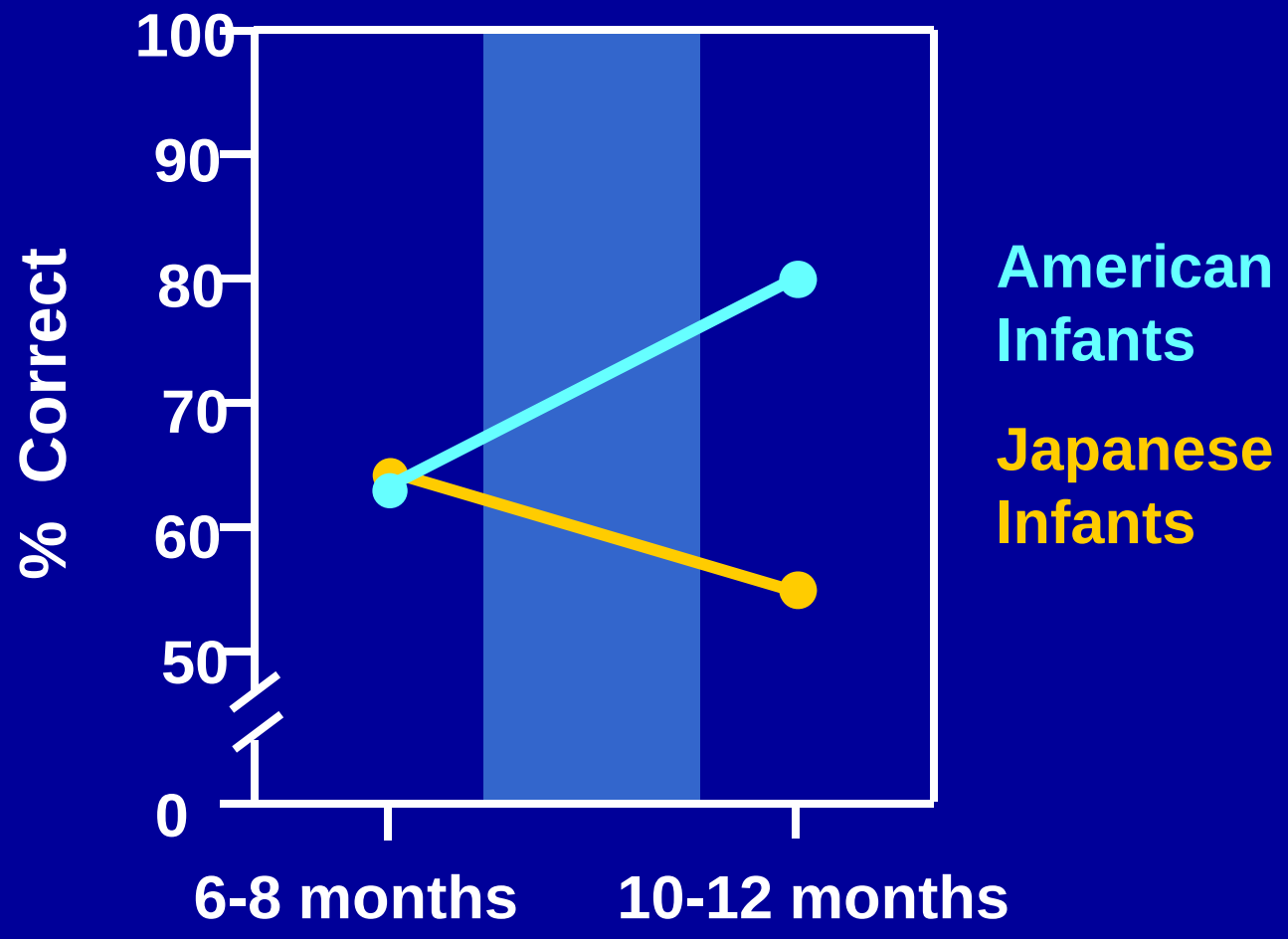
Event-related Potentials (ERPs)



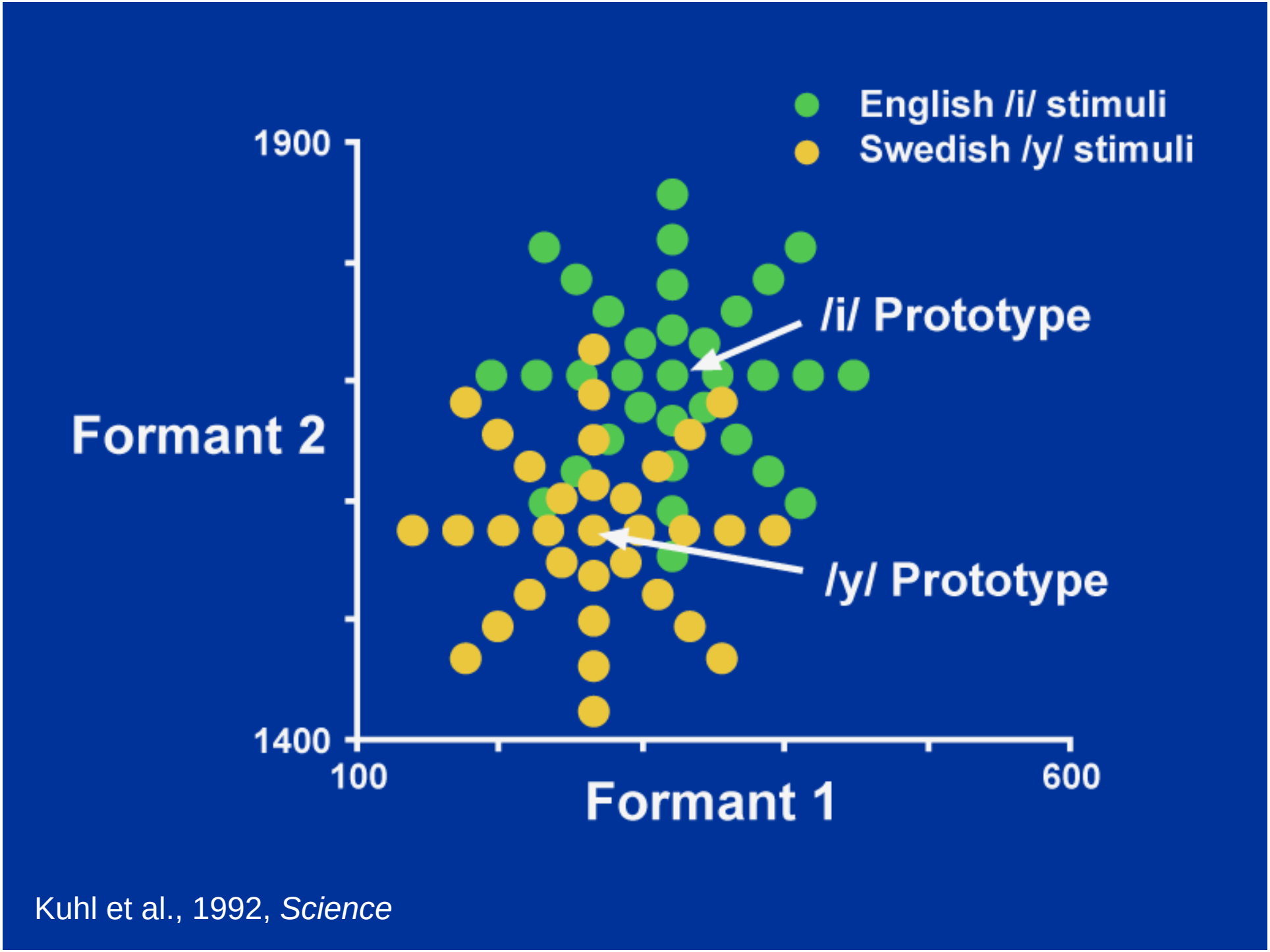
Mismatch Negativity (MMN)

