Intro to Behavioral Neuroscience (B)
Lecture 10: Human Language

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https://youtu.be/mhP3aDp7hFM

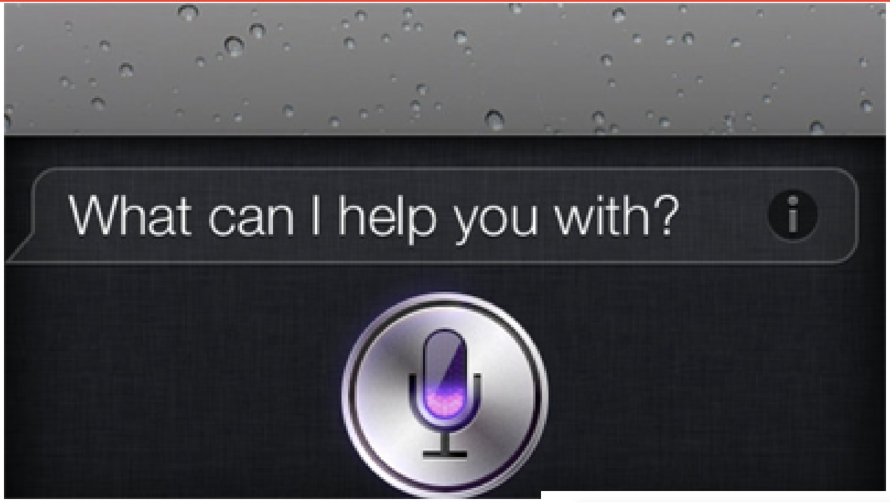
Lecture video at above link.

Today:
Human Language and Disorders

Human Language and language disorders

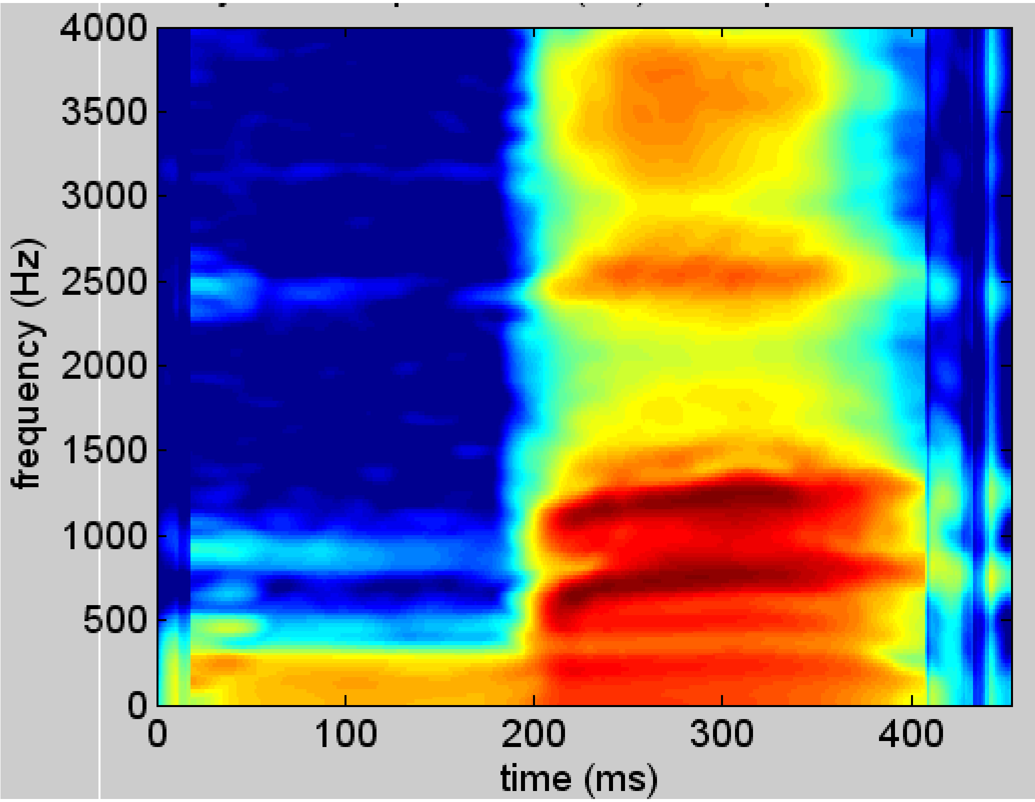
1) Speech perception
2) Categorical perception in humans and songbirds
3) Language development
4) Bilingualism
5) Reading and developmental dyslexia

Language is *hard*



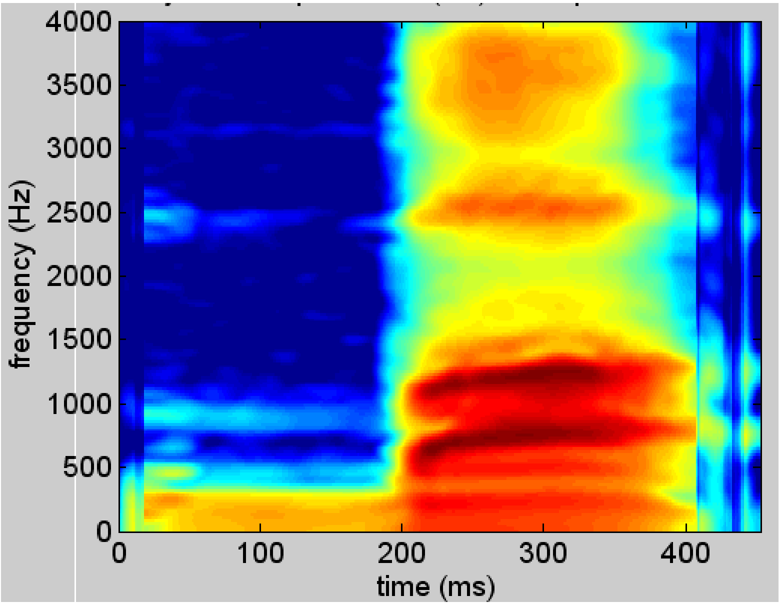
Understanding of natural spoken language and translation are far from trivial. Current attempts to automatize language processing are still far from human performance.

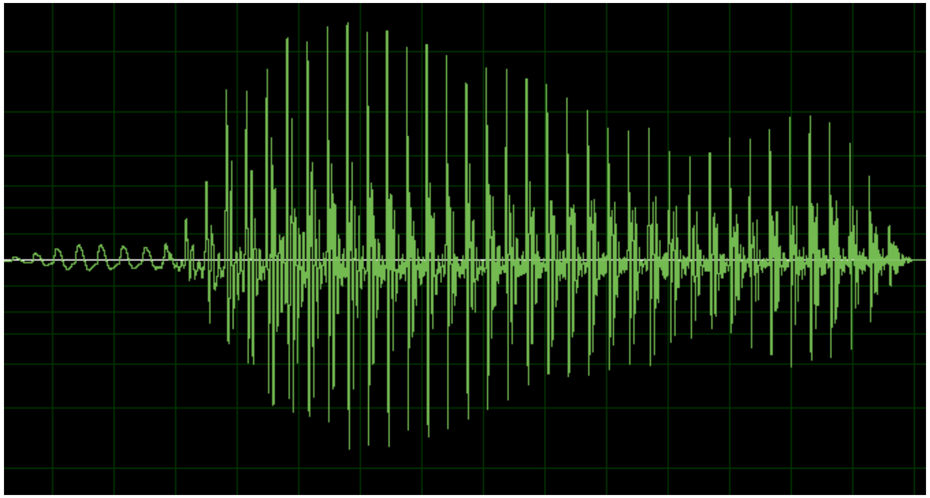
Speech perception



Above is the time-frequency representation of a spoken /ba/ based on short-term Fourier analysis. That is, the original signal is divided into small time windows and these windows are analyzed in terms of their frequency spectrum.
Here, red indicates high power in a specific time-frequency bin, blue is low power.

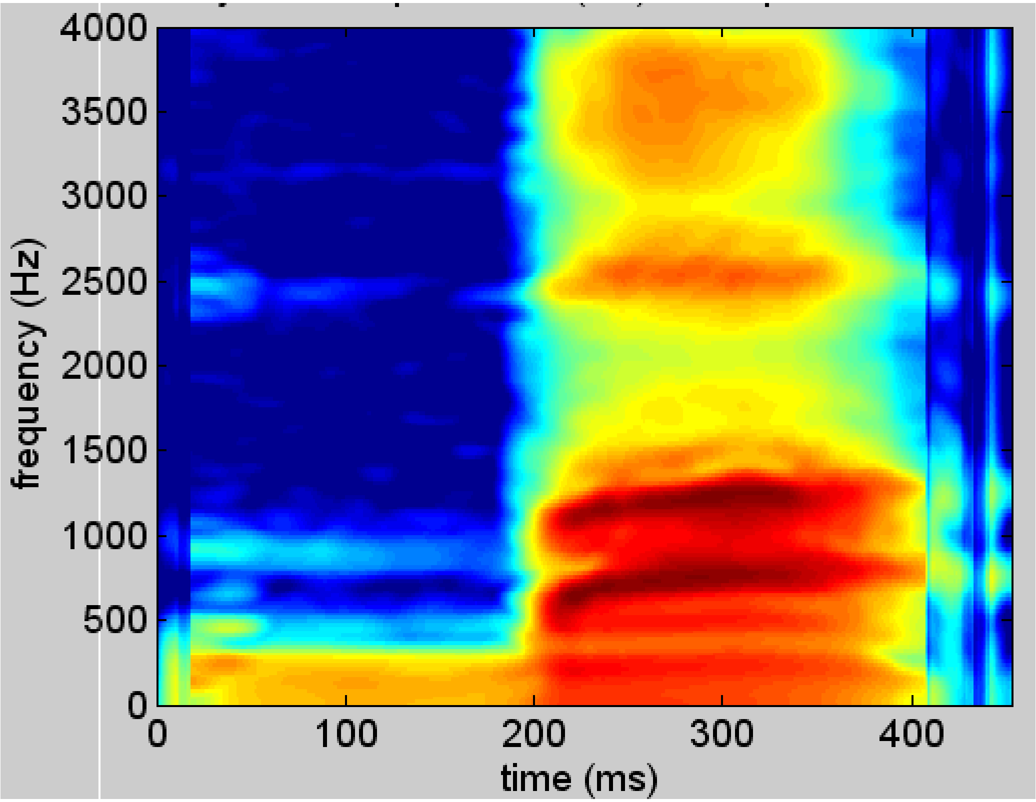
Speech perception





For example, at the beginning of the /ba/, the vocal cords vibrate at the fundamental frequency of ~100-200Hz.

