Characterizing Central Auditory Processing and Sound-in-Noise Listening Deficits in Individuals with FASD

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FAS Diagnostic & Prevention Network

HUSKIES

Roadmap

- Preliminary observations/evidence from UW FASDPN
- Sound-in-noise or ‘active’ listening
  - FASD & auditory processing deficits
- What does it take to accomplish active listening?
  - Behavioral, acoustical, and neural considerations
  - Subcortical processes: temporal & spatial codes
  - Cortical processes: selective attention
  - FASD & selective attention deficits
- UW experimental protocol

Short Sensory Profile

Short Sensory Profile

SENSORY PROFILE
Winnie Dunn,
Ph.D., OTR, FAOTA

Child's Name: ______________________ Birth Date: __________ Date: __________

Completed by: ______________________ Relationship to Child: __________

Service Provider's Name: ______________________ Discipline: __________

INSTRUCTIONS

Please check the box that **best** describes the frequency with which your child does the following behaviors. Please answer all of the statements. If you are unable to comment because you have not observed the behavior or believe that it does not apply to your child, please draw an X through the number for that item. Please do not write in the Section Raw Score Total row.

Use the following key to mark your responses:

ALWAYS	When presented with the opportunity, you child always responds in this manner, 100% of the time.
FREQUENTLY	When presented with the opportunity, your child frequently responds in this manner, about 75% of the time.
OCCASIONALLY	When presented with the opportunity, your child occasionally responds in this manner, about 50% of the time.
SELDOM	When presented with the opportunity, your child seldom responds in this manner, about 25% of the time.
NEVER	When presented with the opportunity, your child never responds in this manner, 0% of the time.

Item	Tactile Sensitivity	ALWAYS	FREQUENTLY	OCCASIONALLY	SELDOM	NEVER
1	Expresses distress during grooming (for example, fights or cries during haircutting, face washing, fingernail cutting)					
2	Prefers long-sleeved clothing when it is warm or short sleeves when it is cold					
3	Avoids going barefoot, especially in sand or grass					
4	Reacts emotionally or aggressively to touch					

Short Sensory Profile: Auditory Filtering

Child "is distracted or has trouble functioning if there is a lot of noise around"

Response choices

- Always (100% of the time)
- Frequently (75% of the time)
- Occasionally (50% of the time)
- Seldom (25% of the time)
- Never (0% of the time)

Short Sensory Profile: Auditory Filtering

Child "appears to not hear what you say (e.g., does not 'tune-in' to what you say, appears to ignore you)"

Response choices

- Always (100% of the time)
- Frequently (75% of the time)
- Occasionally (50% of the time)
- Seldom (25% of the time)
- Never (0% of the time)

Short Sensory Profile: Auditory Filtering

Child "can't work with background noise (e.g., fan, refrigerator)"

Response choices

- Always (100% of the time)
- Frequently (75% of the time)
- Occasionally (50% of the time)
- Seldom (25% of the time)
- Never (0% of the time)

Short Sensory Profile: Auditory Filtering

Child “has trouble completing tasks when the radio is on”

Response choices

- Always (100% of the time)
- Frequently (75% of the time)
- Occasionally (50% of the time)
- Seldom (25% of the time)
- Never (0% of the time)

Short Sensory Profile: Auditory Filtering

Child “doesn’t respond when name is called but you know the child’s hearing is OK”

Response choices

- Always (100% of the time)
- Frequently (75% of the time)
- Occasionally (50% of the time)
- Seldom (25% of the time)
- Never (0% of the time)

Short Sensory Profile: Auditory Filtering

Child “has difficulty paying attention”

Response choices

- Always (100% of the time)
- Frequently (75% of the time)
- Occasionally (50% of the time)
- Seldom (25% of the time)
- Never (0% of the time)

Preliminary SSP data: UW FASDPN clinic

- Data from 377 individuals to date
- 73.6% - “definite difference” from typical performance in category of auditory filtering
  - Greater than 2 S.D. below normative mean
- 13.6% - “probable difference”
  - Between 1 and 2 S.D. below normative mean
- 12.8% - “typical performance”
  - At or above 1 S.D. below normative mean

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“Cocktail party” problem (Cherry 1953)

Katz, The Cocktail Party, 1965. Licensed by VAGA, New York, NY


TEACHER

'Hearing' vs 'listening'

Peripheral

- Ear (middle/inner ear)
- Hearing: ability to detect low amplitude sound signal in quiet background
- Primary assessment: conventional audiogram

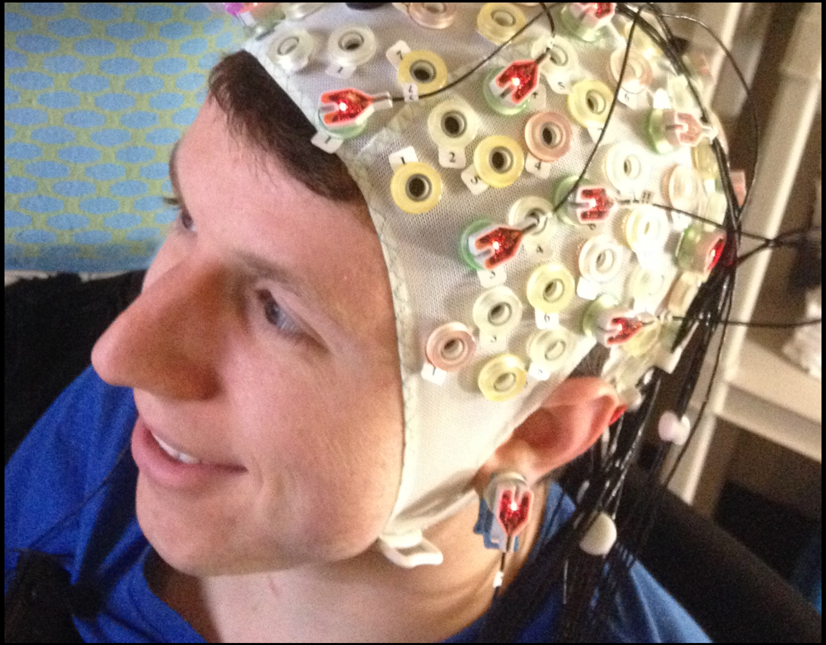
Central

- Brain (subcortical/cortical)
- <u>Active listening</u>: ability to extract key features from sounds loud enough to hear
- Less agreement about assessment

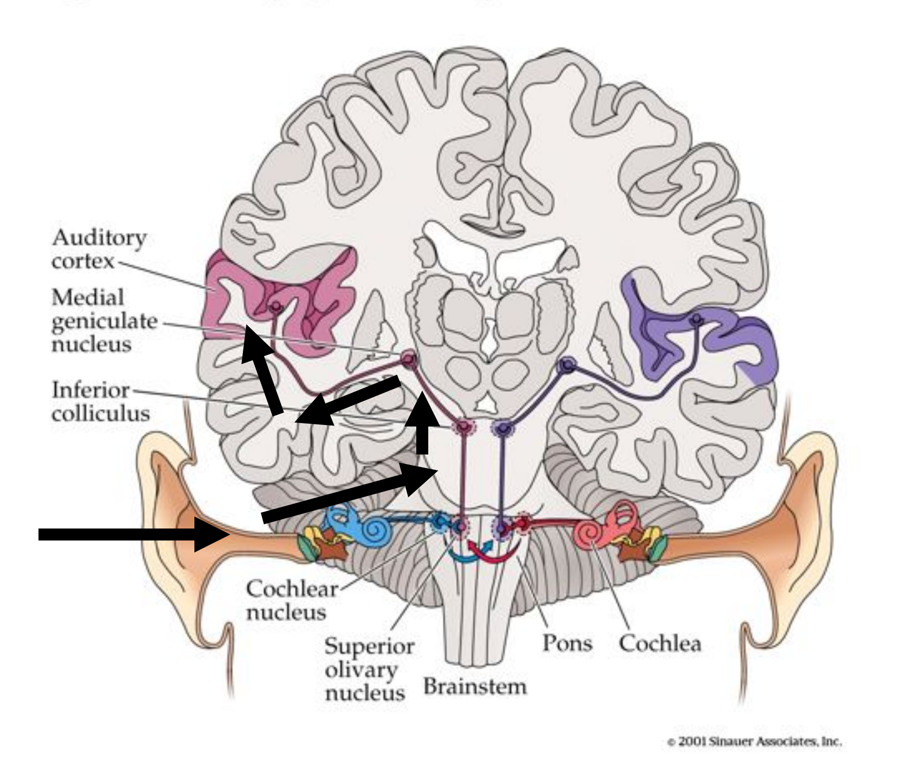
‘Hearing’ vs ‘listening’