Rivera-Gaxiola, Silva-Pereyra, & Kuhl, *Developmental Science,* 2005

Infant perception of /ra/-/la/



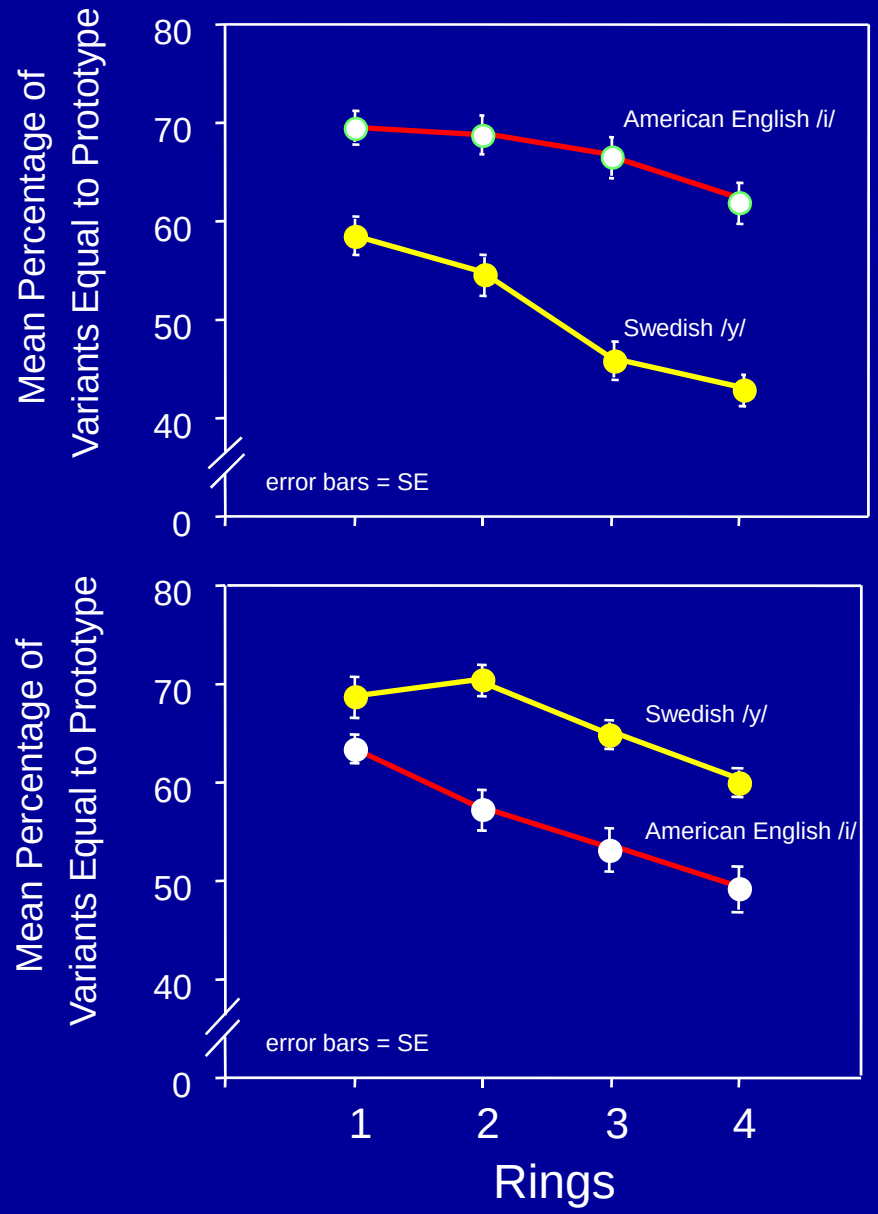
Kuhl et al., *Developmental Science*, 2006