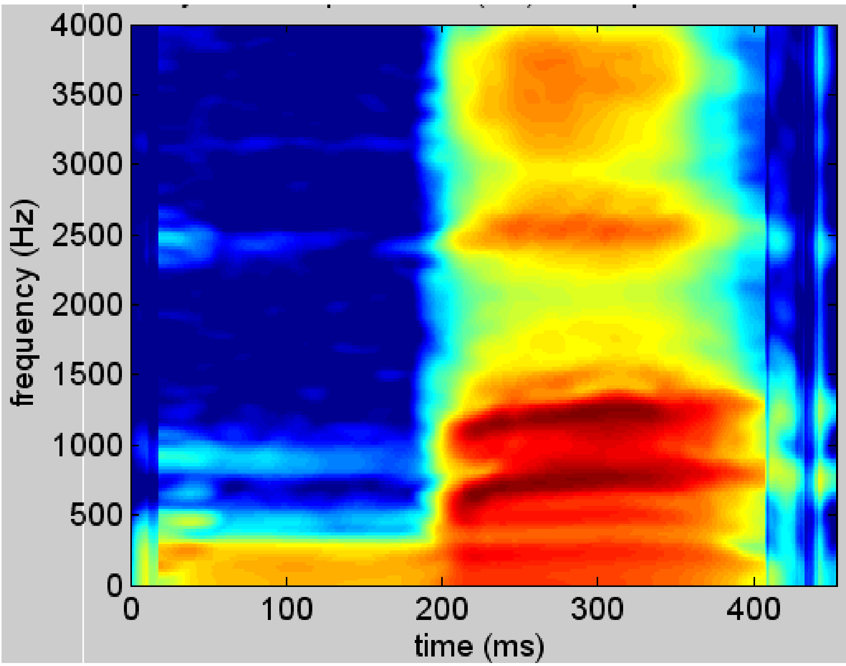
Speech perception



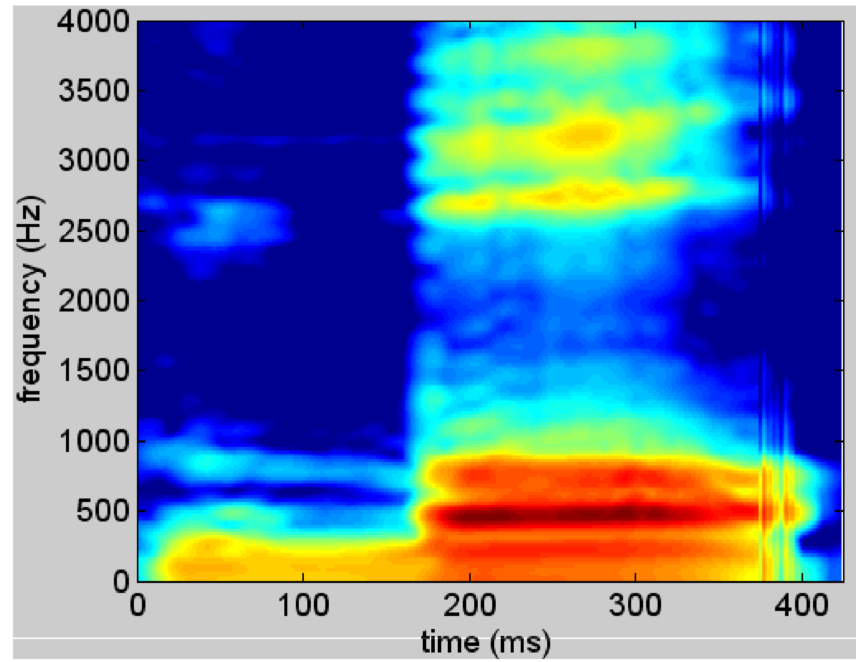
The /ba/ is a plosive stop-consonant; air from the lungs reaches the vocal cords and is stopped by the lips and then released (“plosive”).

Speech perception

/ba/

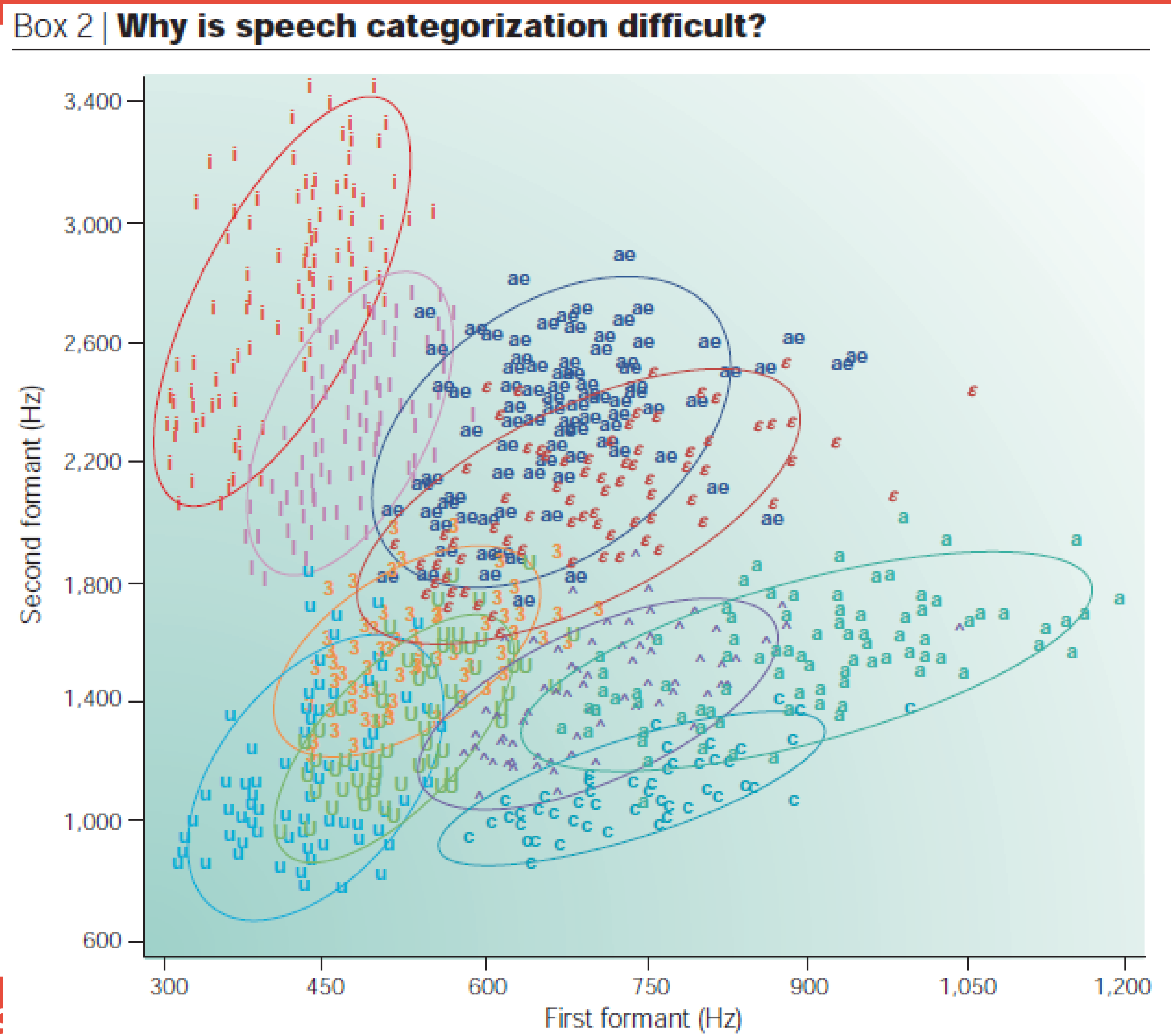


/bo/



A /ba/ and a /bo/ differ by their longer-term frequency contents, in particular the first and second formant.

Difference between vowels

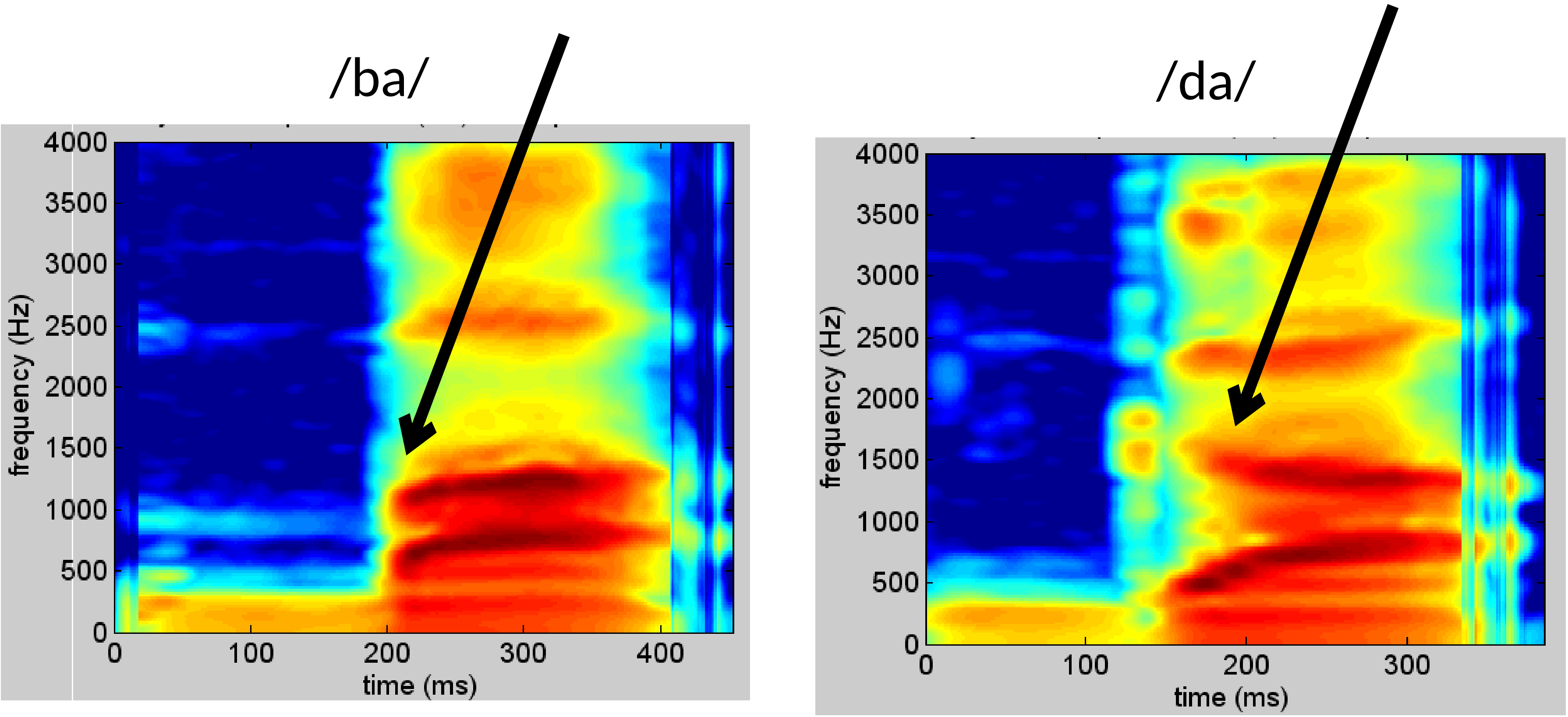


Kuhl, Nature Review Neurosciences, 2004

The differences between vowels depend on the frequency distribution of first and second formants.

