“Neural Signatures”

FROM ANL’S PUBLICATIONS

“Neural Signatures”

- Over the years the Auditory Neuroscience Laboratory (ANL) has found signs of poorer neural synchrony in populations with language or learning difficulties, and signs of increased neural synchrony in populations with enhanced skills.
- cABR/FFR responses can
  - Reflect auditory experience,
  - Elucidate biomarkers inferring problems with auditory encoding.

Developmental Trajectory

- While ABR Wave V responses to clicks are mature [adult-like] by the age of two years, cABR/FFR Wave V responses became quicker in the range of 3 to 8 years, then slowly increased in latency until age 21. They plateaued from age 21 to 40, with further increases in latency in the 40 to 60 year range.
- There is significant change from age 3 to age 5.
- Hypothesis is that this is experience-dependent.
  - Kraus and White-Schwoch 2015

Language Experience (normals)

- Comparison of cABR/FFR between native speakers of [American] English versus native speakers of French.
- "Independently of the stimulus, American participants exhibited greater neural representation of the fundamental frequency compared to French participants, consistent with the importance of the fundamental frequency to convey stress patterns in English…These results align with the hypothesis that language experience shapes sensory processing of speech and that this plasticity occurs as a function of what is meaningful to a listener."
    - Nina Kraus and Daniele Schon, 2016

Linguistic experience: Infants (normals)

- Infants at different ages compared by cABR/FFR responses.
- 1. The cABR can be measured in the 3 to 10 month age group.
- 2. Their responses to the fundamental frequency were better than responses to speech harmonics. Onset, FFR and offset are measurable in this group. Good responses to lower frequencies were present at earliest age tested, while responses to higher frequencies (formants) improved with age.
    - Anderson et al. 2015

Bilinguals (normals)

- Both cortical and subcortical neural encoding is enhanced in bilinguals. Enhanced subcortical [brainstem] neural encoding is correlated to improved auditory attention and high levels of Response Consistency.
- "We interpret these enhancements in neural consistency as the outcome of strengthened attentional control that emerged from experience communicating in two languages."
- "In addition to other forms of auditory-based training, such as computer-based training or music lessons, second-language learning may be another type of training that can be implemented to help stabilize an inconsistent neural response."
- Krizman et al. 2014.

Musical Training

- "Compared with non-musicians, musicians have more robust auditory…brainstem responses [better synchrony] to speech and musical stimuli. Periodicity encoding [phase-locking] is enhanced, especially to the fundamental frequency of the stimulus. Onset responses are earlier and of larger magnitude.[This study] shows the plasticity of the auditory system [responses can be enhanced], the synaptic efficiency of the brainstem can be enhanced, and it shows reciprocal afferent and efferent plasticity, strengthening subcortical and cortical centers simultaneously."
  - Musacchia et al, 2007

Musical Training

- "Musical training results in more efficient neural processing. It strengthens cognitive function [short term memory and auditory attention]…Experience with music contributes to the changes seen in musicians over and above genetic factors."
    - Strait et al. 2010

Musical Training versus Aging

- "Age-related declines in auditory processing are not inevitable. They may be offset by the quality and consistency of everyday auditory experience. Music training appears to be a powerful strategy to support meaningful interactions with sound, mitigating age-related decline in nervous system function. Early auditory experiences, such as through music, are investments in healthy aging that pay lifelong dividends for auditory processing."
  - Kraus and White-Schwoch, 2014

Language-Learning Disorders (children)

- "A subgroup (approximately 33%) of children with learning deficits showed delayed peak latencies, shallow slope of the Wave V/A complex, delayed or absent Wave C and O, and diminished spectral content around the first formant of speech. These children were more susceptible to degradation in noise, and performed worse on perceptually-challenging auditory processing tasks. There were no amplitude differences for the fundamental frequency and responses to clicks were all normal."
  - Wible et al. 2004

Dyslexia (children)

- Children with dyslexia exhibited impaired perception of syllable onsets (Wave V/A). They had reduced neural responses, reduced representation of speech harmonics (probably due to reduced synchrony of neural firing) and greater intertrial variability (poor Response Consistency). Processing of pitch (fundamental frequency) was not affected.
  - Banai et al. 2009

Screen for Literacy Difficulties

- Children of school age tested on neural encoding of speech in noise and on standardized tests of phonological processing and literacy. Predicted which school-aged children had been referred for reading help.
- Conclusion: cABR/FFR in noise could be used as a screening test for children regarding literacy.
  - White-Schwoch et al. 2015

Predictor of literacy difficulties

- Measured cABR/FFR for 4-year-old children (too young for standardized phonological tests).
- Re-tested same children one year later, but with addition of phonological battery.
- Earlier cABR/FFR responses predicted later performance on phonological battery.
- Poor cross-phaseogram (poor encoding of distinctive consonants at consonant-vowel transitions), but fundamental frequency was fine.
    - White-Schwoch and Kraus 2013