Kuhl et al., 1992, *Science*

American Infants

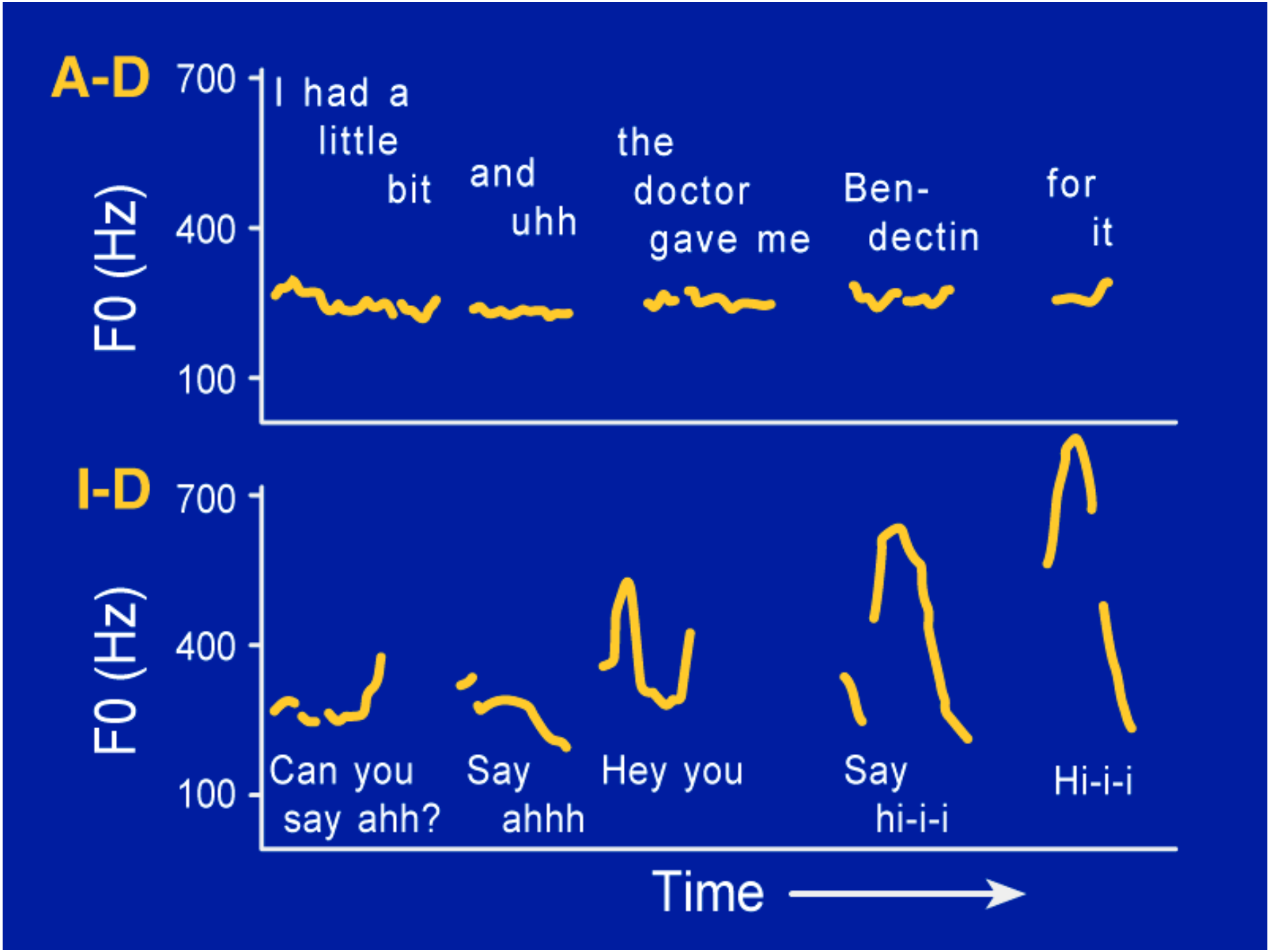
Swedish Infants

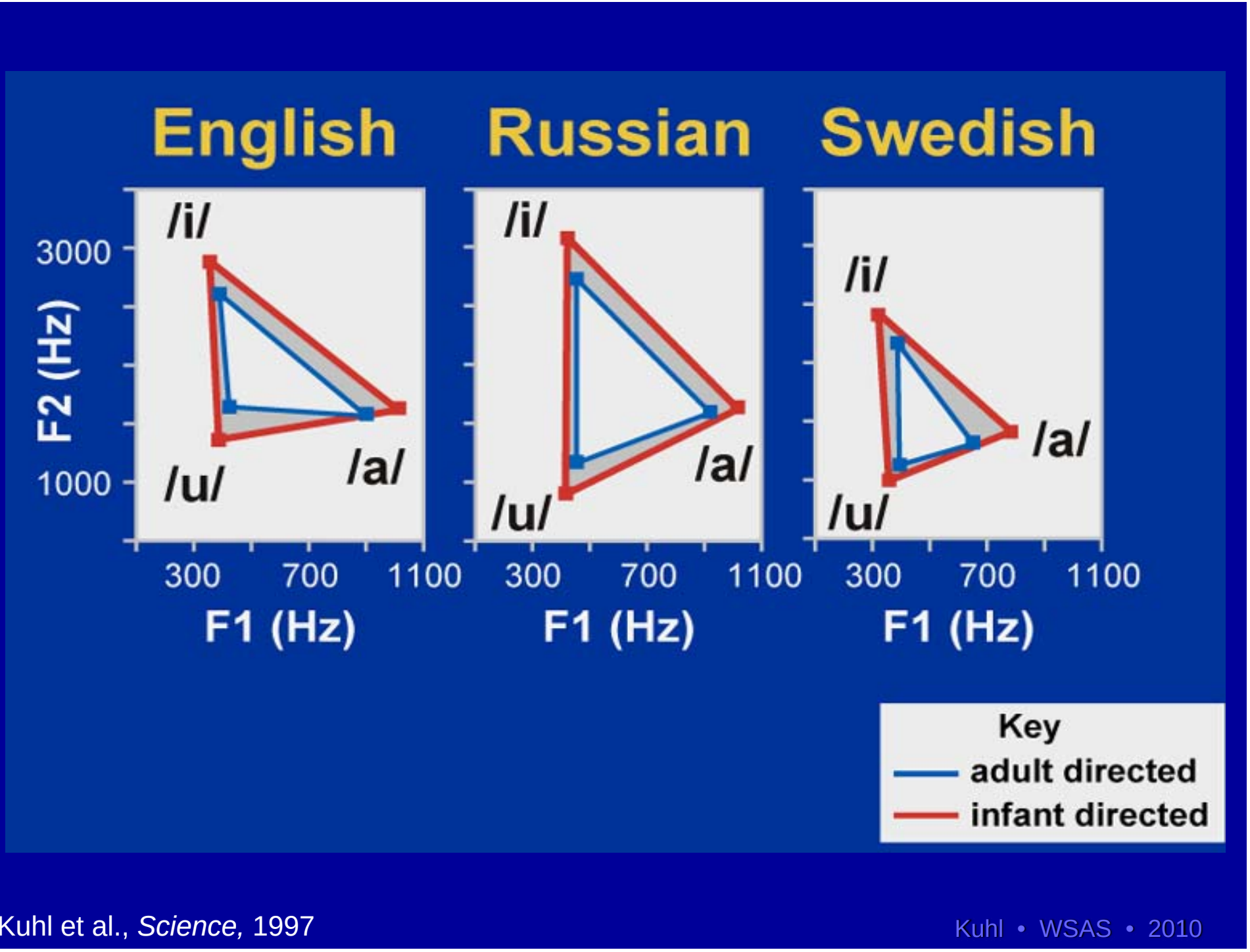


Kuhl et al., 1992, *Science*

Working Hypothesis: Computational skills are ‘gated’ by social interaction

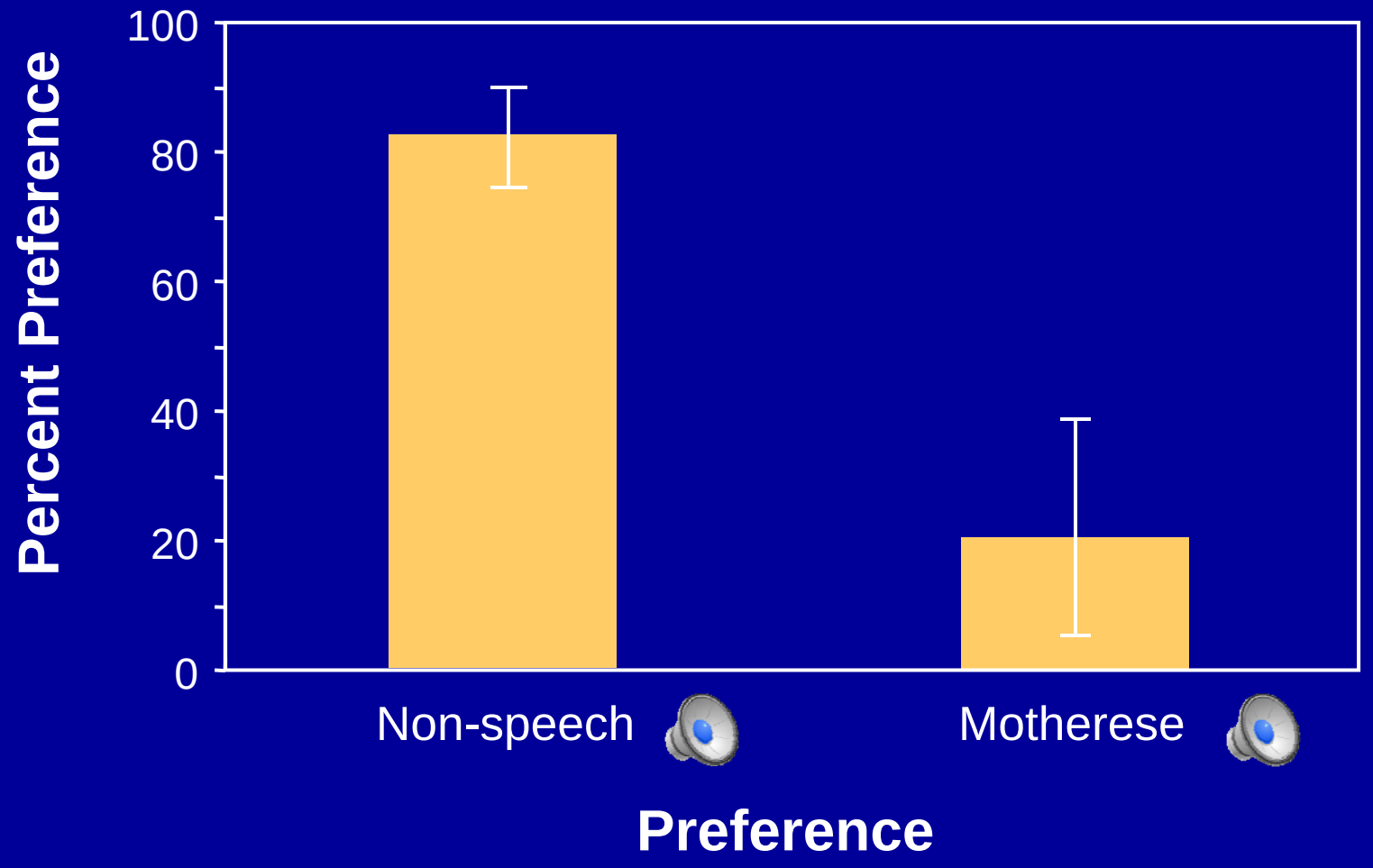

SPL


A-D
700
400
100
F0 (Hz)
I had a little bit
and uhh
the doctor gave me
Ben- dectin
for it
I-D
700
400
100
F0 (Hz)
Can you say ahh?
Say ahhh
Hey you
Say hi-i-i
Hi-i-i
Time