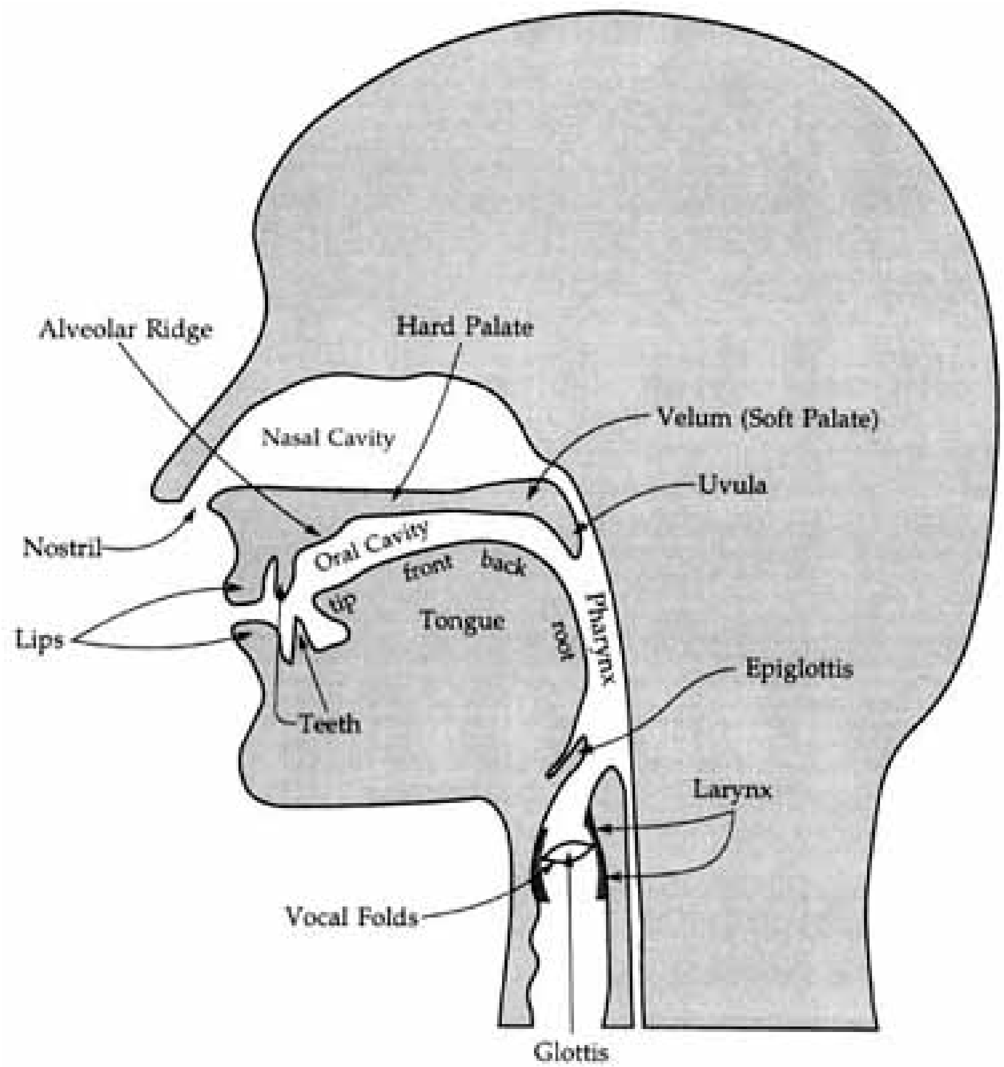
Different speakers will produce the same vowel in a different way, depending on speed rate and context.

Difference between consonants



A /ba/ and a /da/ differ in the place of articulation: the air-stream is stopped by the lips for /ba/ and the alveolar ridge (a bit further in the back of the mouth) for /da/.

Difference between consonants



/ba/ /da/ /ga/
are plosive consonants:

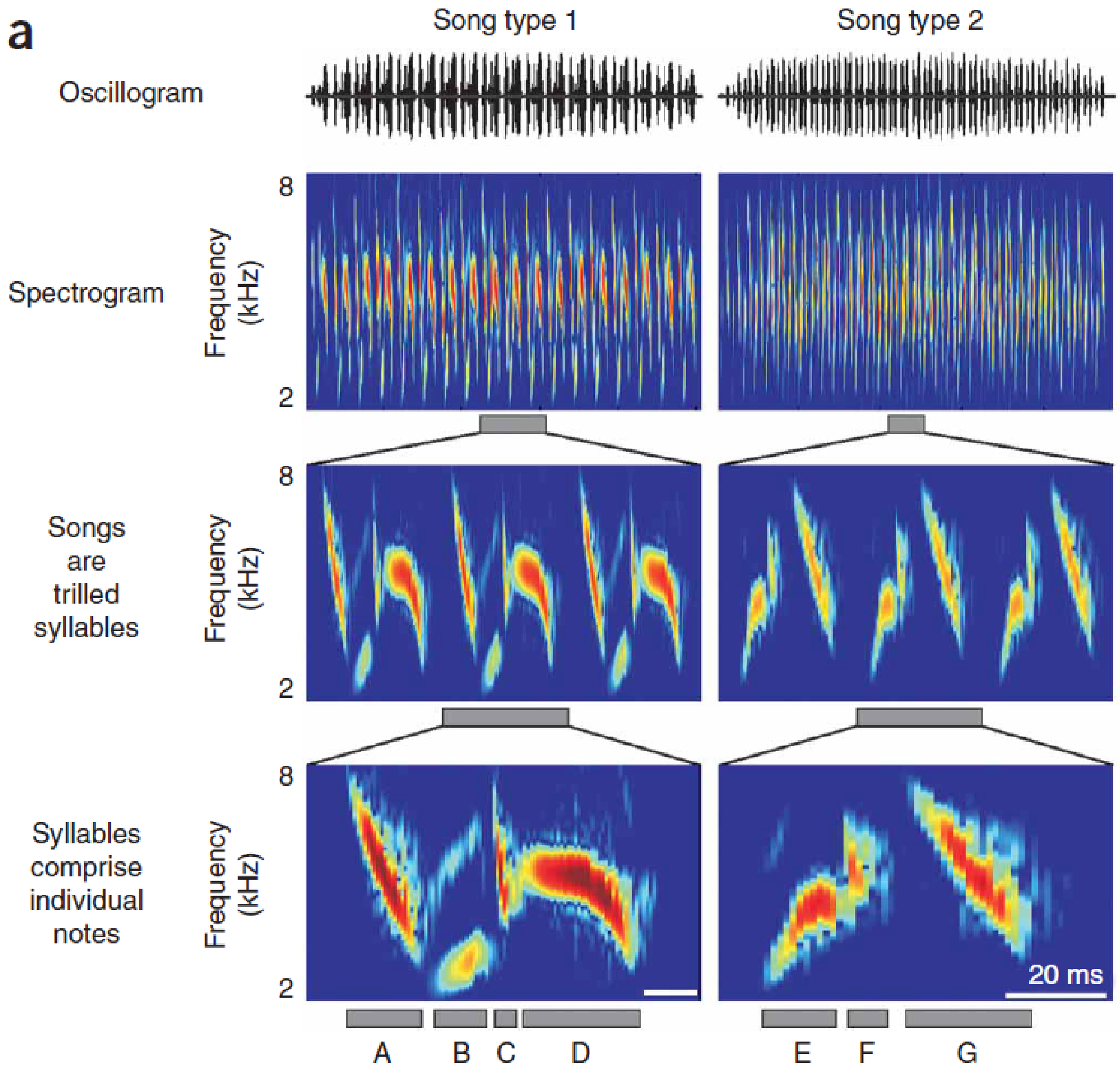
The air-stream from the lung is stopped and then released to produce these sounds.

/ba/: lip

/da/: alveolar ridge

/ga/: velum

Categorical perception in swamp sparrows



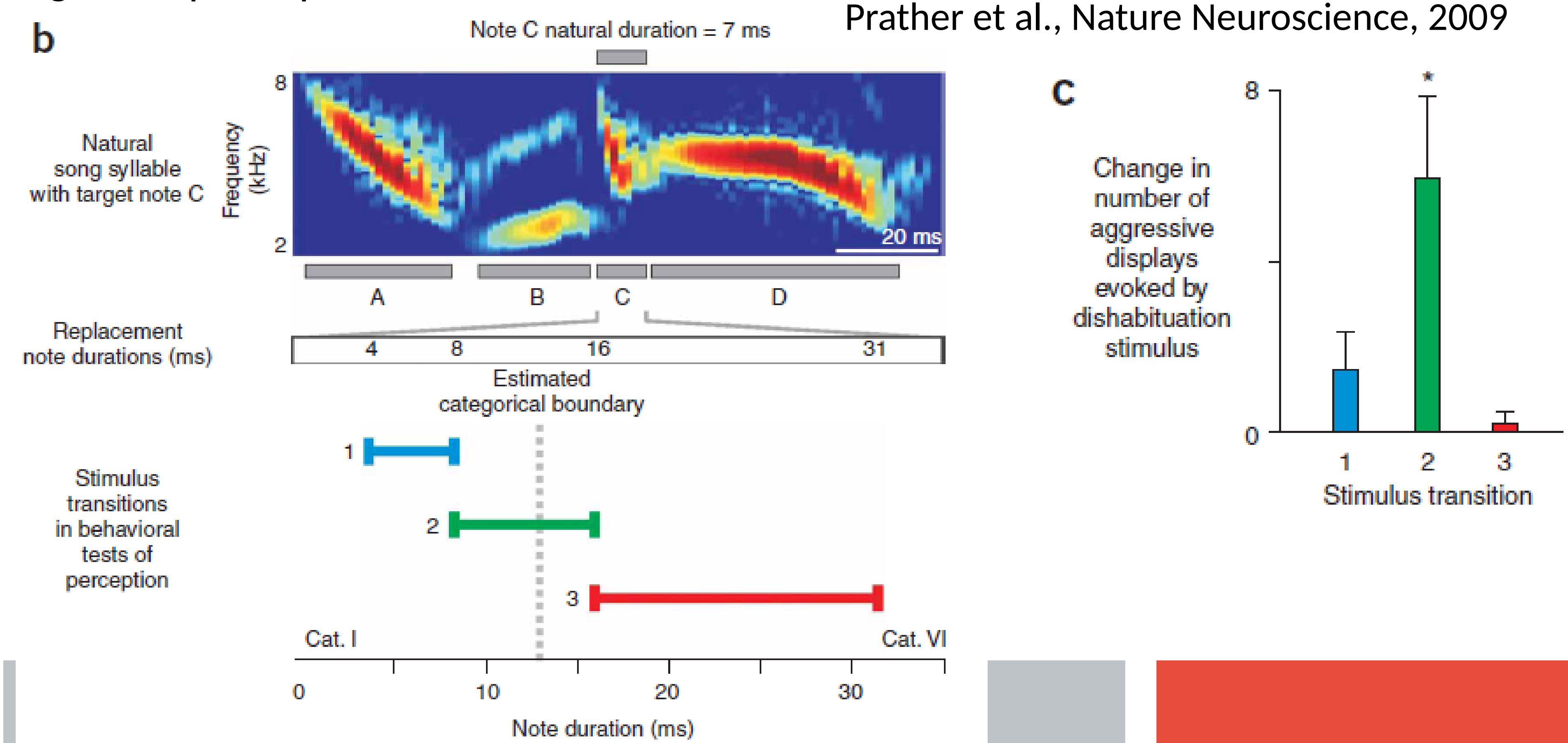
Swamp sparrows produce songs that consist of repeated groups of 2-5 notes. They learn these songs by imitation.