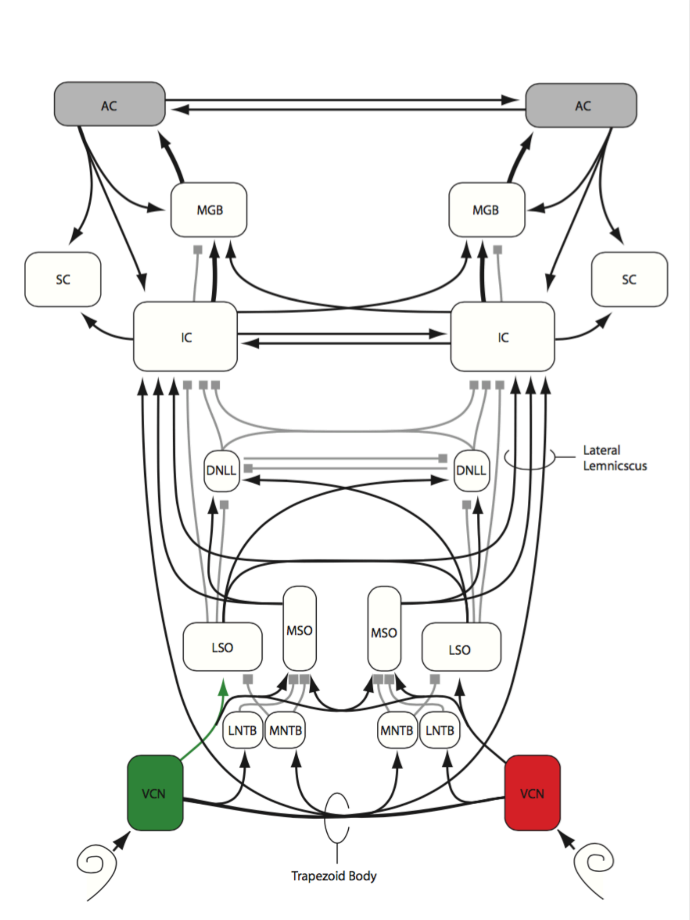
Peripheral

Central



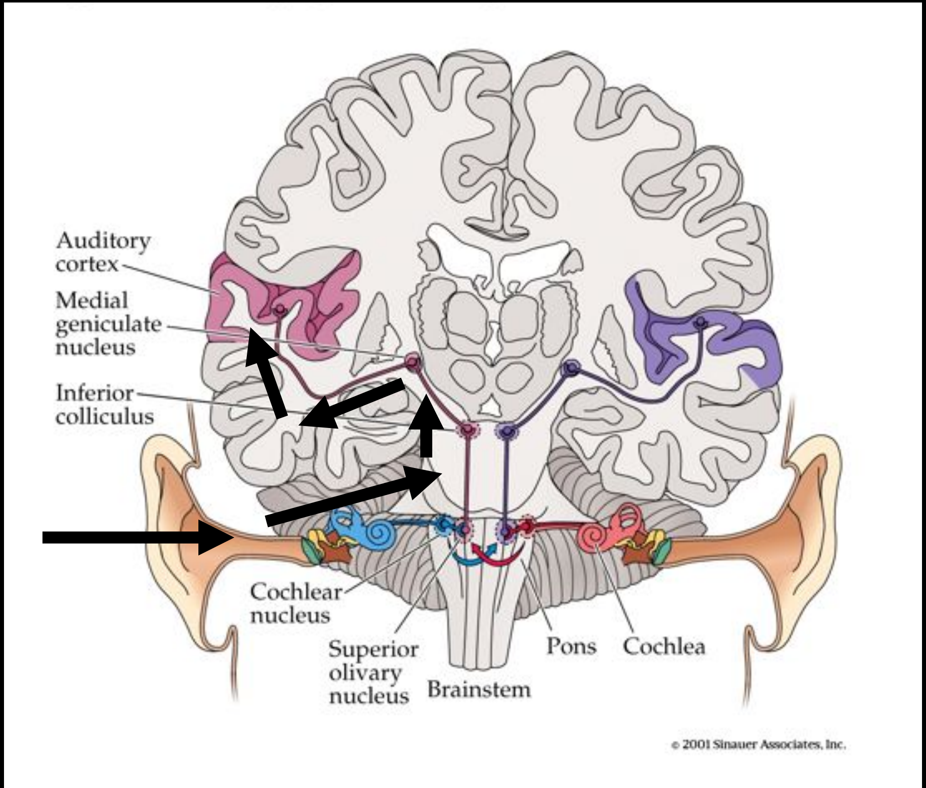
Auditory system

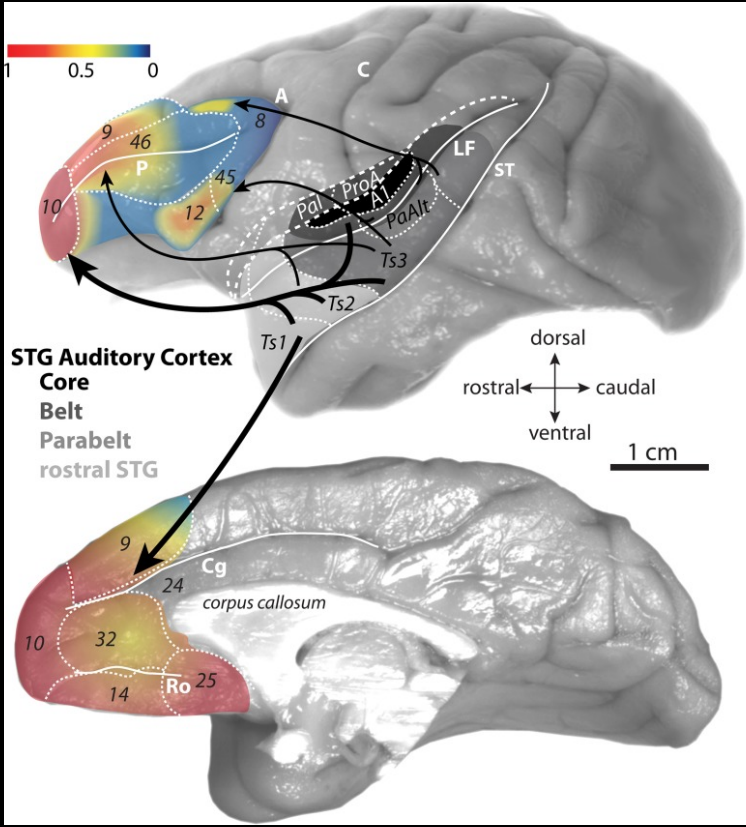




Medalla & Barbas 2014

Auditory system





Medalla & Barbas 2014

Prenatal alcohol exposure & auditory deficits

- Mostly peripheral hearing issues in individuals w/full FAS (or severely exposed) (Human: Church & Gerkin 1988, Rossig et al. 1994, Popova et al. 2016; Rodent: reviewed in Church & Kaltenbach 1997, Church et al. 2012)
- Some evidence of central auditory issues in humans
  - Sound-in-noise listening deficits (Church et al. 1997)
  - Disordered central auditory processes (Kaneko et al. 1996, Stephen et al 2012)
- But research most often involves individuals with full FAS and/or potential hearing loss; hard to disentangle (NB: Stephen et al 2012: ARND)

Our focus

- General FASD population
- Central processes: active listening
  - Individuals w/ full FAS/pFAS may be predisposed to peripheral (& also central?) hearing deficits
  - But those w/o craniofacial dysmorphology may still have central/active listening deficits leading to difficulties hearing sound targets in noise, even in the absence of peripheral hearing loss

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Listening when there are multiple sound sources is difficult

Listeners attend to "objects"

Let's play "Simon Says"
(Listen to the male voice)

What's the password?

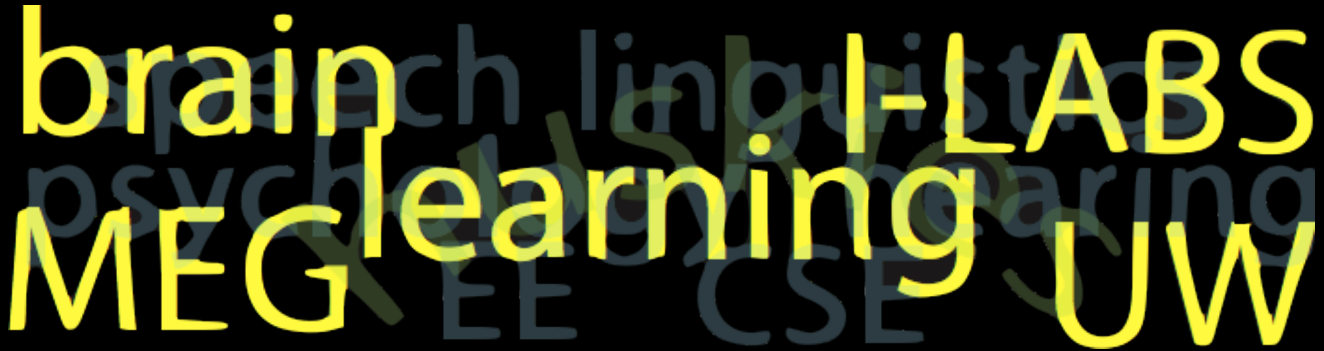
Now listen to the female voice

What did you miss out on?