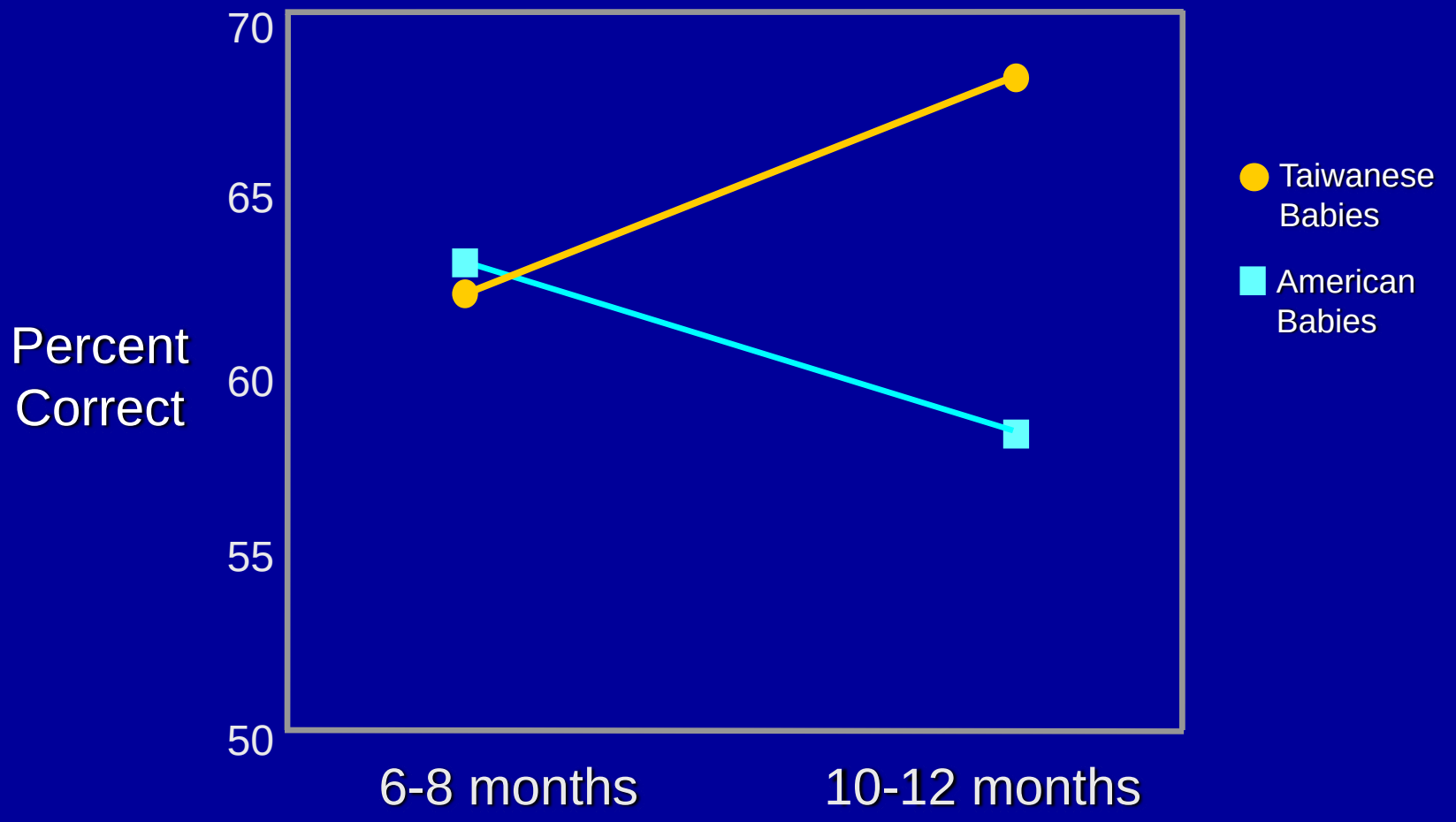
Kuhl et al., *Science,* 1997

Preference for speech in children with Autism



Kuhl et al., *Developmental Science*, 2005

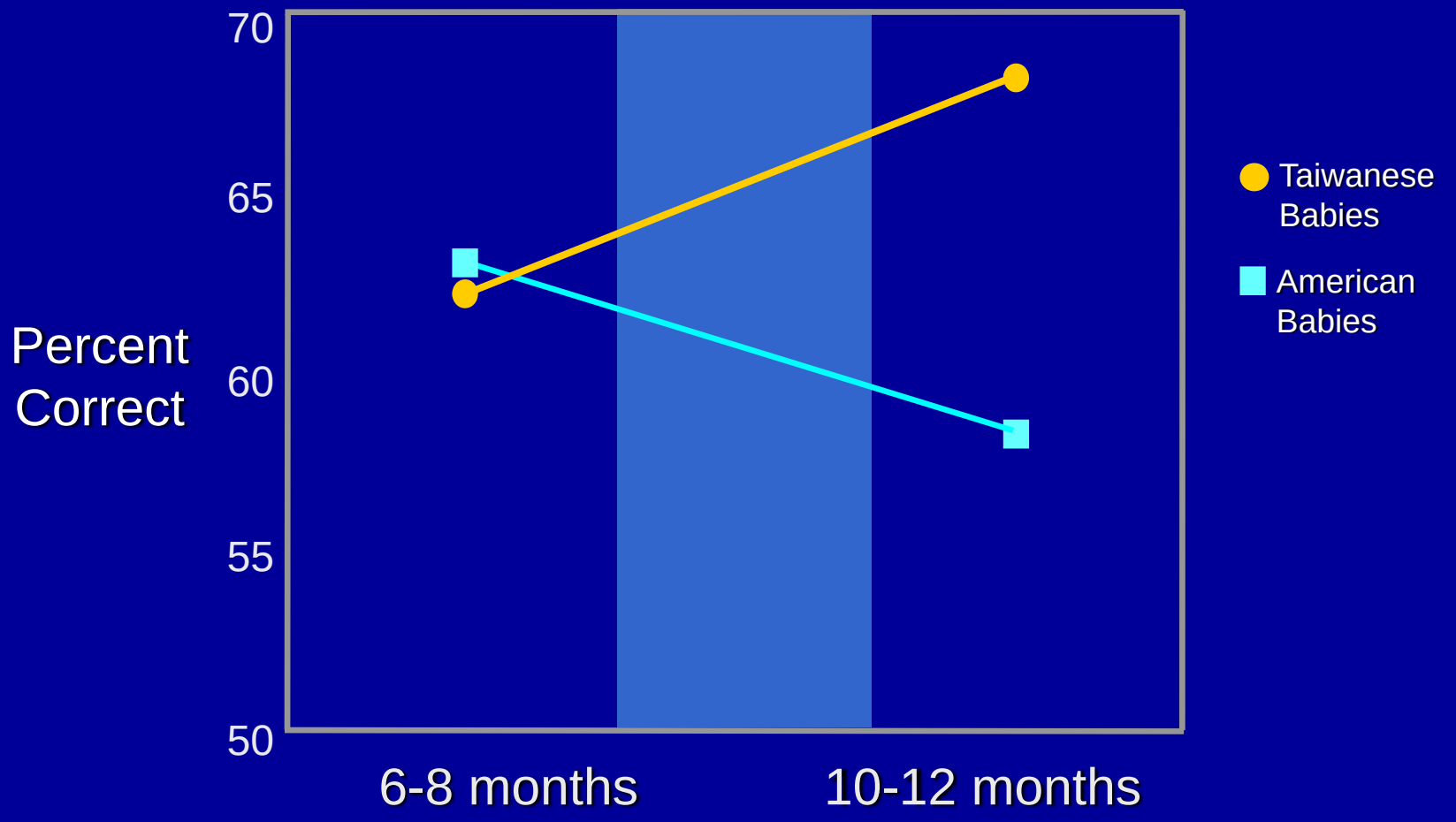
Typical Developmental Pattern Between 6 and 12 Months on Mandarin Chinese Sounds



Kuhl, Tsao & Liu, *Proceedings of the National Academy of Sciences, 2003*

Expose infants to Mandarin Chinese in natural setting:

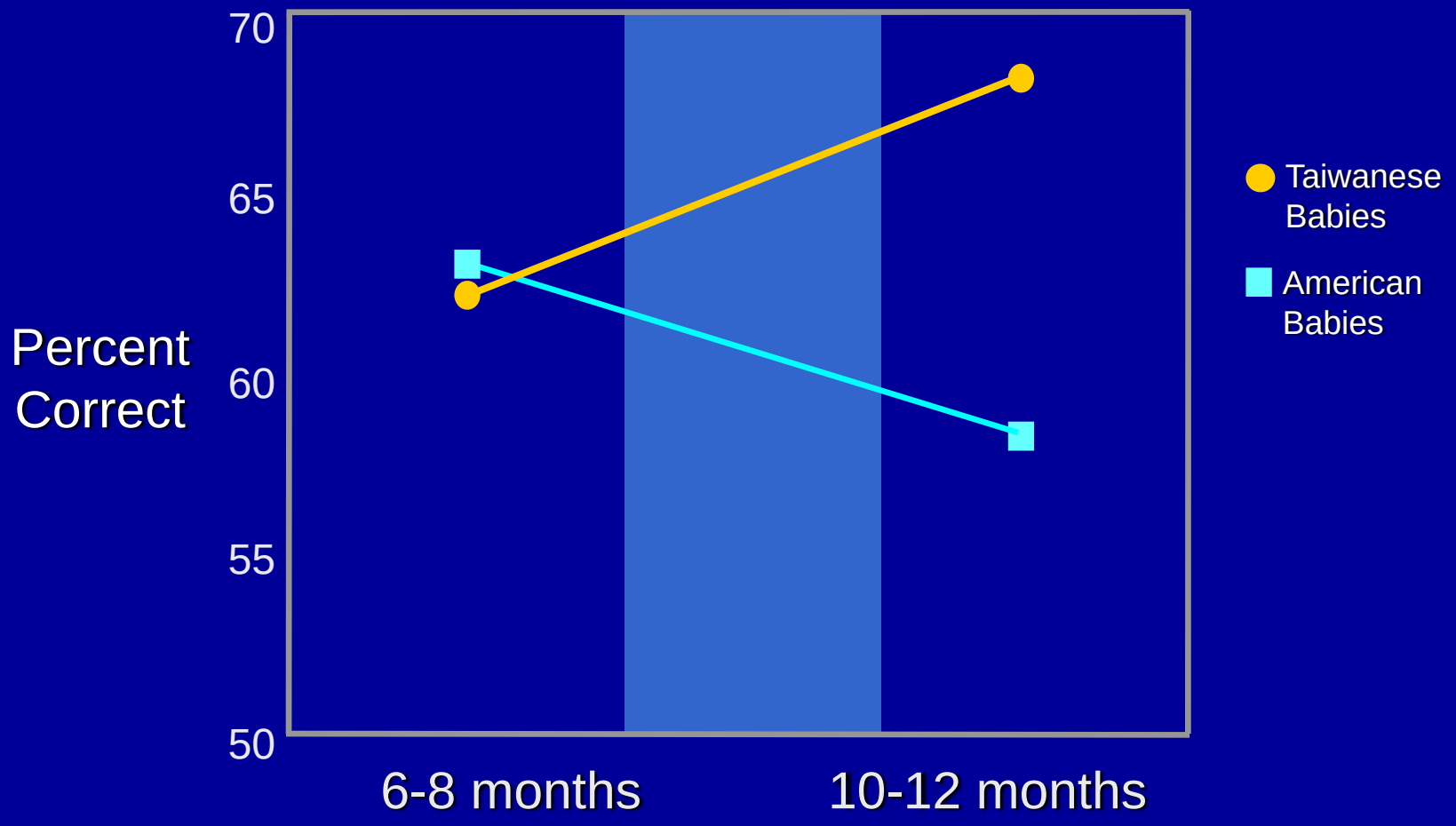
- 12 sessions, 25 minutes each
- 4 different talkers (mean # of syllables = 33,000)