Prather et al., Nature Neuroscience, 2009

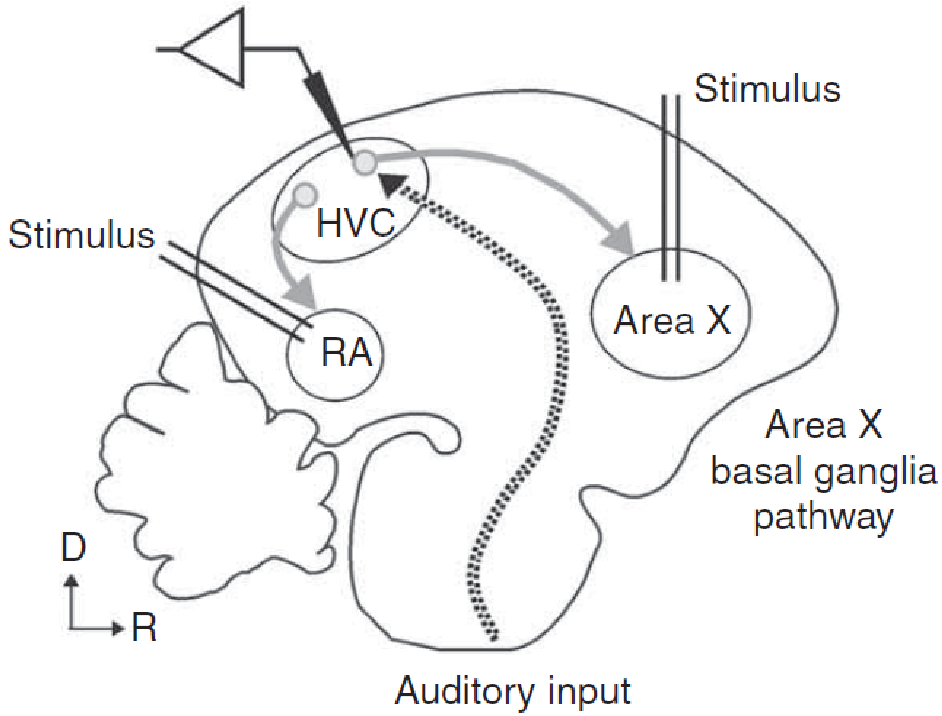
Categorical perception in swamp sparrows

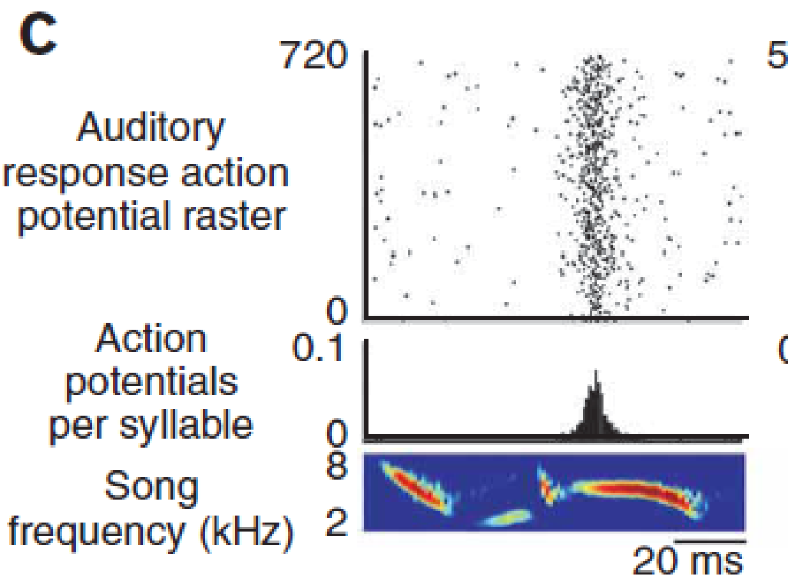
Swamp sparrows are very territorial. When they hear the same song for a while they will habituate and not respond to it. However, if a new song – indicative of a new opponent – appears they will exhibit aggressive behavior. Changing the Note C duration (b) across the boundary leads to an increase of aggressive displays (c) → categorical perception.

Prather et al., Nature Neuroscience, 2009



Categorical perception in swamp sparrows



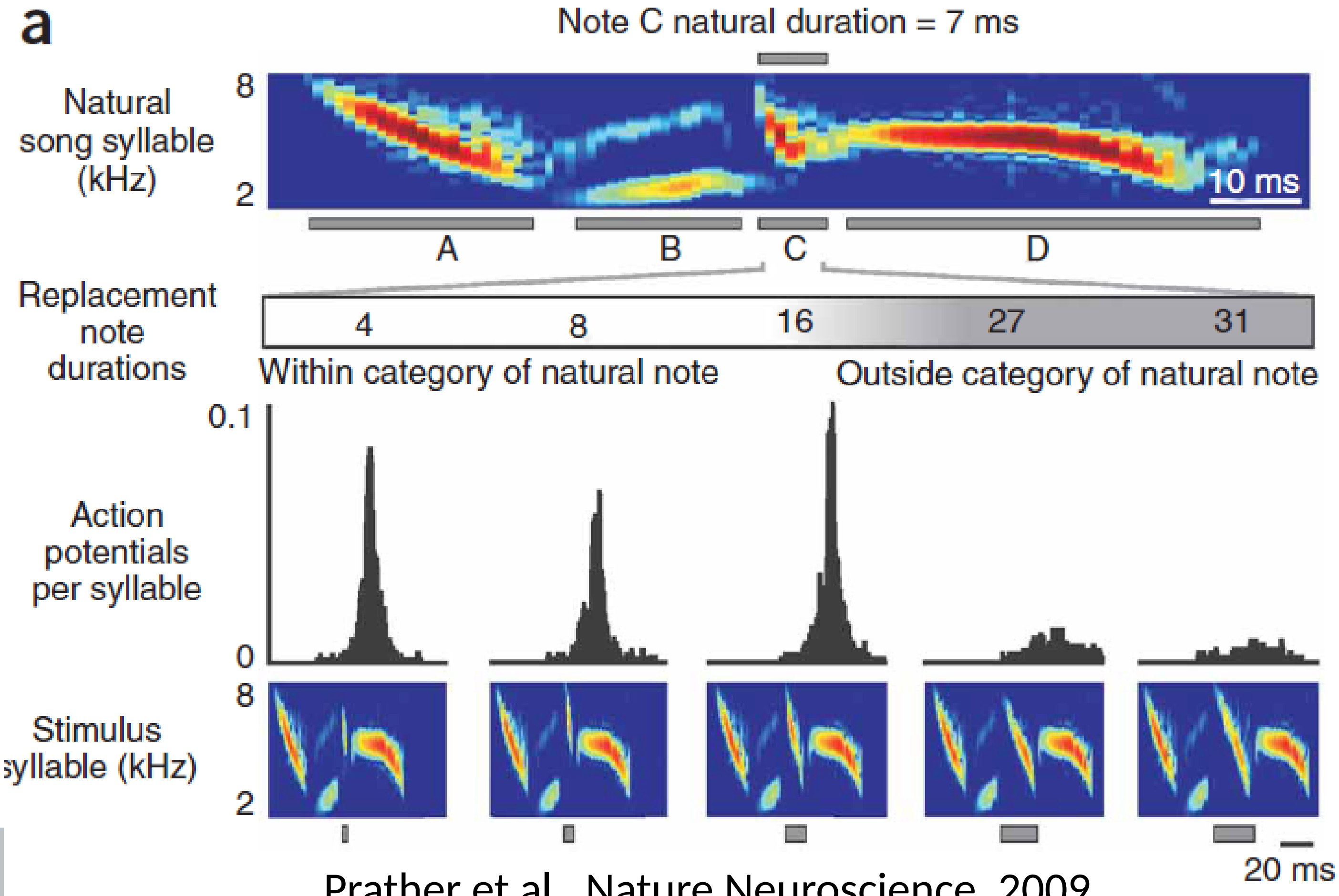


Prather et al., Nature Neuroscience, 2009

Area HVC is a higher area involved in song perception and production. Some HVC neurons project to the striatal Area X (important for song learning). Cell firing of HVC neurons can be elicited in response to specific parts of a song group (right graph).

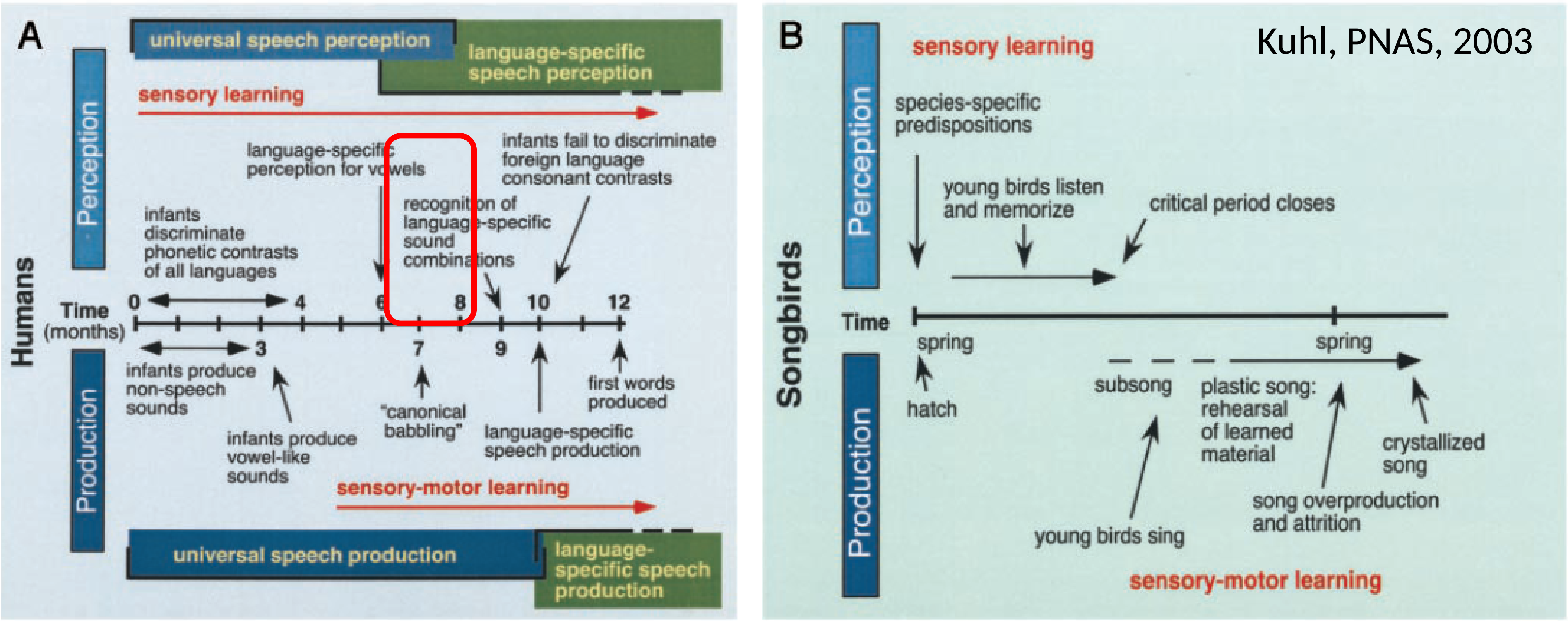
Categorical perception in swamp sparrows

When the duration of note C was manipulated, cell responses selective for the note were at a similar level when the note was still within the category of the natural note, but very low for longer notes. This indicates categorical behavior of HVC neurons in swamp sparrows.