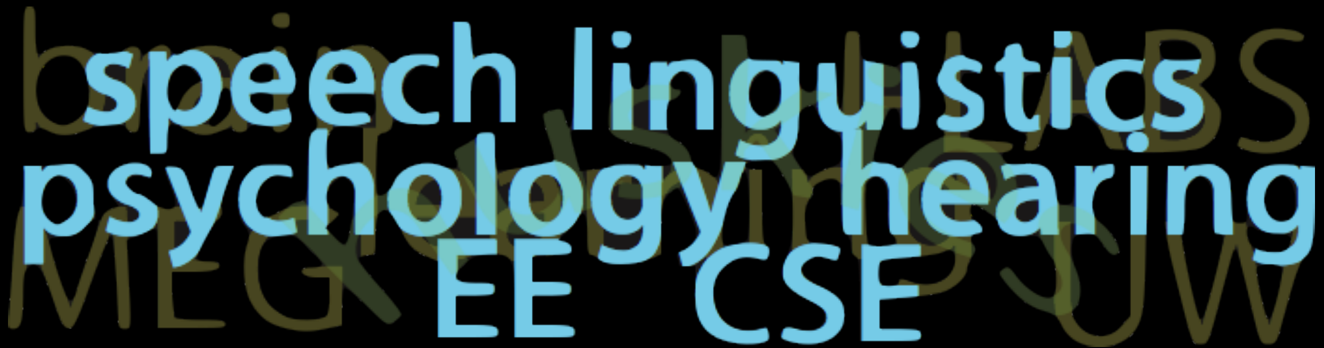
Object formation in a “transparent” scene

Cues aid in segregation of objects

Attending to a specific feature promotes object formation



Each feature can be selectively attended



Priming also helps

Acoustic cues

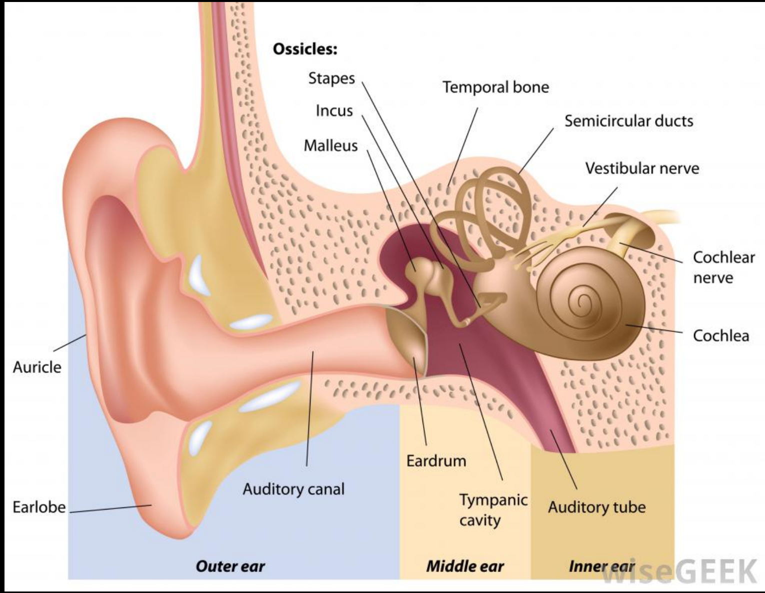
- Pitch
- Space
- Loudness

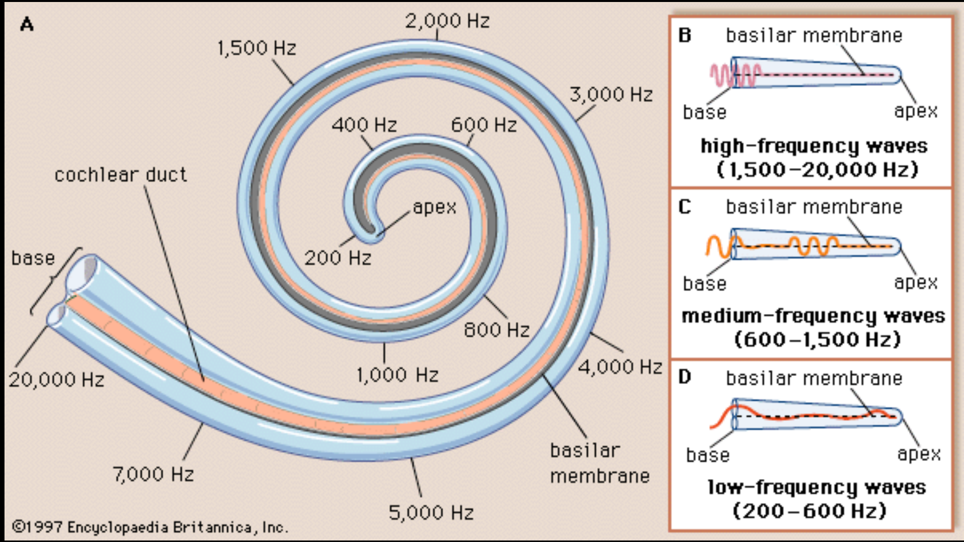
Depend on precise neural coding of temporal aspects of sound

How do the ear and brain extract sound cues and use them to pick out sound in noise?

How can these processes break down?

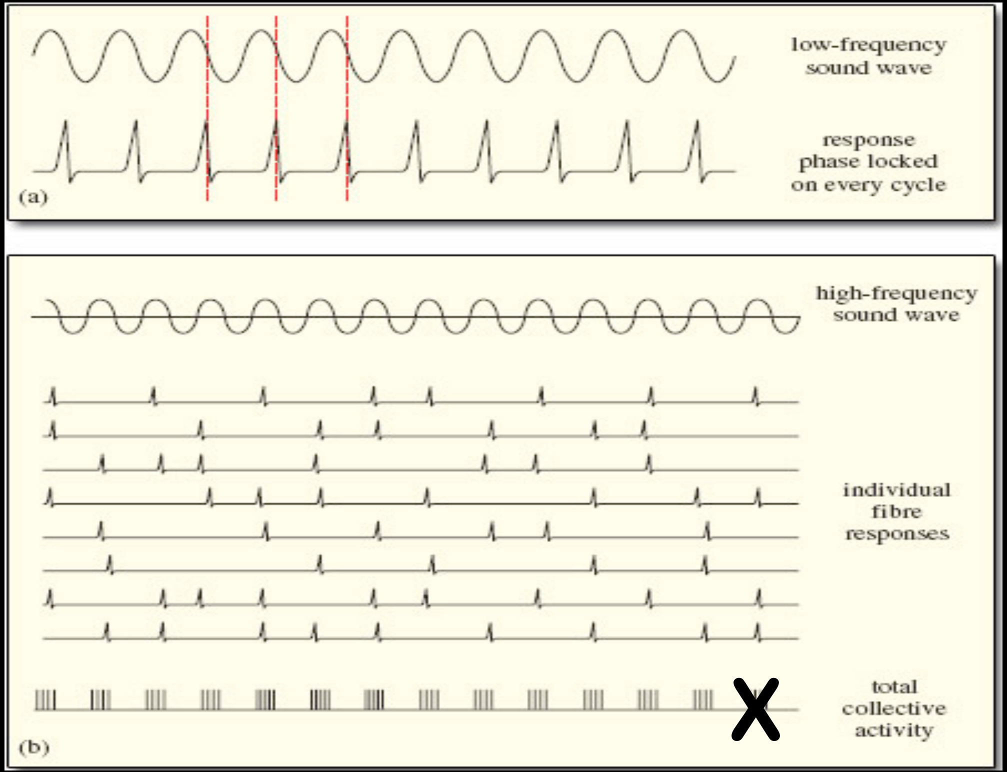
Frequency analysis: “place code”





http://www.ifd.mavt.ethz.ch/research/group_lk/projects/cochlear_mechanics/index

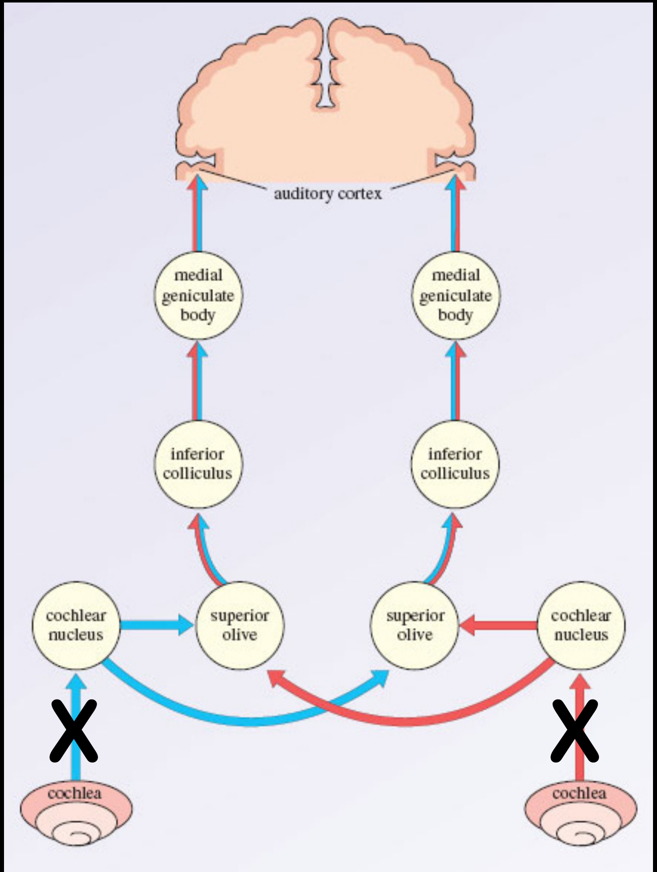
Temporal coding of frequency



http://dspace.jorum.ac.uk/xmlui/bitstream/handle/10949/965/Items/SD329_1_section13.html