Kuhl, Tsao & Liu, *Proceedings of the National Academy of Sciences,* 2003

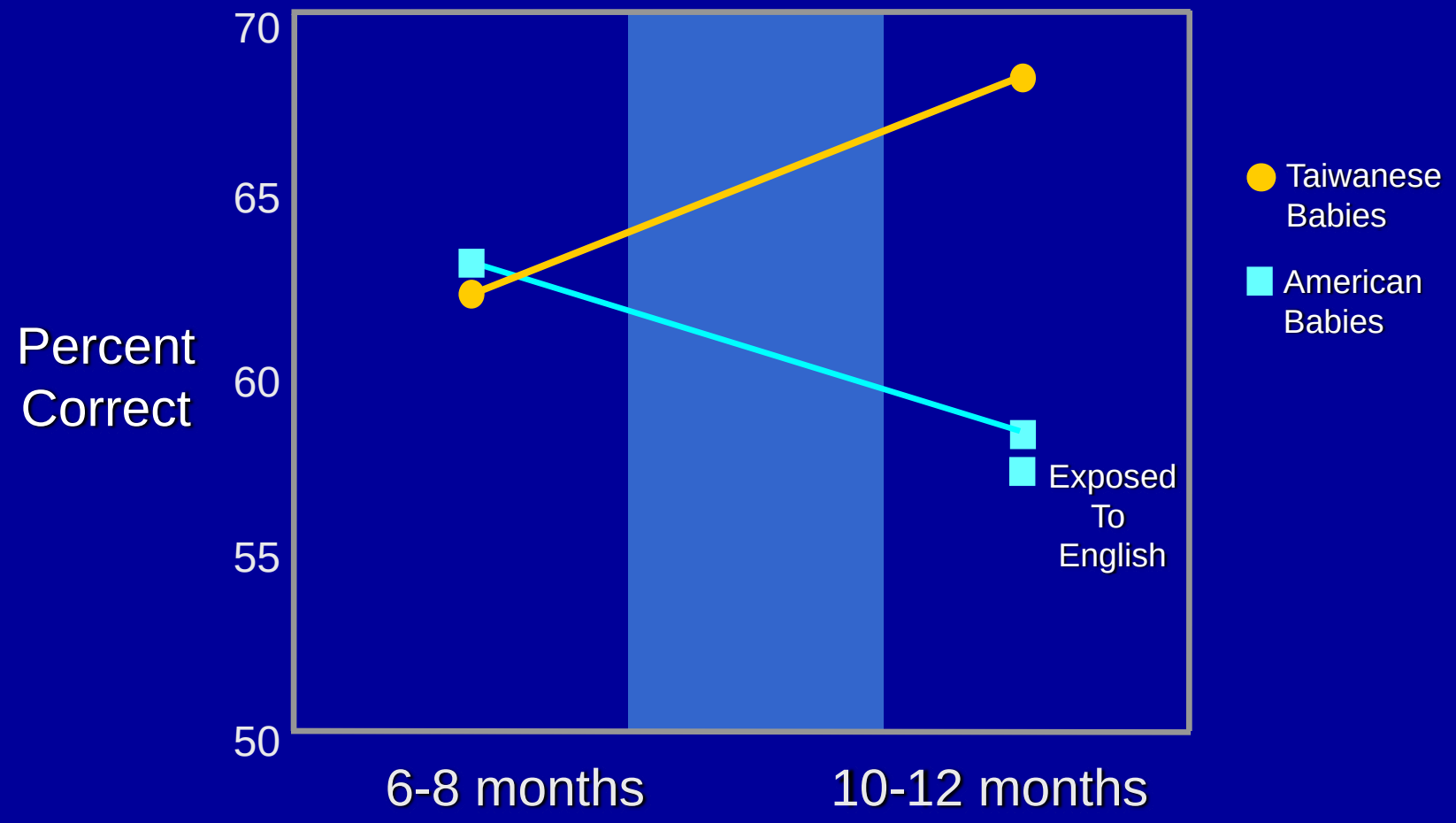
Kuhl • WSAS • 2010

Test Mandarin-exposed and Control infants on the Mandarin sounds after exposure



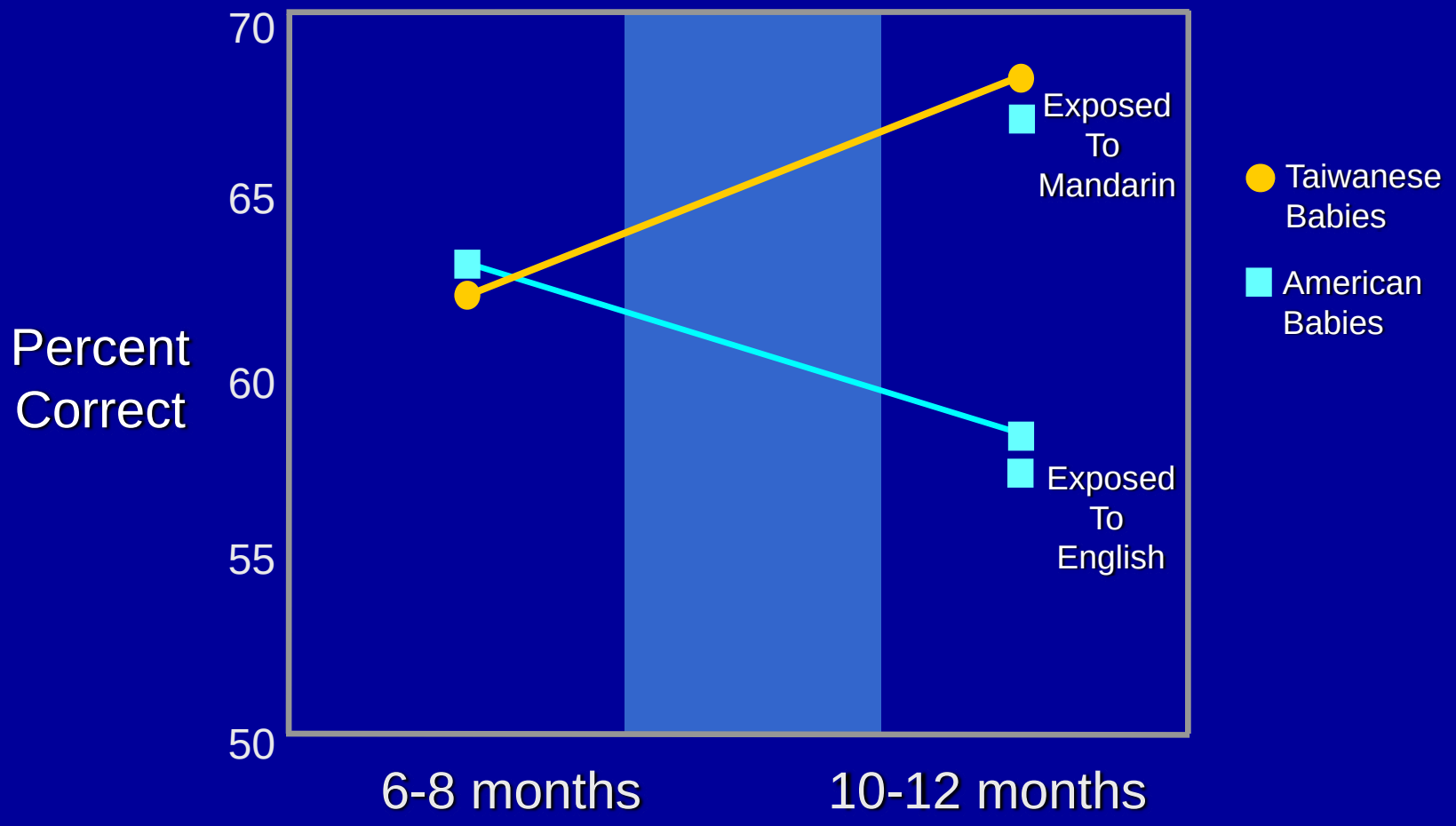
Kuhl, Tsao & Liu, *Proceedings of the National Academy of Sciences*, 2003