Prather et al., Nature Neuroscience, 2009

Humans: Development of speech perception



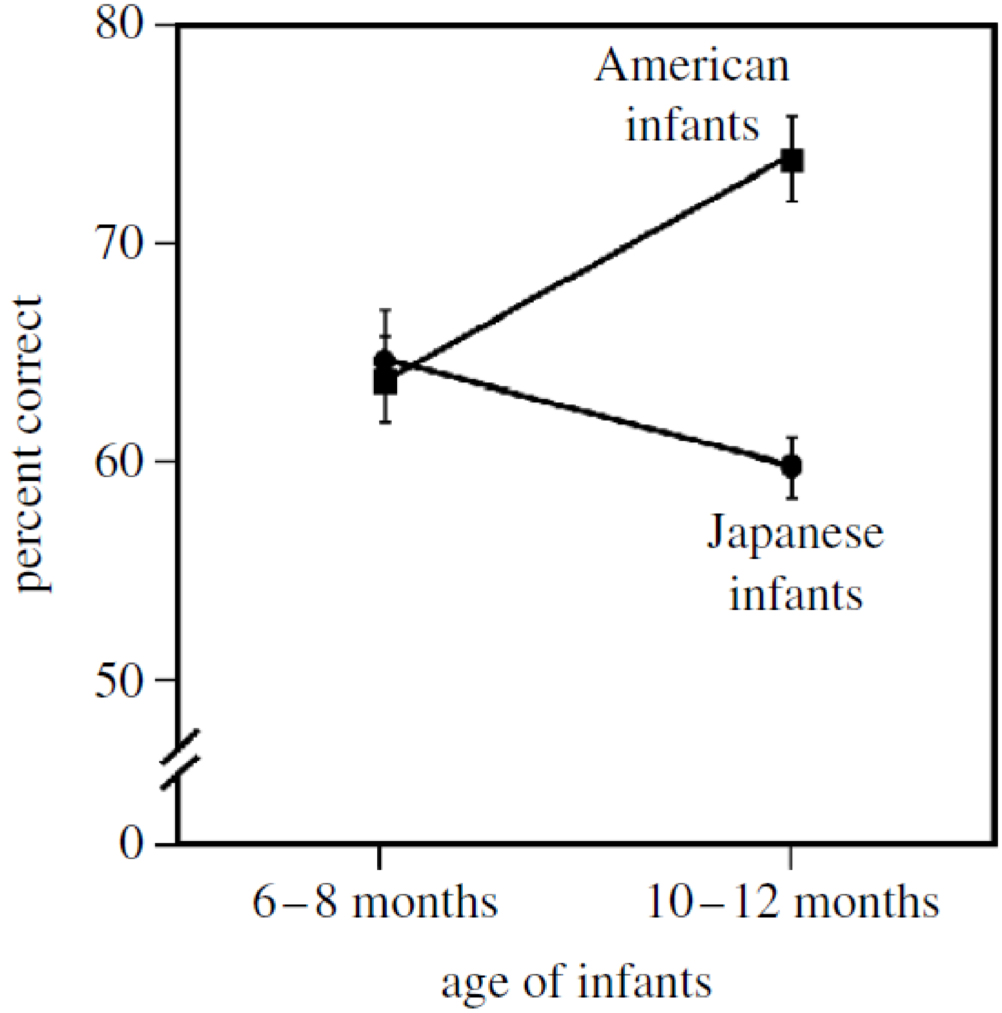
In both humans and songbirds, sensory learning precedes production (sensory-motor learning). Human children start production with non-speech sounds, vowel-like sounds, and “canonical babbling” (e.g., “baba”). Songbirds produce an immature subsong before the mature song is produced.

Development of speech recognition

The graph on the left shows proficiency in distinguishing “ra” and “la” in American and Japanese infants.

While at the age of 6-8 months they are about the same level, speech environment forms speech recognition from 10-12 months:

American infants can distinguish this speech contrast important in English, the Japanese infants get worse.



Kuhl, Neuron, 2010

Conditioned head-turn paradigm

Testing speech and language in infants is challenging, because they cannot report verbally.

In the conditioned head-turn paradigm, a child is presented with engaging toys (blue penguin) to keep its attention. This is paired with background sounds (e.g., a series of “la”).

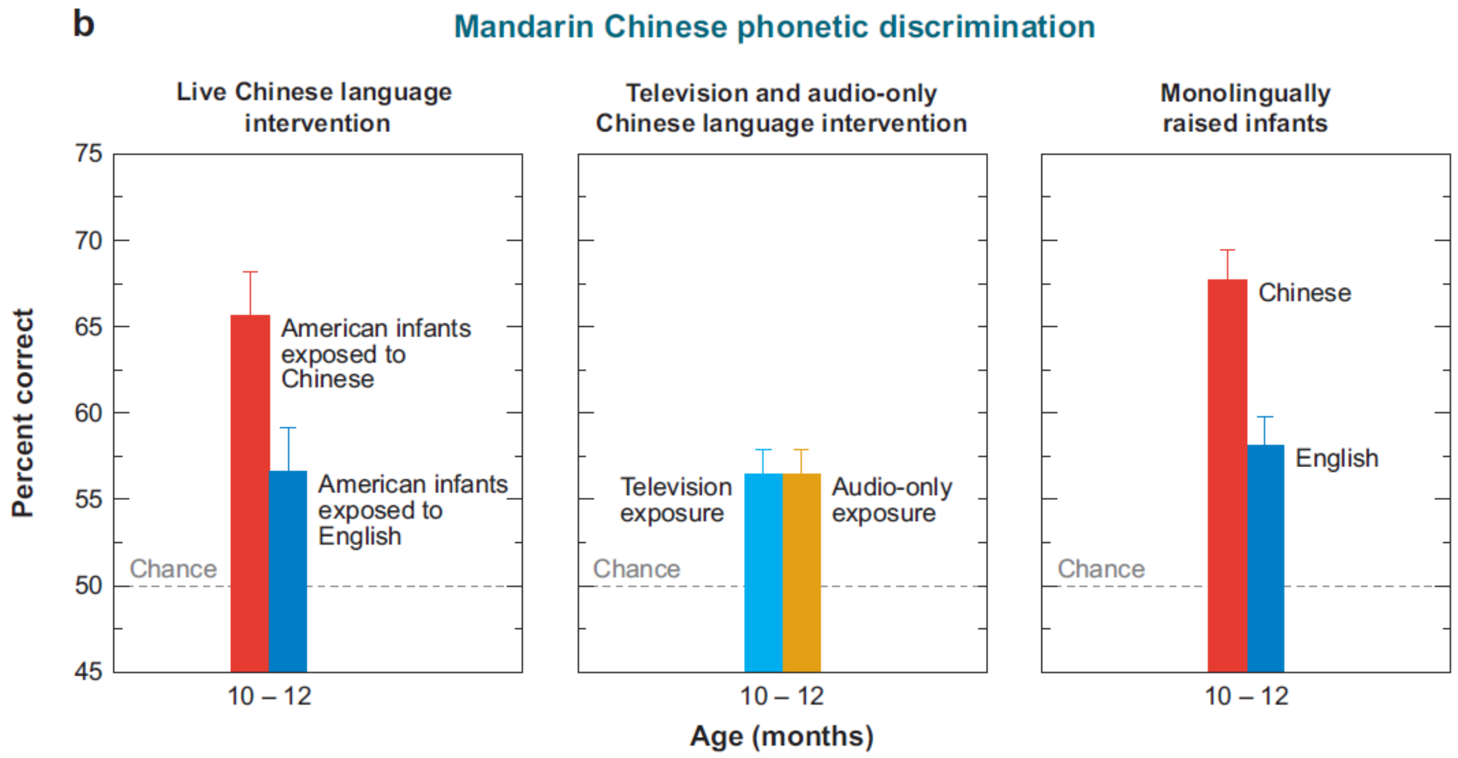
A target sound (e.g., “ra” in a series of “la”) is paired with a visual reward (animated toy). If children can understand that the target sound is coming, they know that the visual reward is coming, too.