Temporal coding of frequency

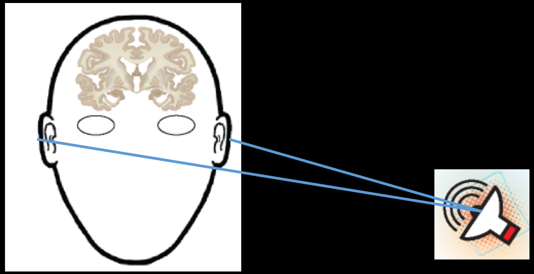
- Degraded temporal coding of sound (e.g., not enough auditory nerve fibers) can affect speech-in-noise listening (Hopkins & Moore 2009)
- Not detected with conventional audiometric screen
- Referred to as “hidden hearing loss”



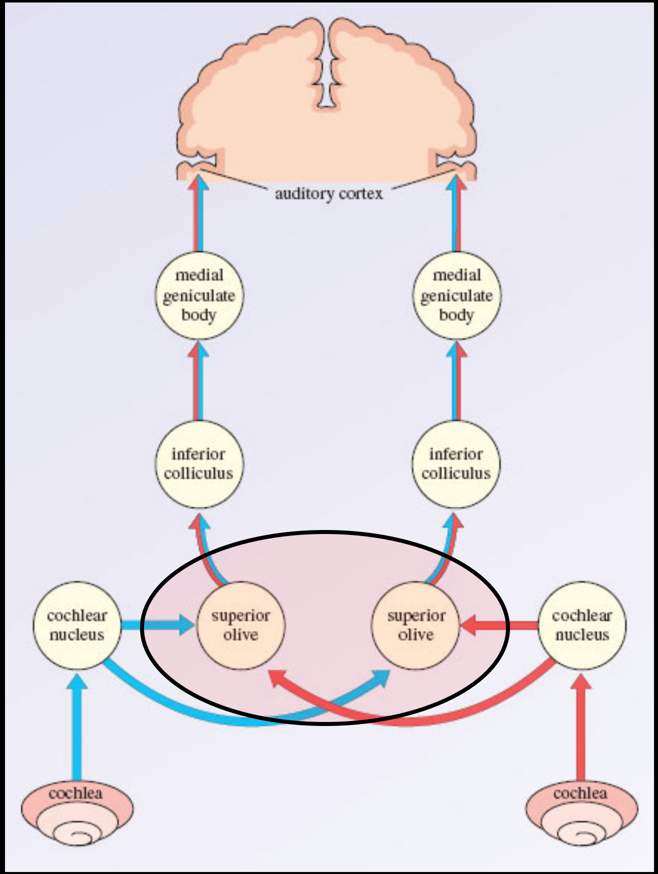
Coding of spatial cues

Interaural time difference (ITD)

Interaural level difference (ILD)

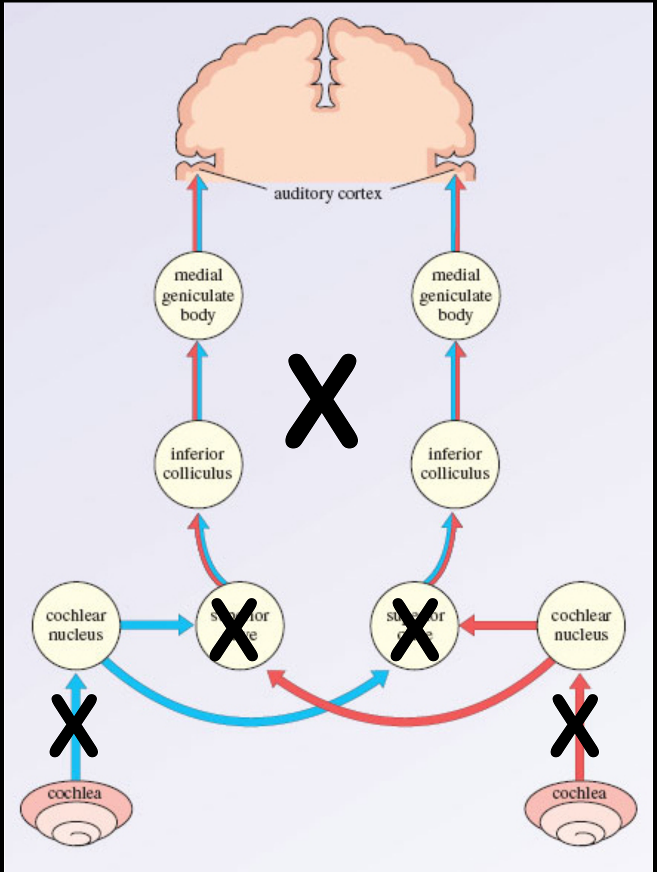


Spatial cues are processed by specialized neurons & structures in the superior olivary complex (SOC)



Spatial processing can be impaired due to:

- Degraded input to the SOC
- Damage to spatial processors
- Degraded spatial representation passed upward to cortex
- Degraded auditory spatial coding can affect speech-in-noise listening (Culling et al. 2004)



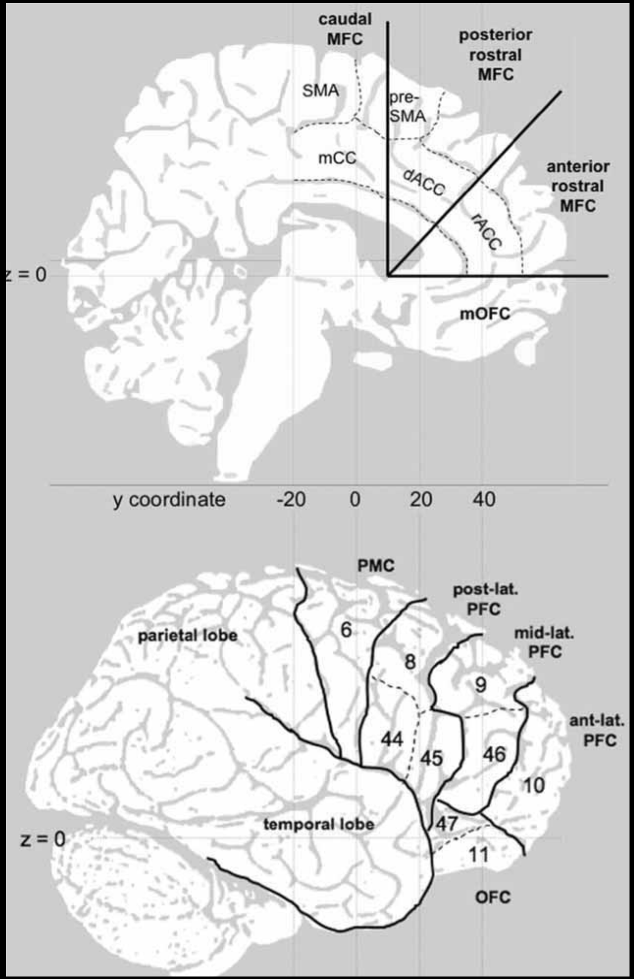
Cognitive control/attention

- Dual-task paradigm
  - Task set reconfiguration & proactive task set interference (Allport et al. 1994, Meiran 2000, Monsell 2003)
- Attentional set-shifting (Monsell 1996)
- Response inhibition
- Most paradigms more broadly cognitive (but see Koch et al. 2011)

BLUE

Cognitive control/attention

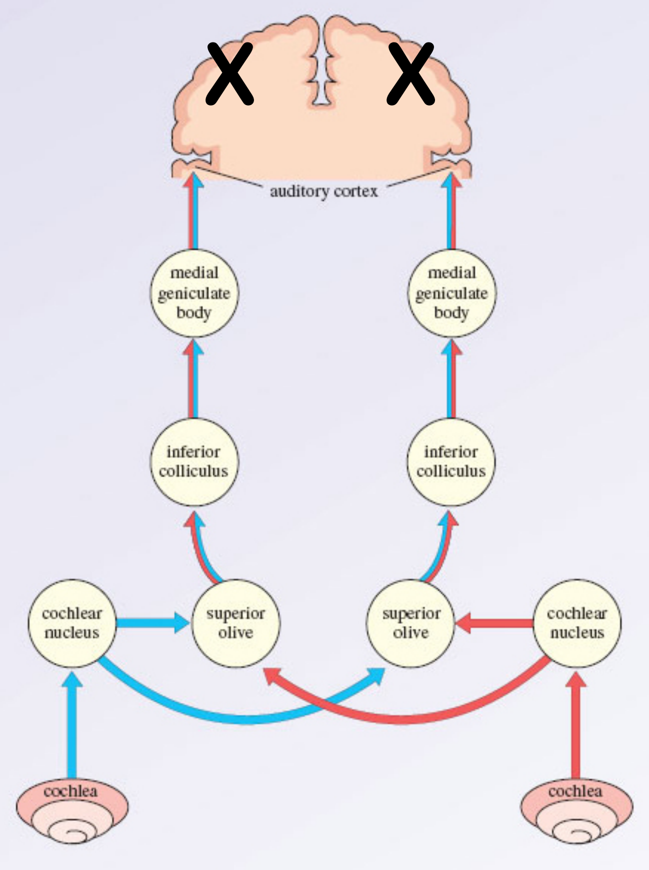
- Network in medial & lateral frontal cortex implicated (Corbetta & Shulman 2002, Dosenbach et al. 2006, Ruge et al. 2013)
  - Anterior cingulate cortex (ACC)
  - Dorsolateral & ventrolateral prefrontal cortex (DLPFC & VLPFC), inferior frontal junction (IFJ)