Control group exposed to English shows no learning



Kuhl, Tsao & Liu, *Proceedings of the National Academy of Sciences,* 2003

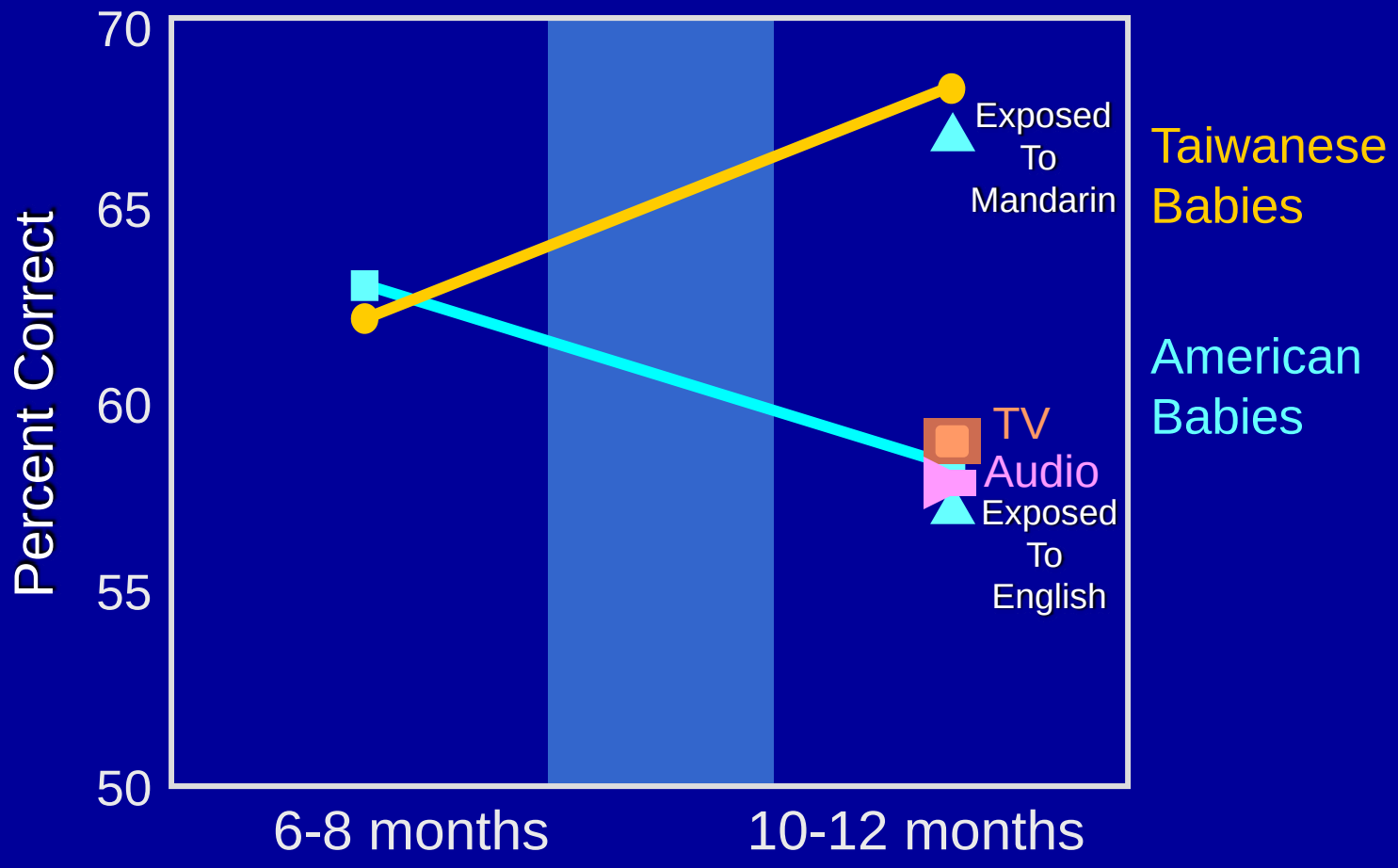
Experimental Group exposed to Mandarin Chinese shows learning



Kuhl, Tsao & Liu, *Proceedings of the National Academy of Sciences,* 2003

Kuhl • WSAS • 2010

Can infants learn language from TV or audio?



Kuhl, Tsao & Liu, *Proceedings of the National Academy of Sciences,* 2003

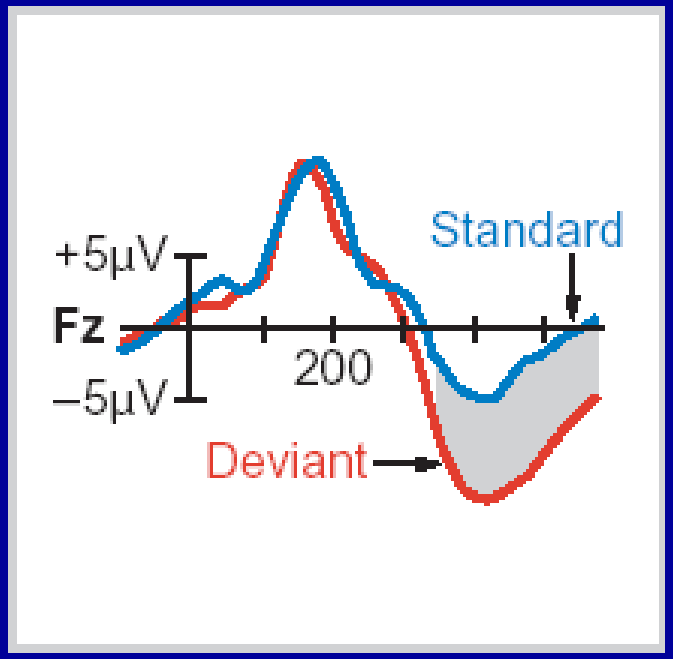
Children's Early Language Learning from Non-Human Sources

Children play with a (Finnish) speaking 'social' robot

Movellan et al. (in progress)

Brain Measures of Speech Discrimination

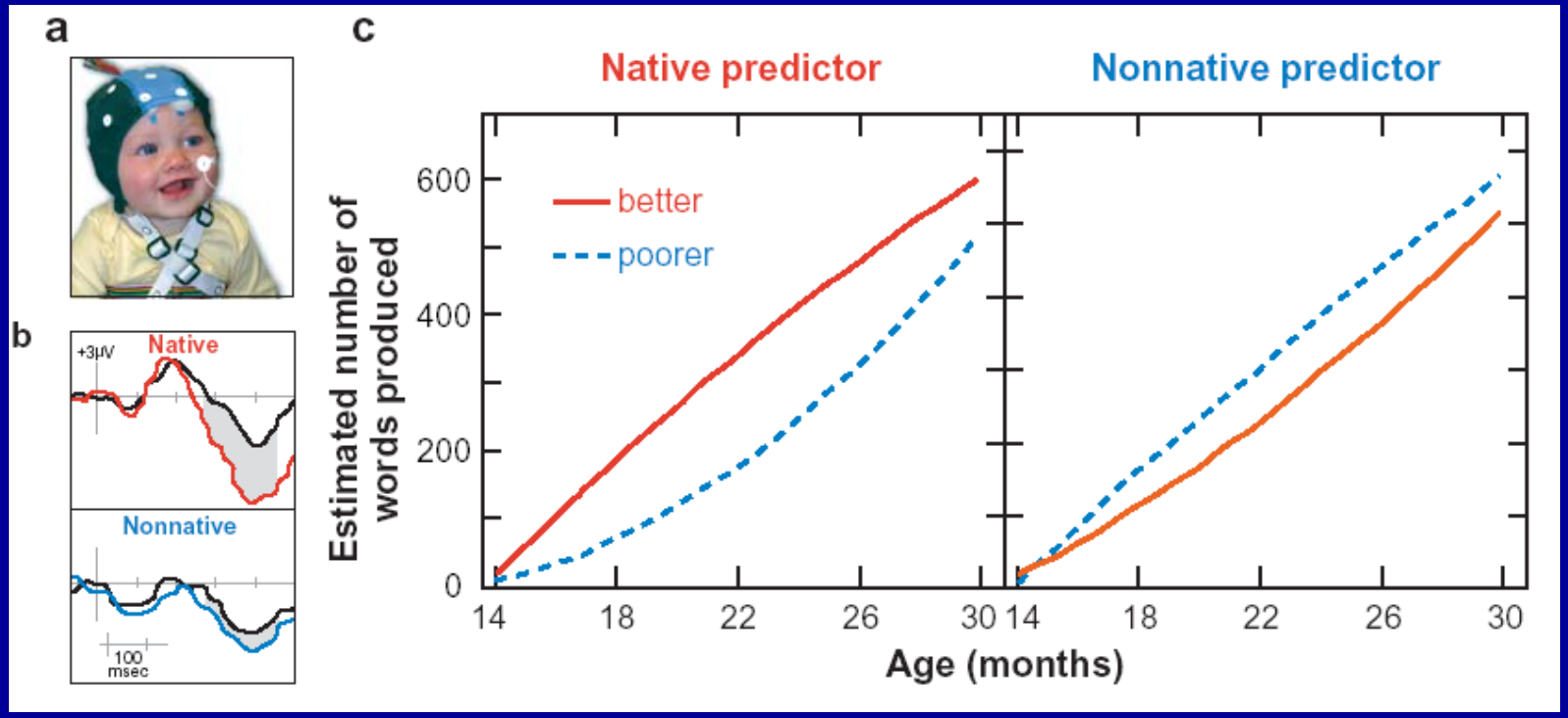
Event-related Potentials (ERPs)