Acquisition of foreign-language phonemes

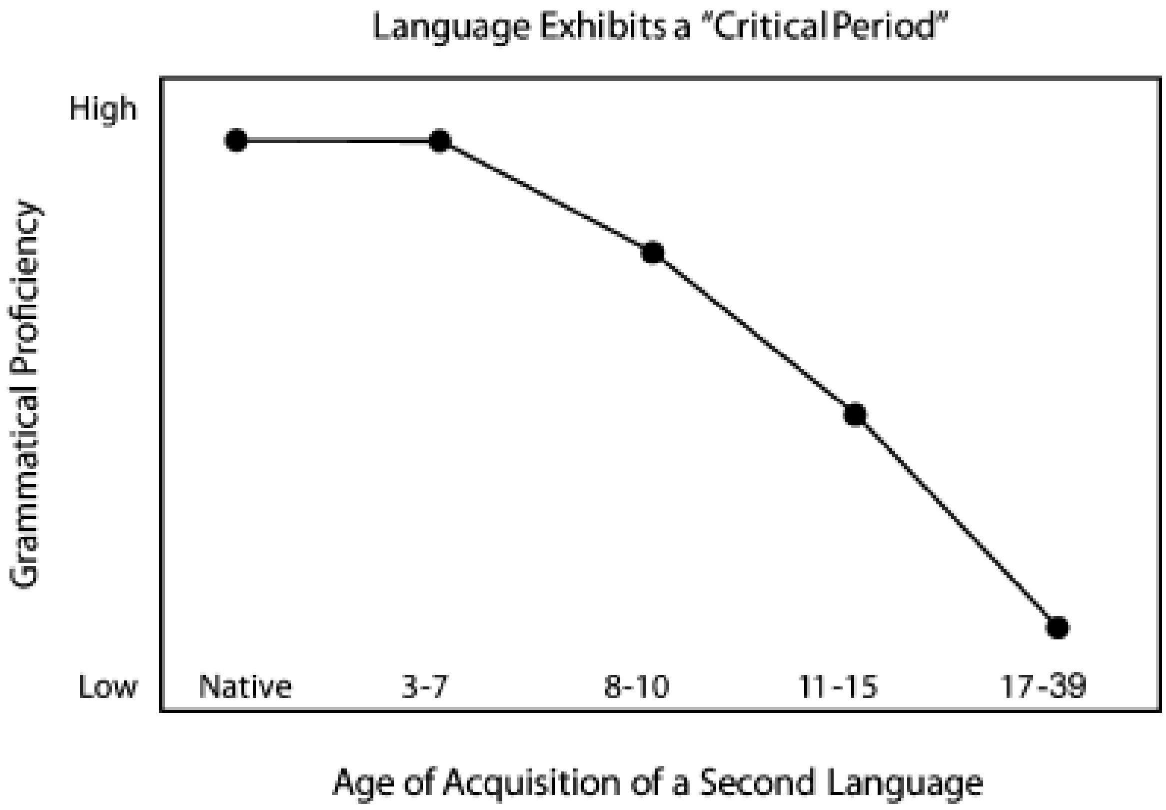
In this study, 9-month old American English infants underwent exposure to Mandarin Chinese (Kuhl et al., 2003). They either underwent 12 sessions of live reading or the same amount of time exposure by television.

Acquisition of foreign-language phonemes

Interestingly, only the American infants (English-speaking parents) that were exposed to live Chinese language showed benefits in phonetic discrimination of Chinese language (and the monolingually raised Chinese infants).
This indicates the importance of social interaction for language acquisition.



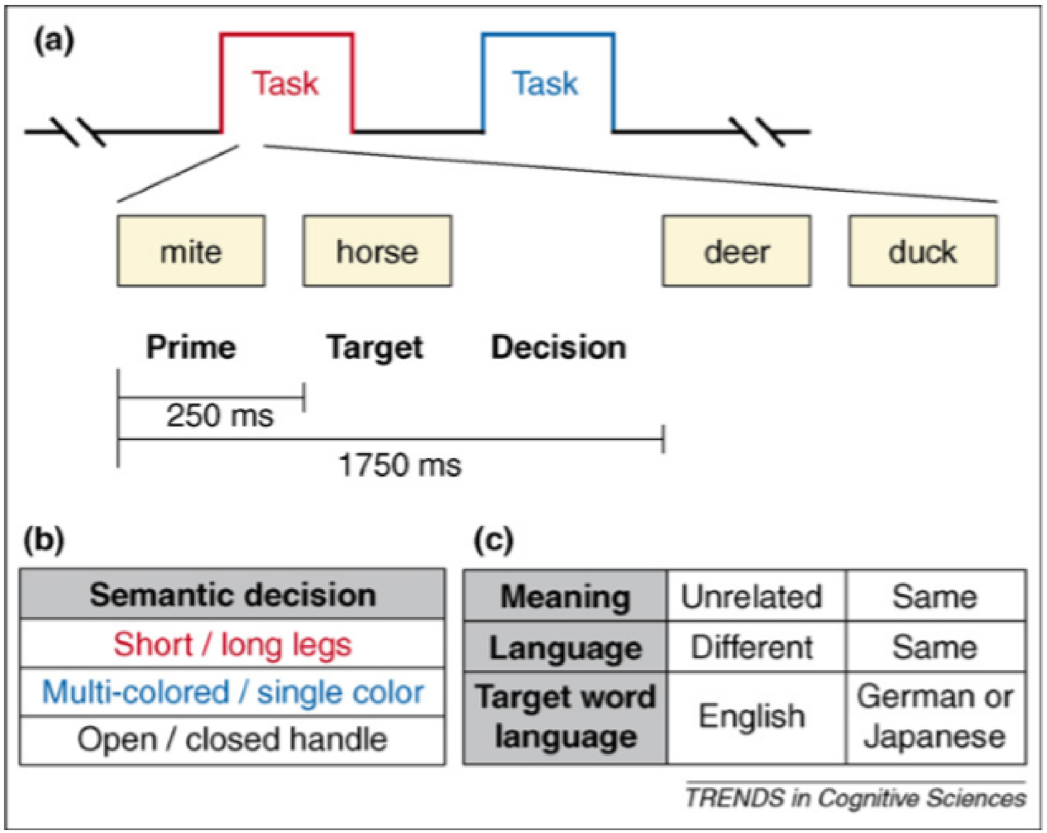
Language development
“Critical period”



Language development has a critical period, i.e., acquisition is most successful in the early years of life. The graph shows the degree of grammatical proficiency as a function of age of second language acquisition (Kuhl, Neuron, 2010).

Bilingual Brain

In bilinguals, how are the two languages represented in their brain?
Do the two languages share similar brain areas? Are there brain areas controlling language switch?



This study tested two groups: German-English and Japanese-English bilinguals.

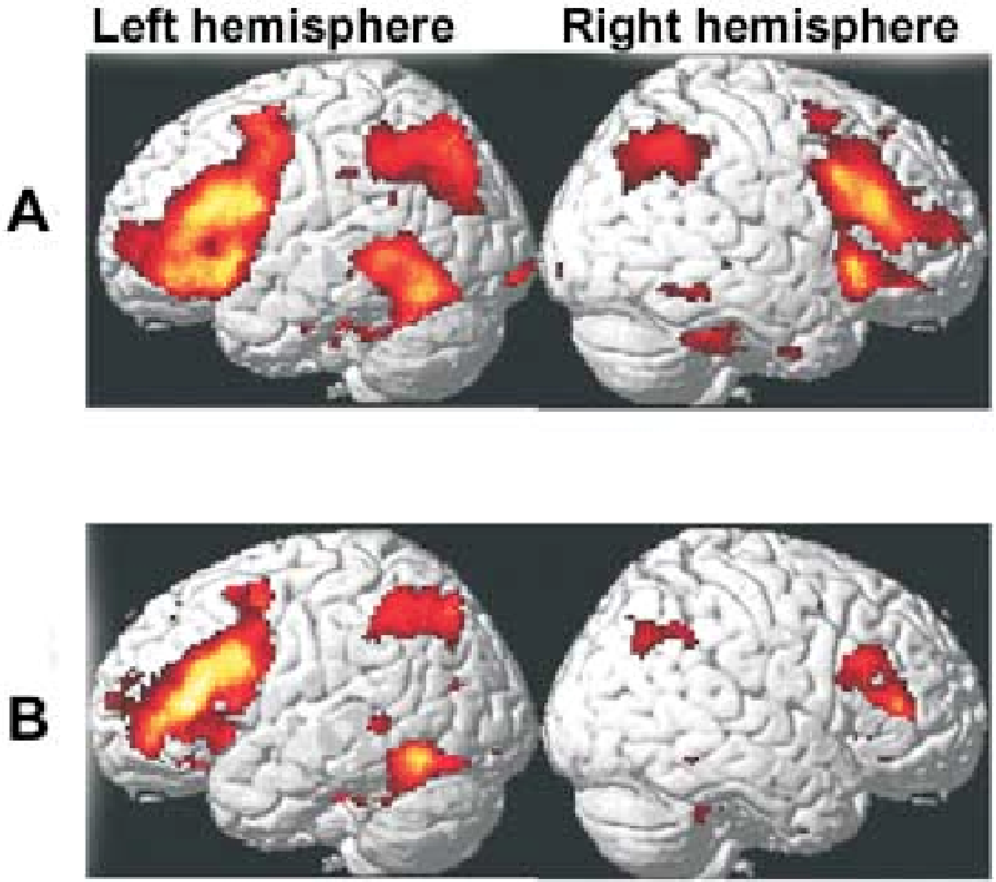
Written words were presented in pairs:

Same Language:
Unrelated meaning: deer – duck
Related meaning: church – bell

Different Language:
Unrelated meaning: Suppenkelle (ladle) – shower
Related meaning: Lachs (salmon) – trout

Crinion et al., Science, 2006

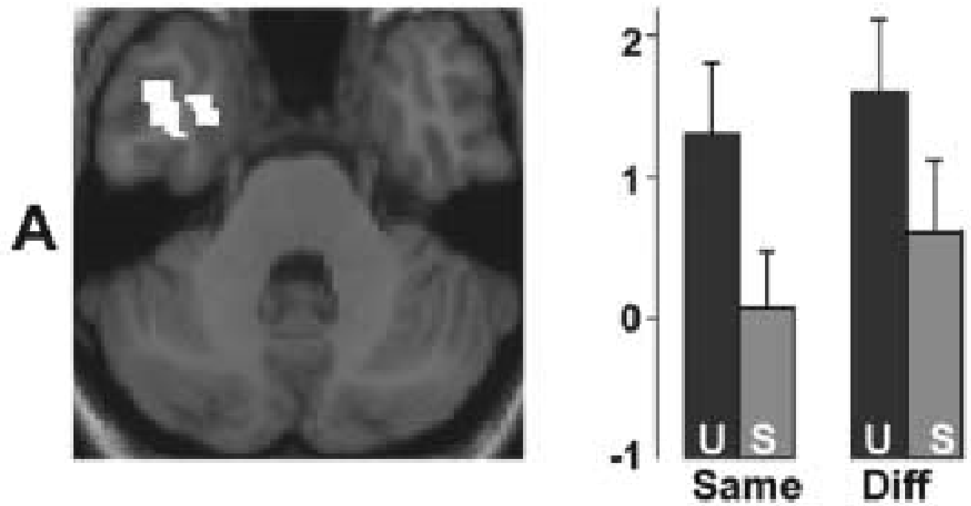
Bilingual Brain



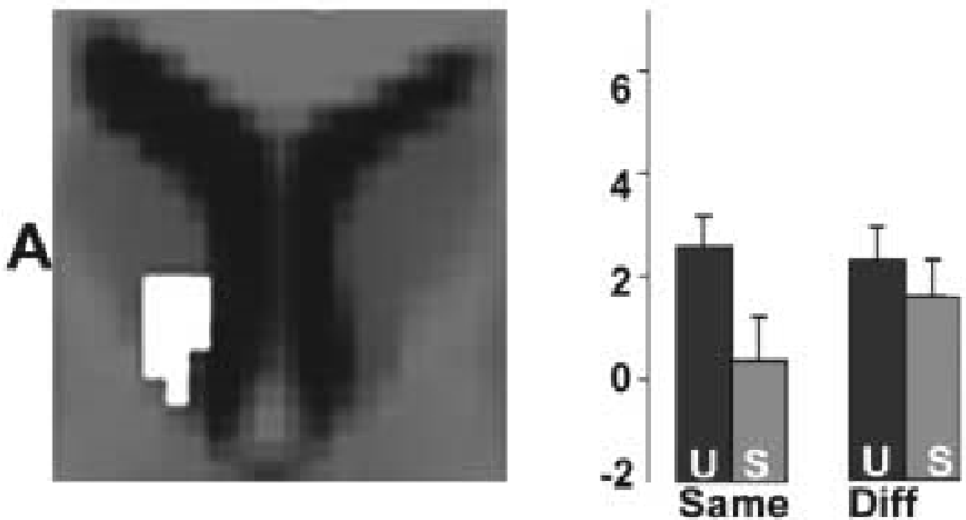
Brain activity was measured by functional magnetic resonance imaging (fMRI), brain activity during the semantic decision tasks (in all conditions) was similar for German-English (A) and Japanese-English bilinguals (B).