Reading Impairment

- "Here we review evidence that auditory processing is tied to literacy development, and outline three clinical protocols for audiological evaluation of literacy…These protocols effectively evaluate auditory processes tied to literacy, they forecast the development of future reading impairment, and they document individual benefits from interventions. Thus, audiologists can play an important role in identifying and managing reading impairment by conducting objective neurophysiologic evaluations."
- Protocols: 1) 170 ms DA in noise, 2) cross-phaseogram to constrastive stop consonants, 3) 40 ms DA.
    - Kraus and White-Schwoch 2019

Hearing in Noise (APD)

- "The most common manifestation of APD is poor comprehension of speech in noise. This is related to difficulty with processing temporal cues (rapid speech, speech in which temporal fine structure is disturbed), poor attention to relevant cues, poor exclusion of irrelevant stimuli, and poor response to rapidly-presented stimuli."
- The differences between normally-hearing children and children with difficulty comprehending speech in noise were less when the groups were tested in quiet, but became very apparent when noise was mixed into stimulus. Children with poor comprehension of speech in noise showed delayed neural timing (delayed latencies, reduced amplitude) to consonant portion of stimulus, but also reduced amplitudes of the fundamental frequency and formants are encoded less precisely in the presence of noise.
    - Kraus and Anderson, 2016

Auditory Processing Disorder

- "Auditory processing impairments negatively impact language learning, the ability to listen effectively in noisy environments, and the development of reading skills. ..The speech-evoked ABR has been linked to communication skills such as speech-in-noise perception and reading ability…"
    - Hornickel and Kraus 2011

Poor speech in noise: remediation can help.

- APD, dyslexia and SLI children all show poor neural encoding of timing differences and poor speech in noise responses on cABR/FFR
- Noise disrupts neural encoding of consonants more than encoding of vowels.
- Augmenting classroom signal-to-noise ratios through assistive listening devices leads to stronger reading outcomes and better neural encoding of speech.
  - Kraus and White-Schwoch 2015

Across age span:
Poor Speech in Noise: children, adults

- Children and adults show similar performance on SIN tests and neural encoding.
  - Brain-injured (concussion): poorer encoding, poorer SIN scores
  - Musicians: better encoding, better SIN scores
- Neural Signature Characteristics:
  - 1. Poor encoding of fundamental frequency
  - 2. Poor encoding of onset response (Wave V/A)
  - 3. Poor Stimulus-to-Response correlation
- Auditory training can improve performance

    - Kraus and White-Schwoch 2017

Hearing in Noise

- "Pitch, an essential factor in speaker identification, aids the listener in tracking a specific voice from a background of voices. The results of this study suggest that the robustness of subcortical neural encoding of pitch features in time-varying signals is a key factor in determining success with perceiving speech in noise. In children with poor speech-in-noise perception, we find impaired encoding of the fundamental frequency and the second harmonic, two important cues for pitch perception."
    - Anderson et al. 2010

Autism Spectrum Disorder

- "Using speech syllables with variable pitch, we have a demonstrated deficient brainstem encoding of pitch in a subgroup of verbal children with ASD. Specifically these children with ASD had abberant, non-direction-specifc pitch tracking and reduced neural phaselocking."
    - Russo et al. 2008

ASD

- Children with ASD showed: 1) poor onset synchrony (delayed Wave V/A complex, and longer duration of the complex), reduced fundamental frequency information (Waves D and F delayed), 2) reduced fidelity of the response in background noise with respect to the stimulus (stimulus-response correlation lower in noise than in quiet), 3) reduced quiet-to-noise inter-response correlations with robust encoding of frequencies in the first formant range.
- Across all the stimuli, the ASD group had more variable neurophysiological response to sound than the control group. This effect could not be explained by the quality of the recording, such as the number of artifacts.
    - Russo et al. 2009

Concussion

- "Functional listening skills – such as the ability to understand speech in noise, and the ability to sustain performance over time in taxing auditory conditions – were compromised in a group of adolescents [when they were compared to peers who had musculo-skeletal injuries]. "
- "These impairments may exacerbate cognitive and academic challenges associated with concussion injuries, and should be considered in return-to-learn and return-to-play decisions.
    - Thompson et al. 2018

Low Socio-economic Status

- "Children raised in homes with lower-income and less-educated parents are at an auditory disadvantage compared with children who come from more priviledged circumstances."
- "In addition to lower literacy levels, the low SES children had reduced intertrial response consistency and smaller spectral amplitudes in their cABRs [when compared to peers matched for age, sex and ethnicity]. In addition, they had higher neural noise levels in the regions of the response where no stimulus was presented."
    - Kraus and Anderson, 2015

Music enrichment programs improve neural encoding of speech in at-risk children

- Participation in community music program (instrumental music) induced improved neural encoding in low SES children at risk for learning and social problems.
- "One year of training was insufficient to elicit changes in nervous system function; beyond the first year, however, greater amount of instrumental music training were associated with larger gains in neural processing."
- Active listening (playing instrument) associated with improvements, but passive listening (video games with music) was not.
    - Kraus et al. 2014