Mismatch Negativity (MMN)

Rivera-Gaxiola, Silva-Pereyra, & Kuhl, *Developmental Science,* 2005

ERPs to Speech at 7.5 months Predict Language Growth to 30 Months



Kuhl & Rivera-Gaxiola, *Annual Review of Neuroscience,* 2008

Bilingual Babies: Language and Cognition

- 55 families enrolled in longitudinal study
- Home visits

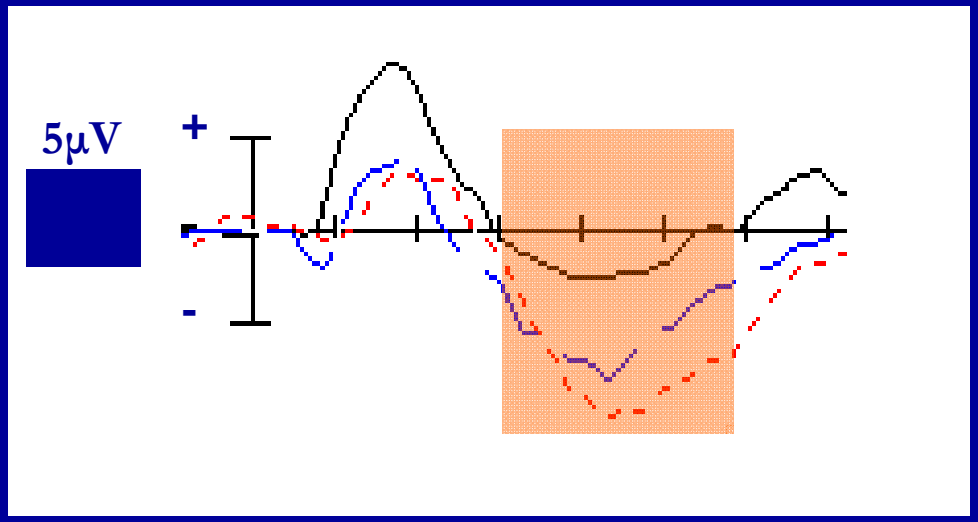
Early Tests and 5-yr Follow-up

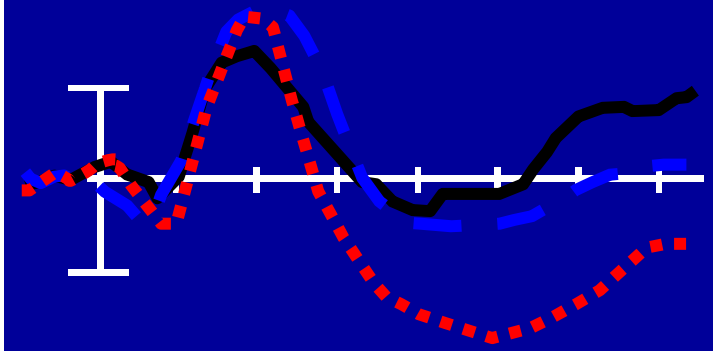
Brain and behavioral measures:
- Language and executive function
- Family assessments