Crinion et al., Science, 2006

Bilingual Brain



Language



Language

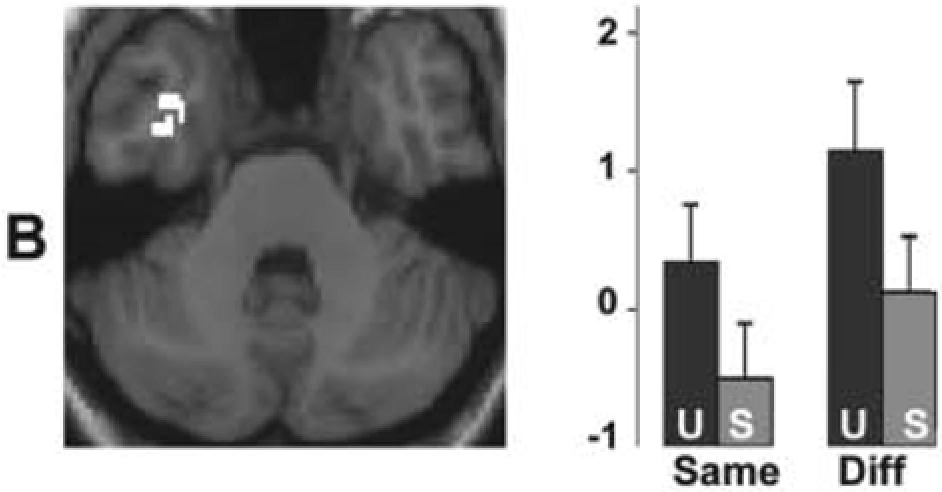
<u>German-English bilinguals</u> (A):

In the left inferior temporal lobe, brain activity was higher for pairs of unrelated compared to related word pairs, regardless of the language. That is based on the repetition suppression effect: neuronal activity goes down for repeated information.

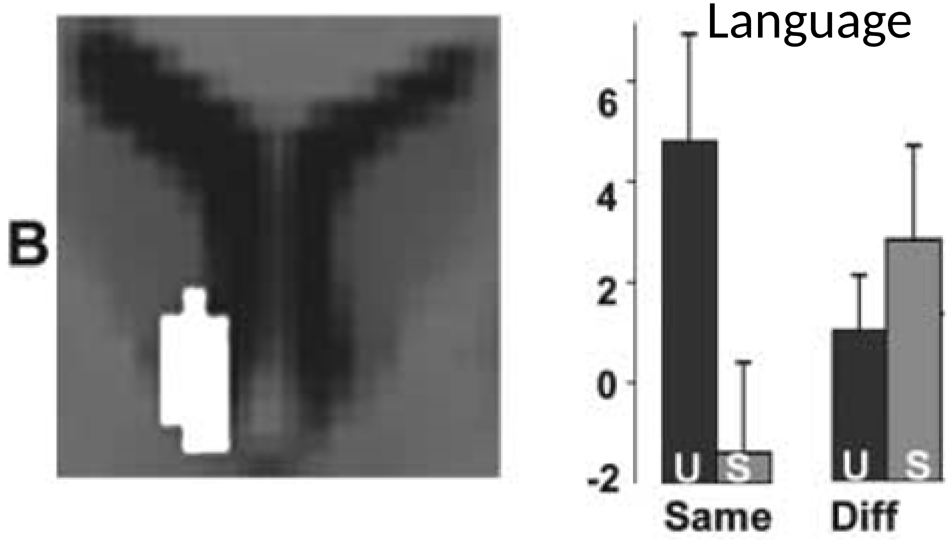
In the left caudate nucleus (part of the basal ganglia), brain activity was higher for unrelated word pairs and for a switch of language.

Crinion et al., Science, 2006

Bilingual Brain



Language



Language

Crinion et al., Science, 2006

<u>Japanese-English bilinguals</u> (A):

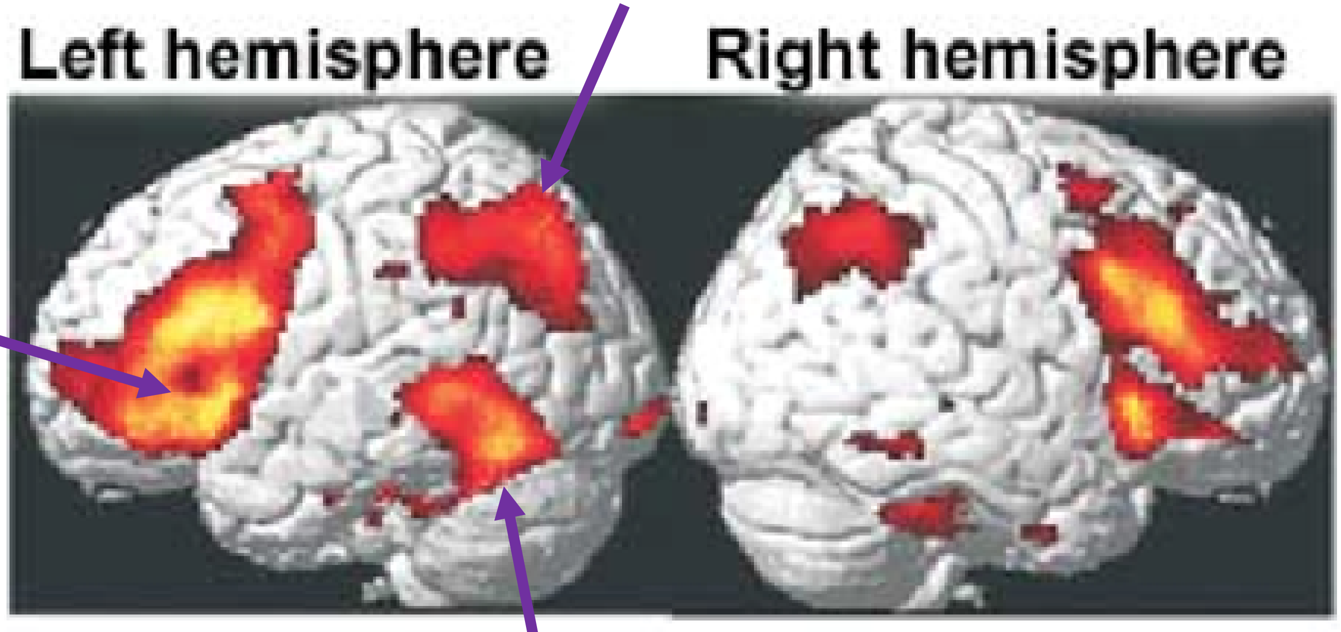
Again, in left inferior temporal lobe brain activity was higher for pairs of unrelated words, regardless of the language.

In the left caudate nucleus (part of the basal ganglia), brain activity was higher for unrelated word pairs and a switch of language.

This suggests a shared semantic storage in the left temporal lobe and a role of the caudate nucleus in the lexical-semantic control (the lexicon of which language is used).

Written Language: Reading

Reading involves several cortical areas, in particular in the left hemisphere, for the analysis of visual information and the linking of orthographic to phonological and semantic representations.



Crinion et al., Science, 2006

Developmental dyslexia

Developmental dyslexia is a difficulty in reading / learning to read not explained by:

- sensory deficits
- intellectual deficits
- lack of education or motivation

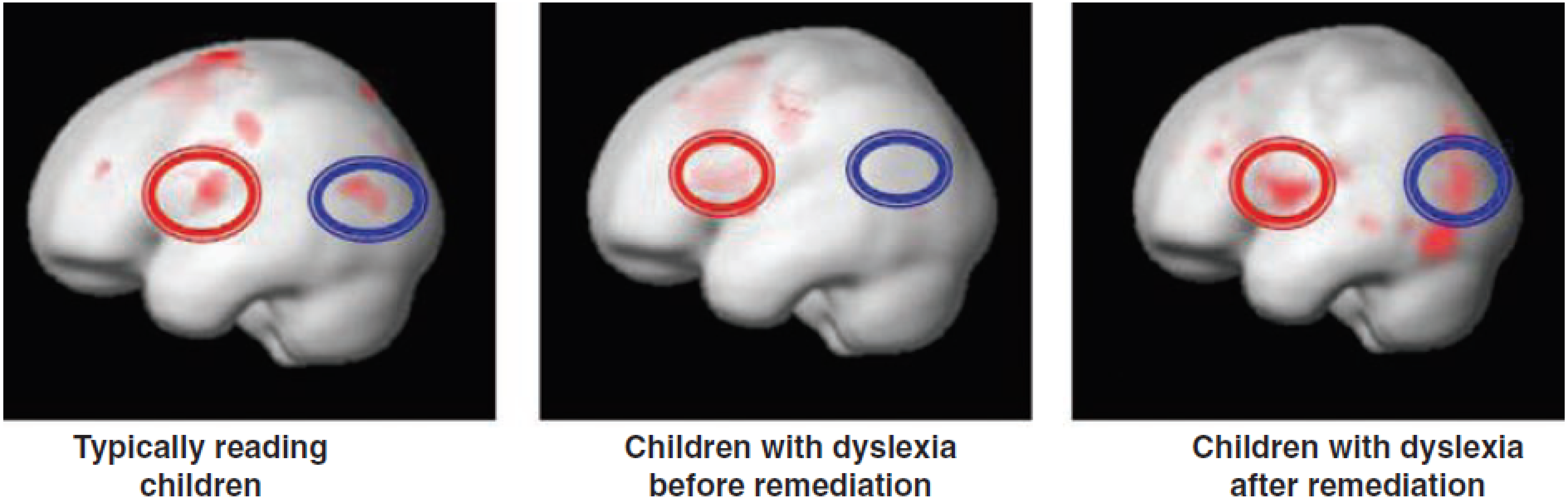
Prevalence is 5-17% for English (Gabrieli, Science, 2009), the prevalence is much lower in Japanese language: < 2% (Wydell and Kondo, Curr. Dev. Disord. Rep., 2015). Risk for developmental dyslexia is 50% with a parent or sibling who has it (identical twin: 68%).