Summerfield & Koechlin 2009

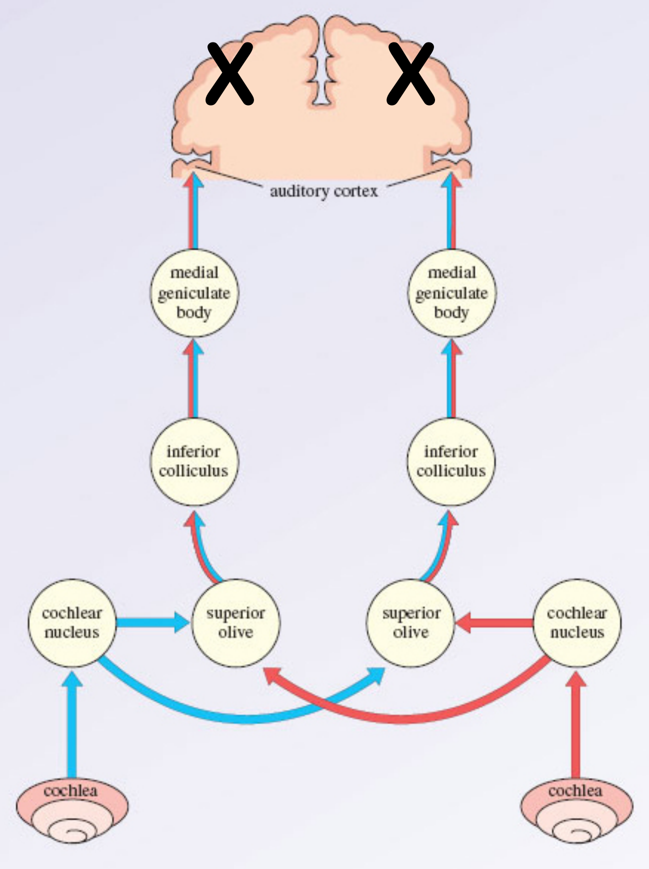
Cognitive/attentional deficits in FASD

- Executive control deficits (Kodituwakku 2009, Mattson et al. 2011)
  - Set shifting & response inhibition deficits: Stroop, antisaccade, Go/NoGo, NEPSY-II & Wisconsin Card Sorting tasks (Green et al. 2009, Paolozza et al. 2014, Khoury et al. 2015, Kingdon et al. 2016)
  - Atypical DLPFC, ACC, & IFJ function (Fryer et al. 2007, O'Brien et al. 2013, Ware et al. 2015, Kodali et al. 2017) & atypical ACC structure (Migliorini et al. 2015) associated with response inhibition deficits in FASD

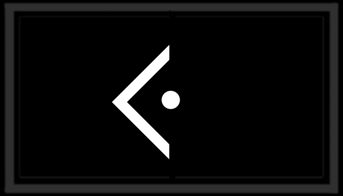


Cognitive/attentional deficits in FASD

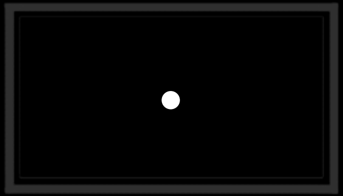
- Reduced brain volume in frontal regions (Astley et al. 2009, Gautam et al. 2015)
  - Cingulate gyrus (Bjorkquist et al. 2010, Eckstrand et al. 2012)
- Reduced integrity of white matter connections to frontal lobe
  - Cingulum, uncinate fasciculus & superior longitudinal fasciculus (Lebel et al. 2008, Paolozza et al. 2017)



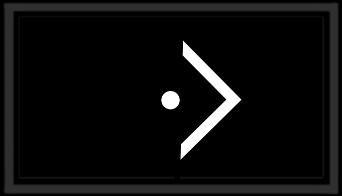
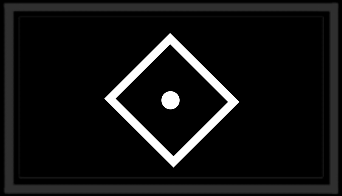
Behavioral paradigm: Cue to attend space

Time	Visual	Auditory
-600 to -400 ms		

Maintaining Fixation

Time	Visual	Auditory
-400 – 0 ms		

Behavioral paradigm: “Just Kidding” cue

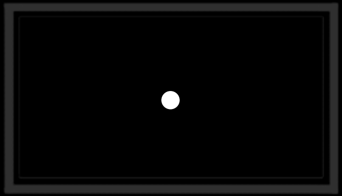
Time	Visual	Auditory
0 - 200 ms		*Switch Trial*
		*Hold Trial*

Stimulus (DIGITS) onset

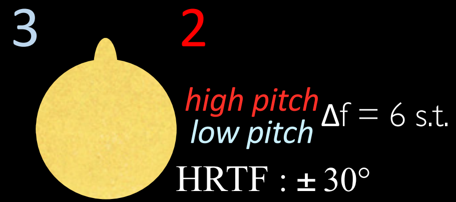
Time

600 – 1600 ms

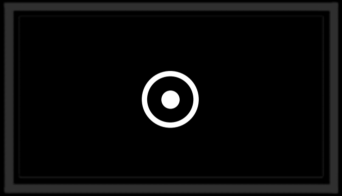
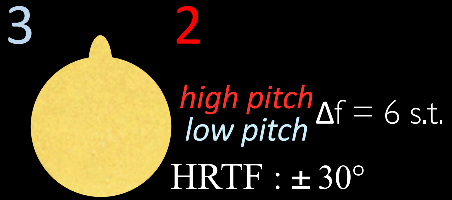
Visual



Auditory



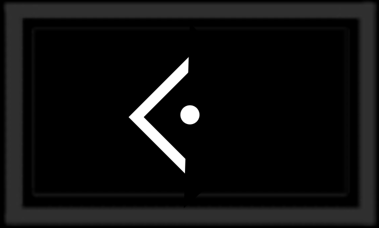
Response period

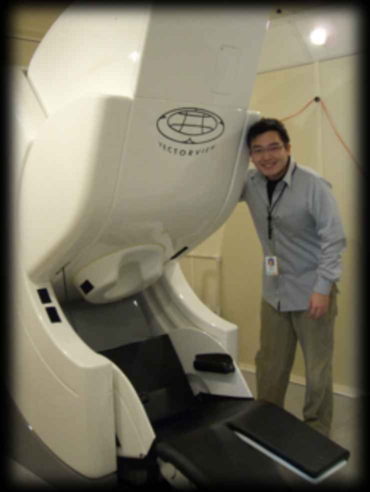
Time	Visual	Auditory
1600 – 2600 ms		

Switch Trial Response: 2

Hold Trial Response: 3

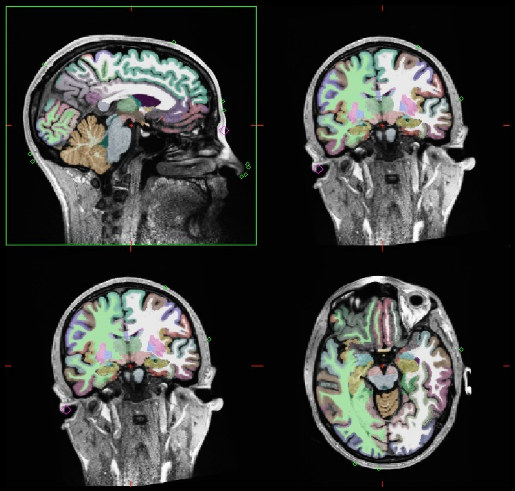
Original cue

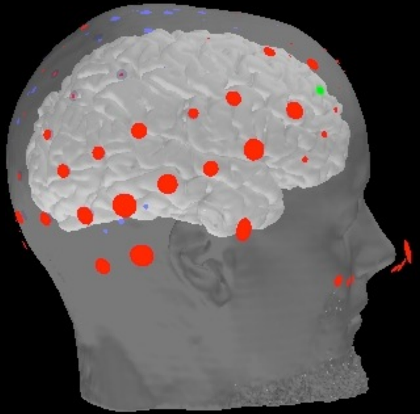




MEG measurement

Simultaneous EEG



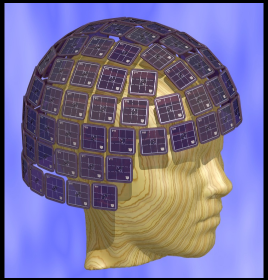


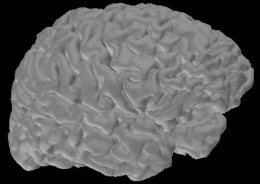
Anatomical scan

Co-registration

Inverse Imaging

Mapping M/EEG signal onto the cortex





Forward solution

M/EEG

$$\mathbf{y} = \mathbf{G}\mathbf{q} + \varepsilon$$

Equivalent currents

Inverse estimate

$$E\left\{\varepsilon\varepsilon^T\right\} = \mathbf{C}$$

$$\hat{\mathbf{q}} = \arg\min_{\mathbf{q}}\left(\|\mathbf{y} - \mathbf{G}\mathbf{q}\|_{\mathbf{C}}^2 + f(\mathbf{q})\right)$$