Garcia-Sierra et al., in press

Event Related Potentials (ERPs) to Spanish & English Sounds

Bilinguals	Monolinguals
Ages 10-12 months	Ages 10-12 months



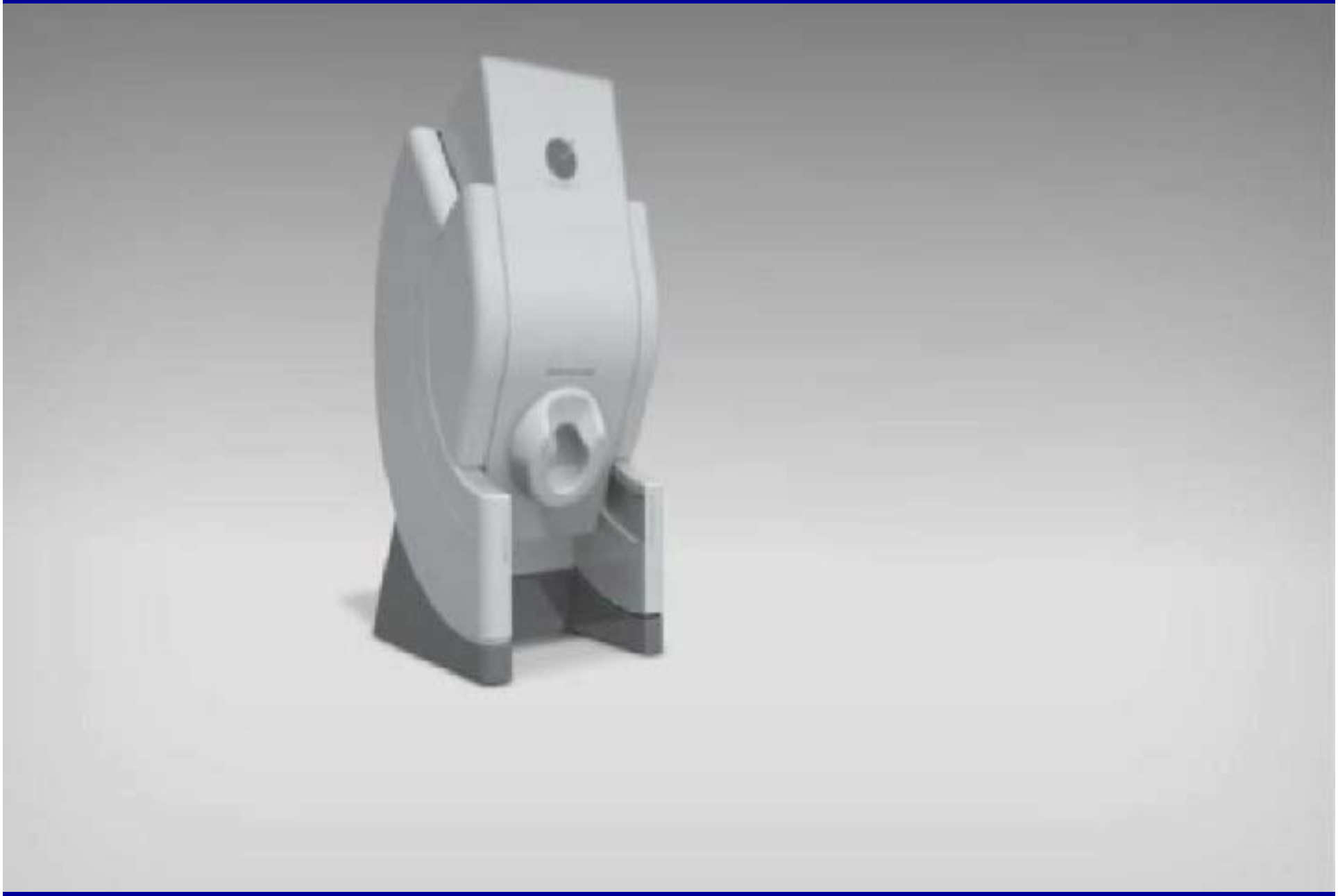


Spanish
English

Garcia-Sierra et al., in press

May 24, 2010

I-LABS MEG Brain Imaging Center at the UW

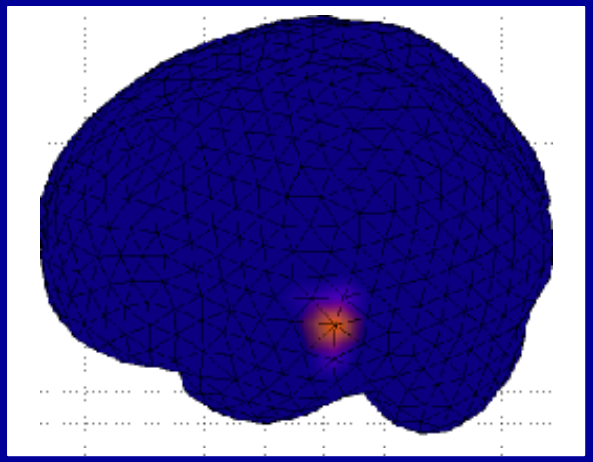


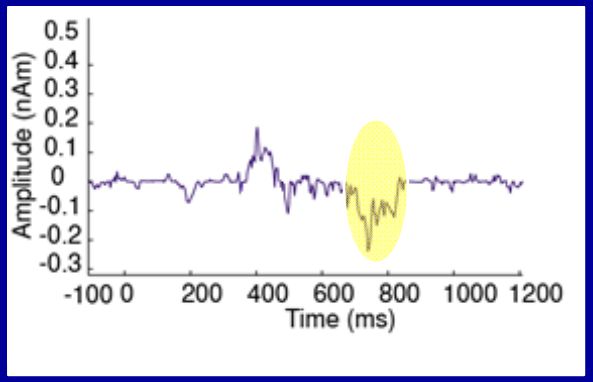
Imada, Zhang, Kuhl et al., *NeuroReport,* 2006

Brain Activation in Response to Speech

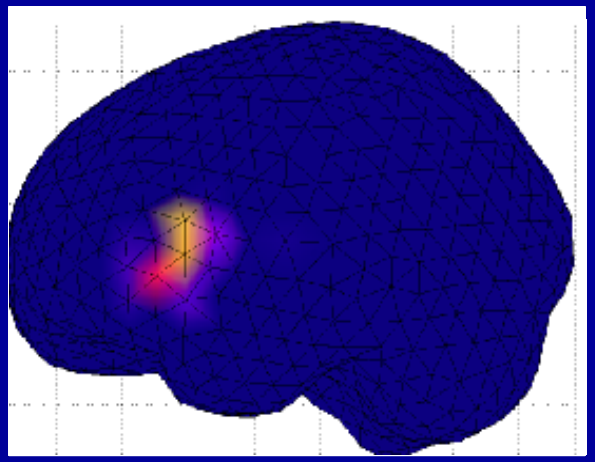
12-month old infants

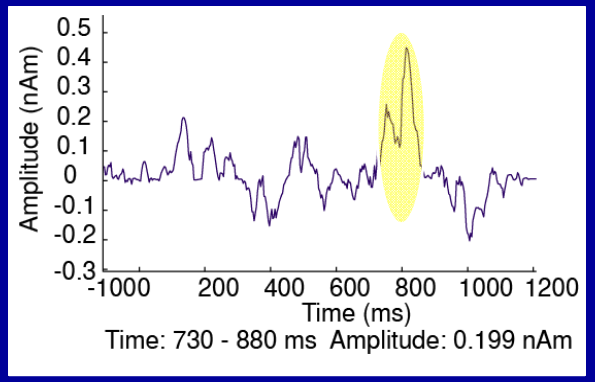
Superior Temporal





Inferior Frontal

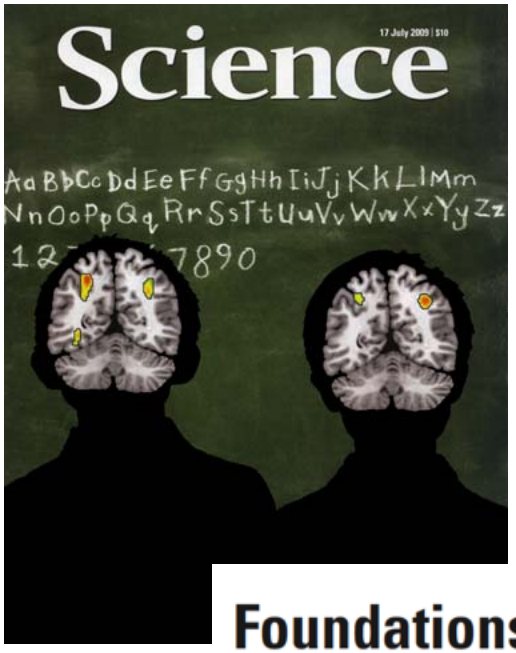


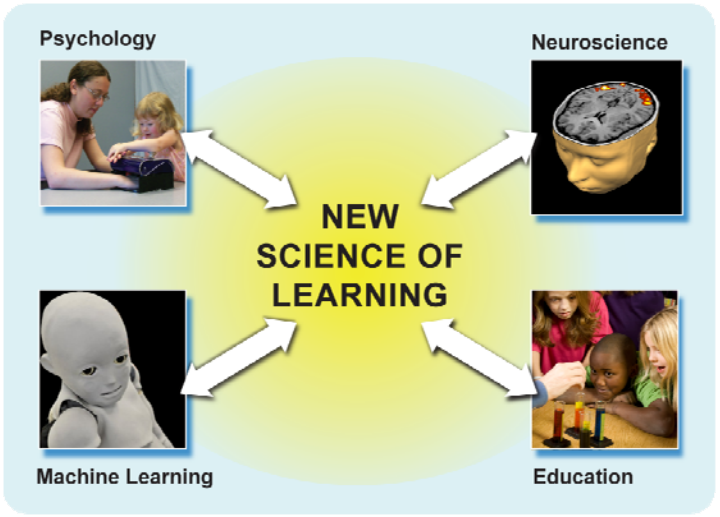


Z scores relative to the baseline activities

Imada, Zhang, Cheour, Taulu, Ahonen & Kuhl, 2006

The Science of Learning





Foundations for a New Science of Learning

Andrew N. Meltzoff,[1,2,3]* Patricia K. Kuhl,[1,3,4] Javier Movellan,[5,6] Terrence J. Sejnowski[5,6,7,8]

Human learning is distinguished by the range and complexity of skills that can be learned and the degree of abstraction that can be achieved compared with those of other species. *Homo sapiens* is also the only species that has developed formal ways to enhance learning: teachers, schools, and curricula. Human infants have an intense interest in people and their behavior and possess powerful implicit learning mechanisms that are affected by social interaction. Neuroscientists are beginning to understand the brain mechanisms underlying learning and how shared brain systems for perception and action support social learning. Machine learning algorithms are being developed that allow robots and computers to learn autonomously. New insights from many different fields are converging to create a new science of learning that may transform educational practices.

Meltzoff, Kuhl, Movellan & Sejnowski, *Science* (July, 2009)

Conclusions:

1. Infant early language = Computational + Social
2. ‘Motherese’ may assist learning
3. Speech provides potential biomarkers for autism
4. Phonetic learning predicts language growth
5. The ‘critical period’ is affected by experience as well as time: *Neural Commitment*
6. Systems neuroscience tools (MEG) will greatly inform early development during the next decade

Lab Group & Collaborators

Predicting Language
- F-M Tsao
- Barbara Conboy
- Lindsay Klarman
- Maritza Rivera-Gaxiola

Prototype Studies
- Paul Iverson

Animal Studies
- Jim Miller

Newborn Studies
- Christine Moon

Motherese Studies
- Jean Andruski
- H-M Liu

ERP Studies
- Maritza Rivera-Gaxiola
- Sharon Coffey-Corina
- Juan Silva-Pereyra
- Barbara Conboy

Autism Studies
- Denise Padden
- Geri Dawson
- Sharon Coffey-Corina

Lab Group & Collaborators

MEG Studies

- Toshi Imada
- Yang Zhang
- Elina Pihko
- Antti Ahonen
- Jyrki Makela

Brain-Behavior Relations Studies

- Todd Richards
- Raj Raizada

HFSP Collaborators

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- Ludmilla Chistovich
- Toshisada Deguchi
- Shigeru Kiritani
- Elena Kozhevnikova
- Francisco Lacerda
- Bjorn Lindblom
- Ken Stevens
- Ulla Sundberg
- Reiko Yamada
- Yoh'ichi Tohkura
- Hugo Lagercrantz

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- The Hsin-Yi Foundation
- The McDonnell Foundation
- The Human Frontiers Science Program
- Cure Autism Now

Thank You!