It is highly persistent: a 1st year student with reading difficulties will read poorly in 4th grade with 90% probability, in high school with 75%.

→ Early treatment important!

Developmental dyslexia

Gabrieli, Science, 2009

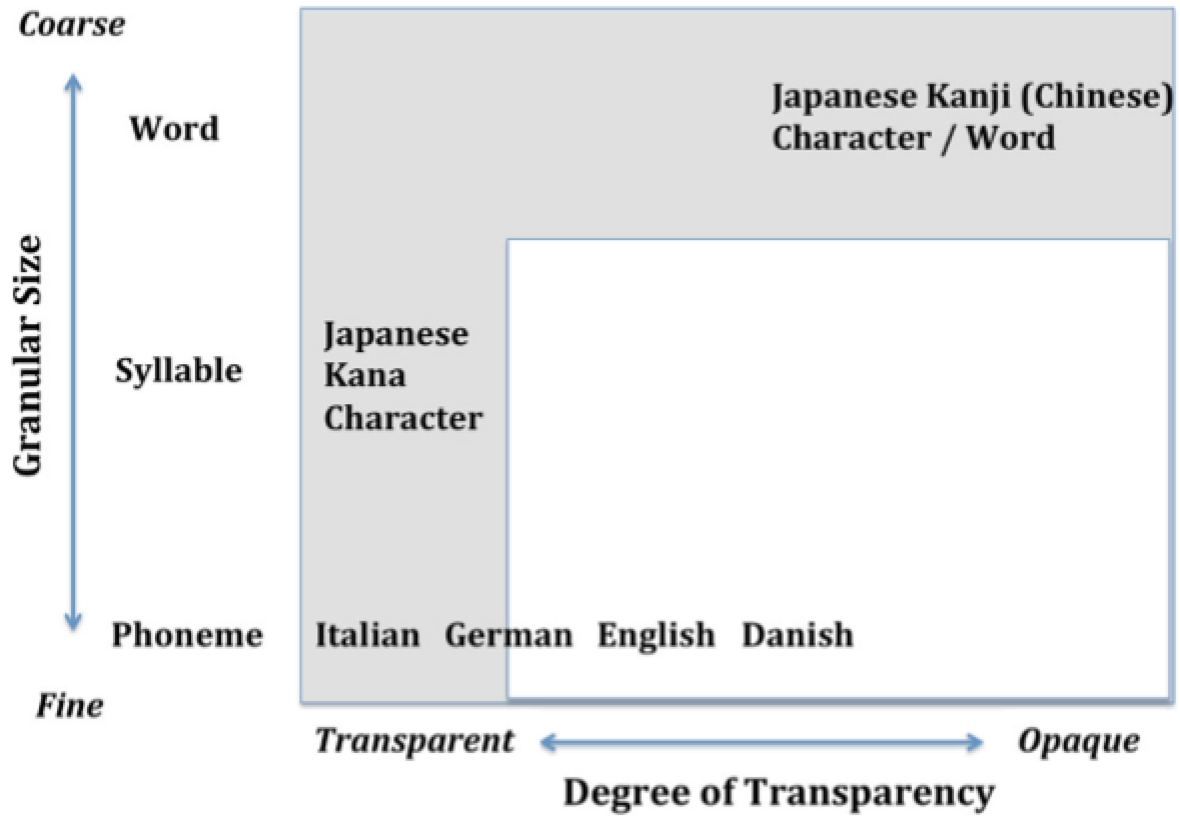


In comparison to normal children (left), children with dyslexia (middle) show lower brain activity in inferior parietal and inferior frontal regions during reading. Treatment (remediation) decreases this effect (right), which means brain activity increases after treatment.

Developmental dyslexia: Cross-language differences

One hypothesis for the differences in dyslexia prevalence is that alphabetic languages are more granular (representation of phonemes rather than syllables or words) leading to more vulnerability to dyslexia.

Secondly, some languages such as Danish or English have a more opaque relationship between letters and phonology, making them more vulnerable to dyslexia. Accordingly, Italian and German have lower dyslexia prevalence.



Wydell and Kondo, Curr Dev Disord Rep, 2015

Developmental dyslexia: Cross-language differences

AS is an English-Japanese bilingual who at the age of 16 showed good reading skills in Japanese similar to other Japanese students. In English, however, he was diagnosed with developmental dyslexia, which persisted, even though he then successfully took a BSc course in an English-speaking country .

He exhibited marked difficulties in reading/phonological tests in English both compared to English and normal Japanese controls.

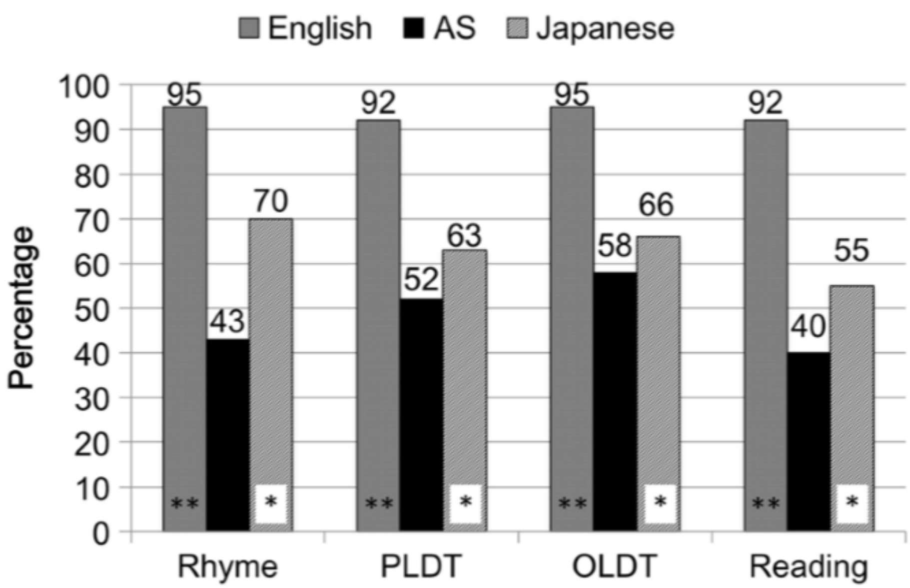
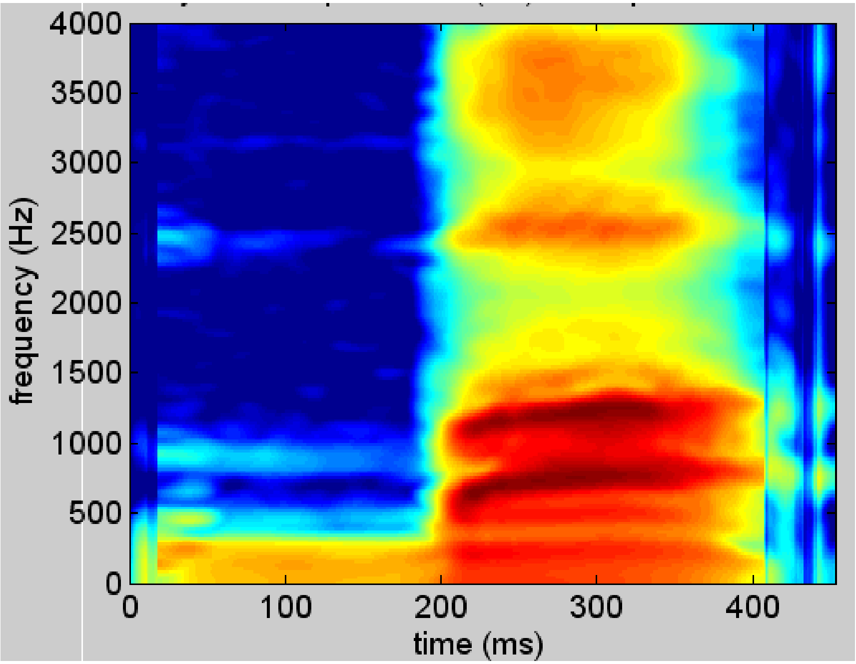
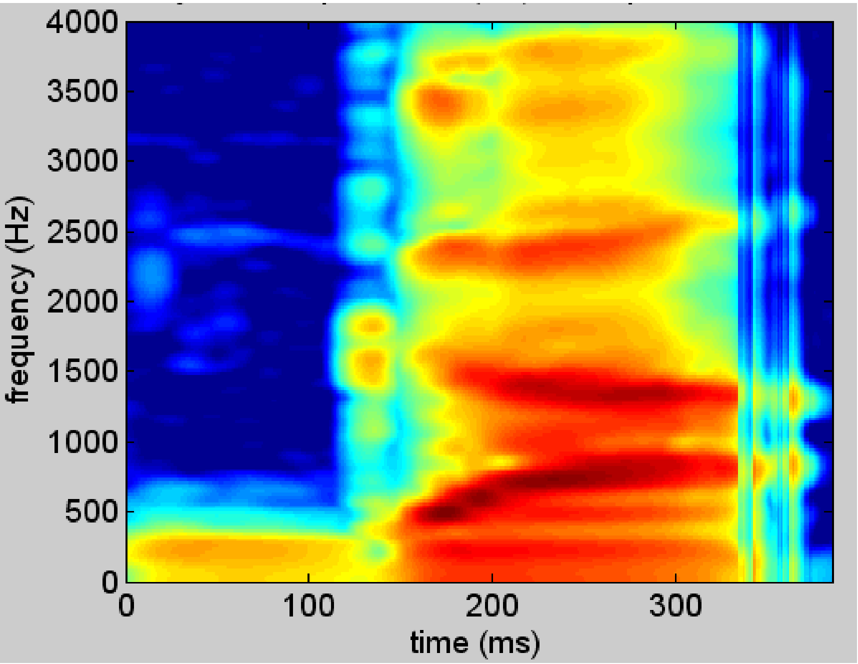


Fig. 1 Reading/phonological tests performance by AS, and the English and Japanese control participants from Wydell and Kondo (2003). An *asterisk* denotes $p<.05$ and *two asterisks* denote $p<.01$. *Rhyme*=rhyme judgments; *PLDT*=phonological lexical decisions; *OLDT*=orthographic lexical decisions (spell check); *Reading*=reading aloud of the stimuli used in PLDT

Treatment of developmental dyslexia

“ba”





“da”

Several theories have been put forward to explain developmental dyslexia. One common observation is that children lack phonological awareness: the ability to understand that words consist of smaller units: phonemes.

It has been suggested that more general auditory deficits in rapid processing of sounds cause this problem (Tallal et al., Nature, 1973). These deficits include rapid processing of sound order and rapid frequency changes (similar to those that distinguish phonemes).

Developmental dyslexia: Treatment

FastForWord (image from Tallal, 2013) is a game-like training program that addresses several deficits in language / reading impairments.

For example, the non-verbal auditory deficits in processing frequency changes is addressed by practicing the distinction between different sounds with increasing difficulty.

Two million children in 46 countries have been participating in this program.