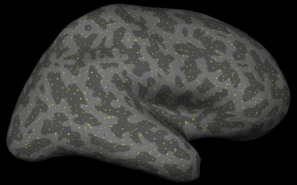
Observed data

Noise covariance

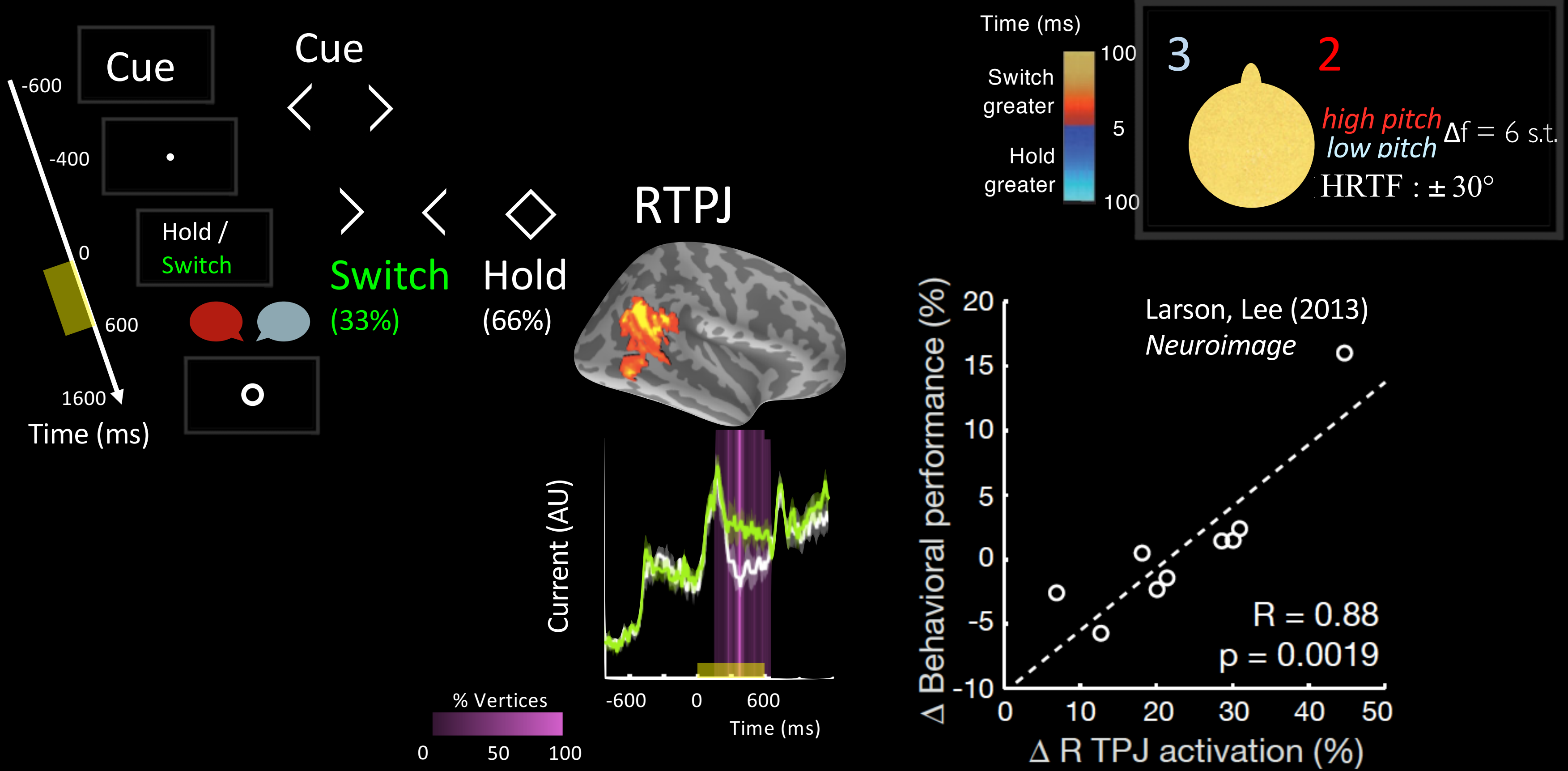
Penalty term

Minimum L2-norm: $|\mathbf{q}|^2$

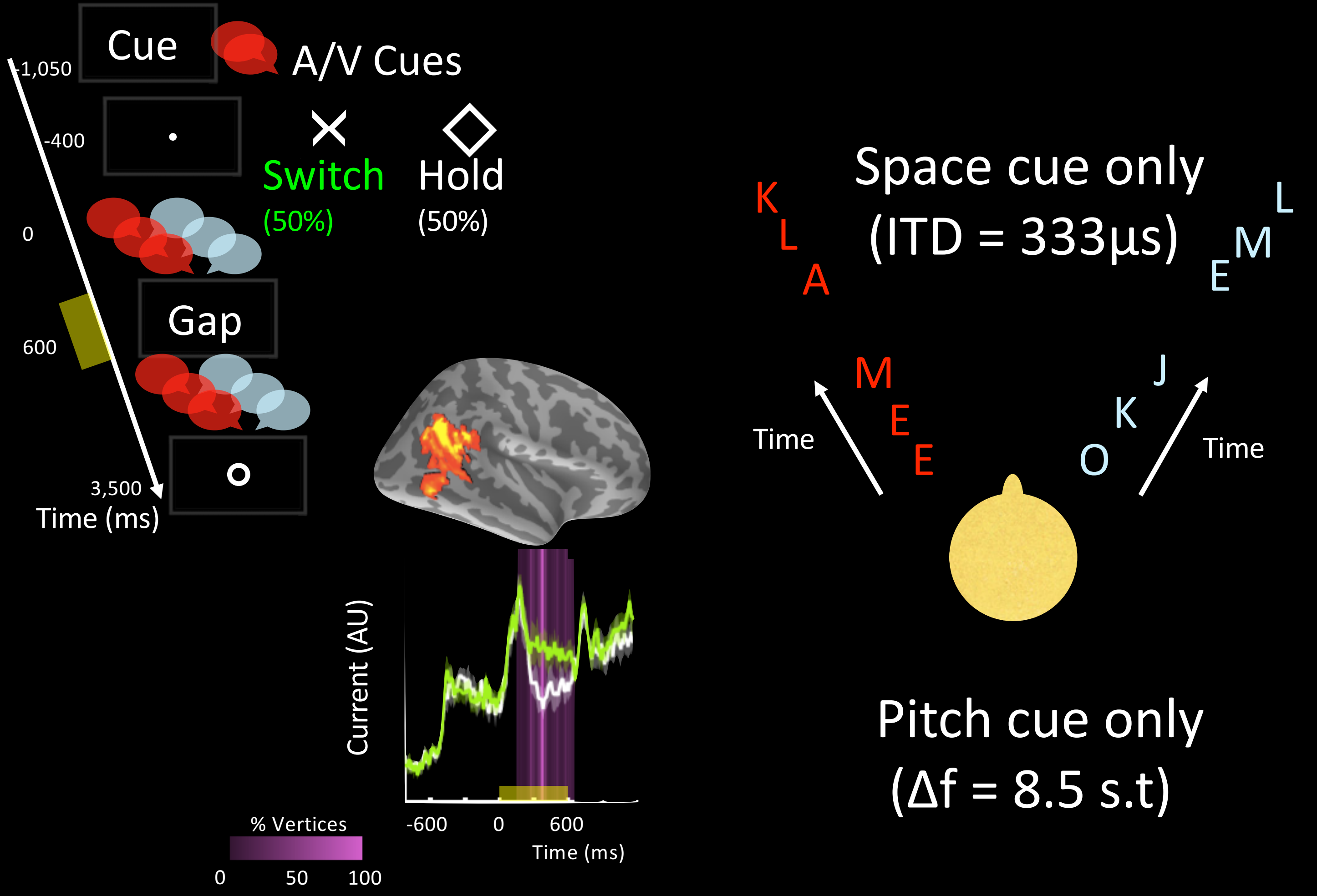
Minimum Current: $|\mathbf{q}|$



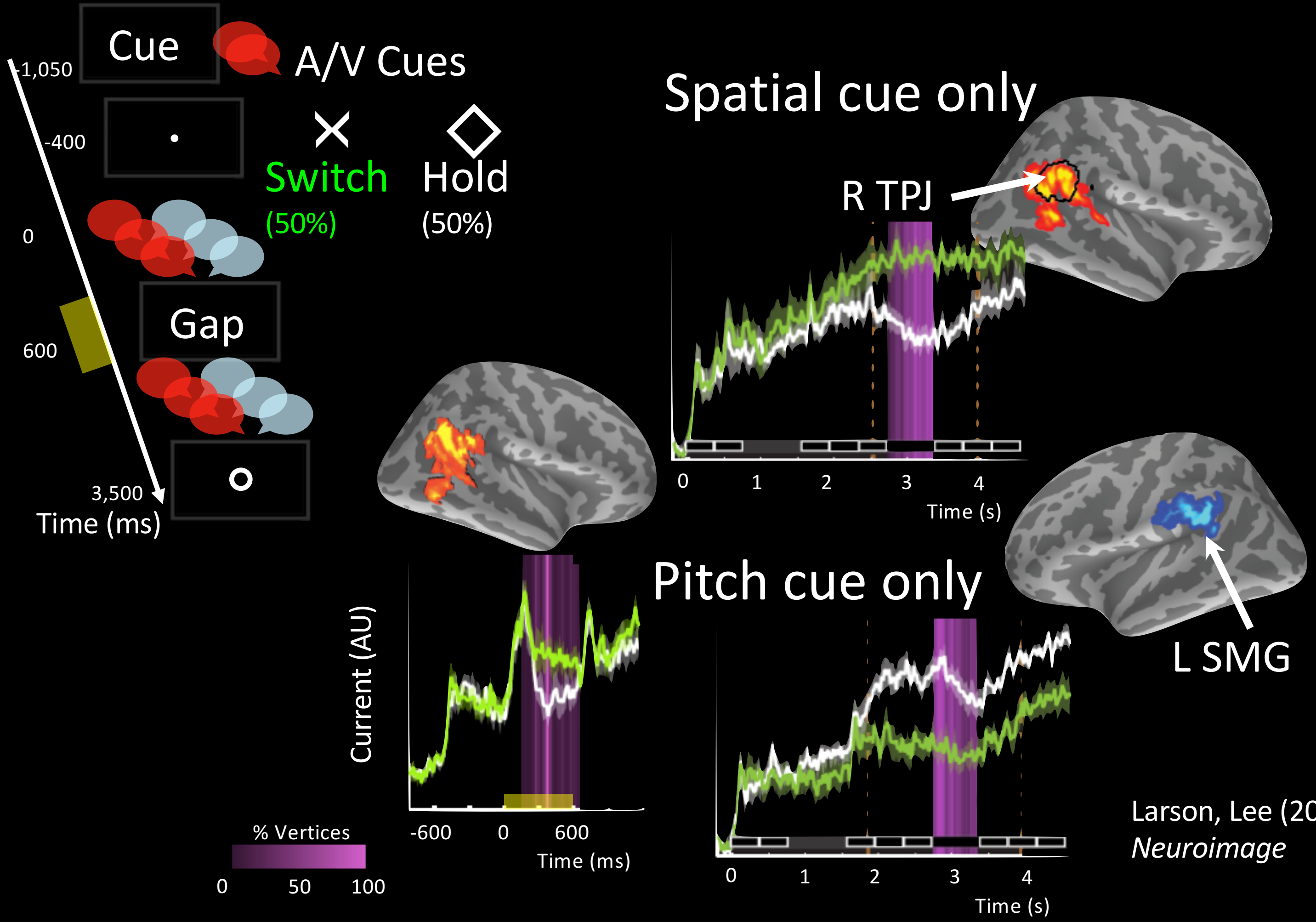
Switching attention



Space vs pitch

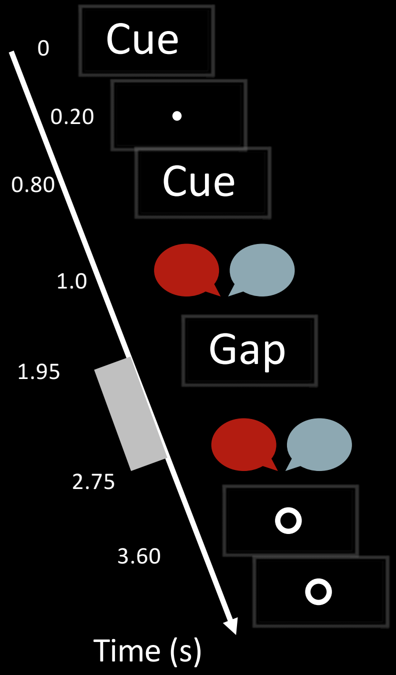


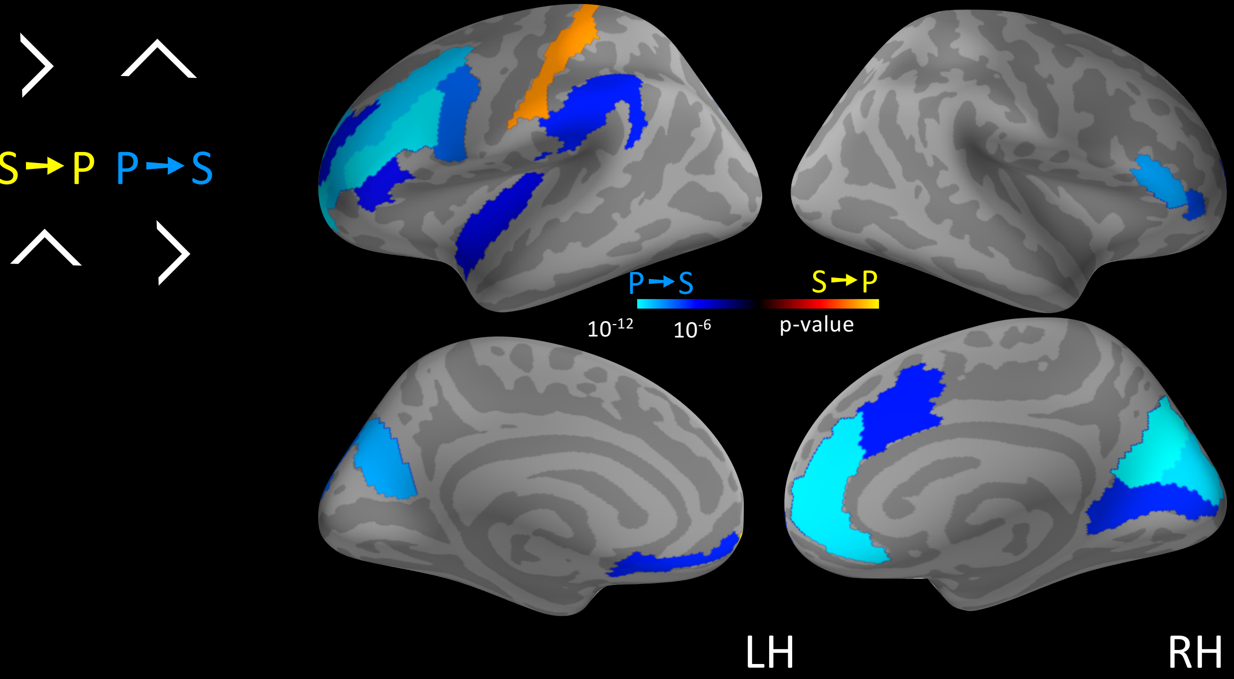
Space vs pitch



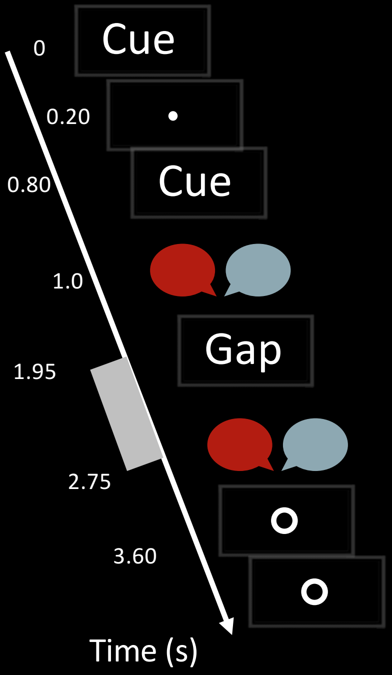
Larson, Lee (2014) *Neuroimage*

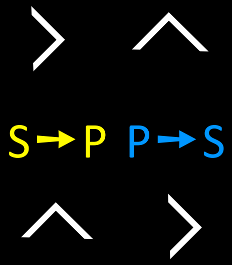
Switching across features

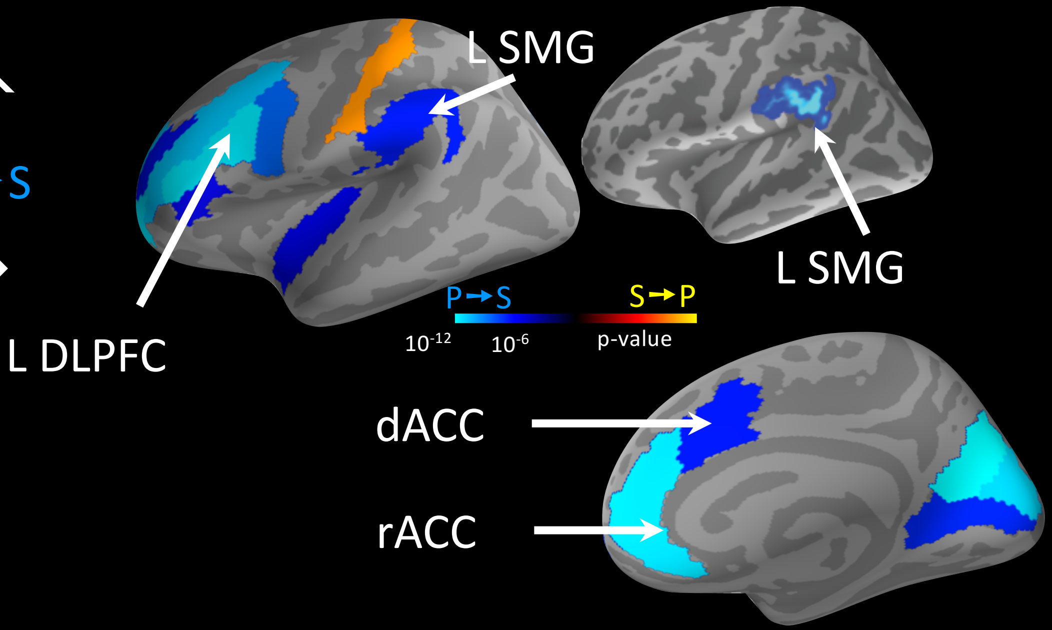




Asymmetric switching effect

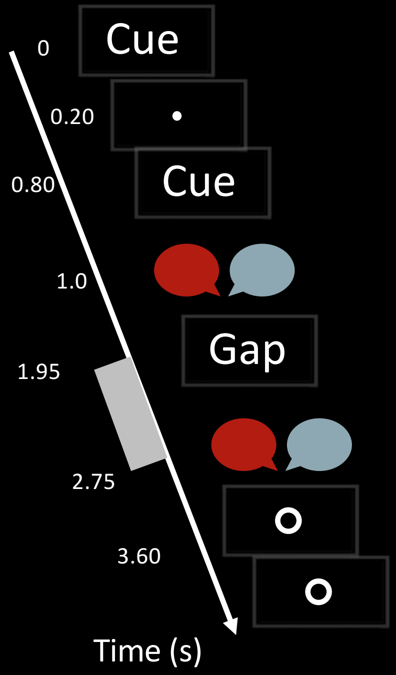


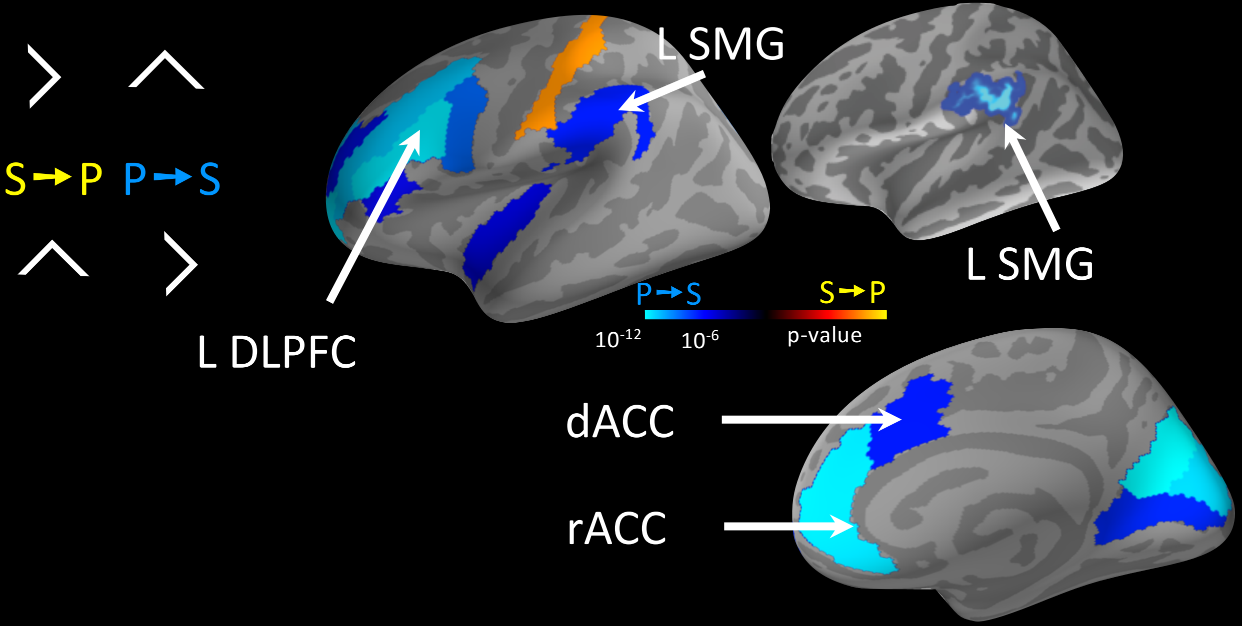




- Brain regions involved in task switching
  - dorsal lateral prefrontal cortex (DLPFC) anterior cingulate cortex (ACC)
  - (Monsell, ‘03; Hyafil, ’09)

Harder to switch out of a hard task





- ACC configures the priorities associated with a new task
- DLPFC tackles interference from recently active, rivalrous task sets

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Study design overview

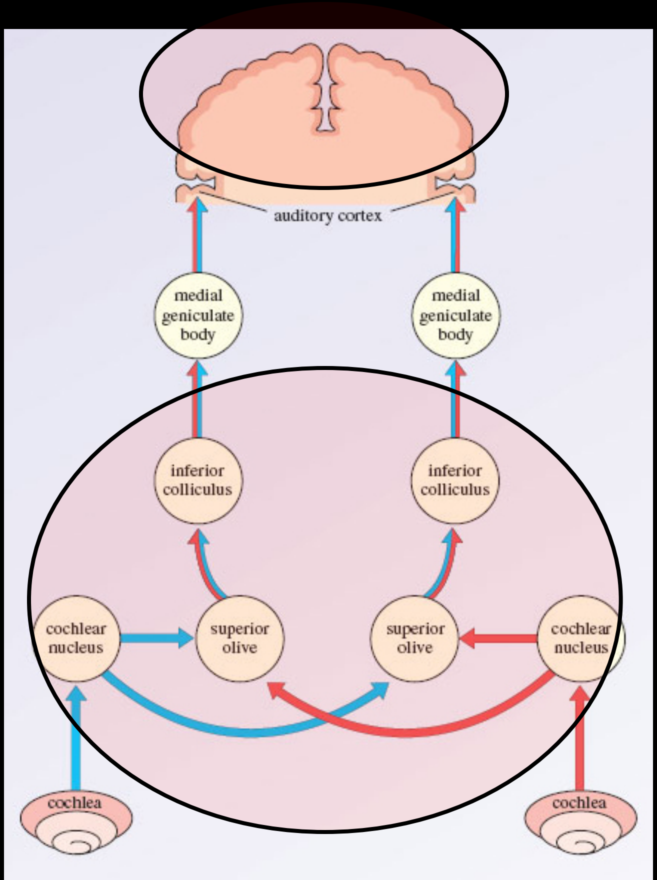
- Comprehensive battery: self-report listening, audiological, cognitive, linguistic, behavioral, EEG & MEG
- Two groups (age 13+): Individuals diagnosed with FASD (target N = 60) and matched controls

Audiological & language assessment

- Audiological
  - Pure-tone hearing thresholds
  - Inner ear & brainstem health (otoacoustic emission/OAE, auditory brainstem response/ABR)
  - Self-report questionnaire : Speech, Spatial, and Qualities of Hearing Scale (SSQ) (Gatehouse & Noble 2004)
- Expressive language task (Thorne 2006)

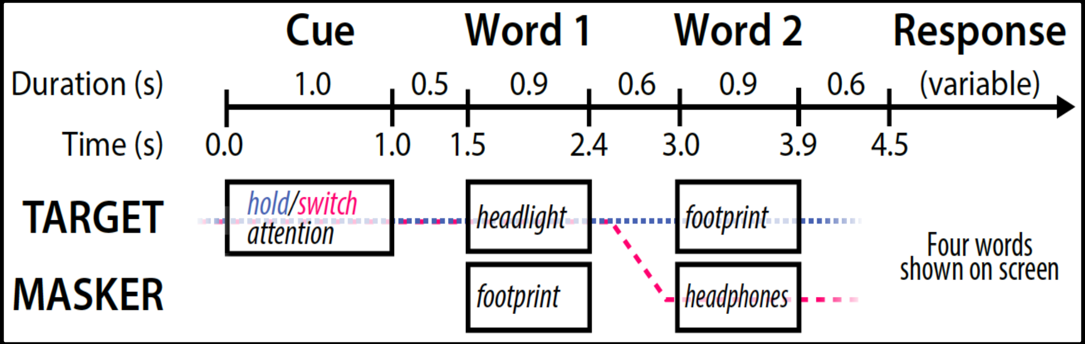
Behavioral, EEG & MEG measures

- Probing:
  - Temporal encoding of sound
  - Spatial listening
  - Auditory attention



Behavioral, EEG & MEG measures

- Speech-in-noise task (Gallun et al. 2013; Maddox & Lee 2016)
- Temporal envelope encoding (Bharadwaj et al. 2015) & subcortical spatial encoding (Ross et al. 2007, Maddox & Lee 2016)
- Auditory attention task (Dillon 2012; Lee et al. 2013)



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Thank you