# Building Language Resources for Exploring Autism Spectrum Disorders

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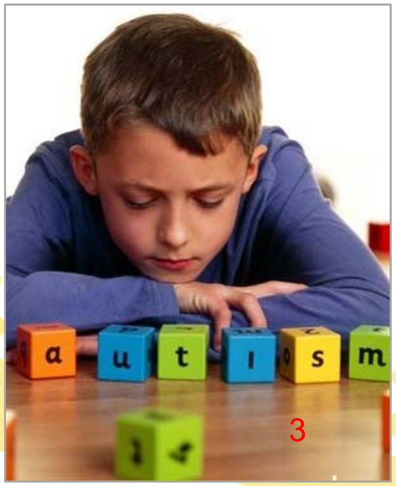
# Outline

- Autism
- Challenges
- Opportunities
- Prior research
- Current collaboration
- Future projects

# Autism Spectrum Disorder

- Brain-based disorder typically identified in early childhood
  1.5% of U.S. children (CDC, 2016)
- Diagnostic criteria:
  - Impairments in social communication
  - Presence of repetitive behaviors or restricted patterns of interests
- "Spectrum" = mild to severe symptoms
- Significant public health cost
- Swift, accurate, early diagnosis is critical to improved outcomes
- Behaviorally defined: no brain scan or blood test
- Significant symptom overlap with other disorders
- Many children diagnosed late



# Challenges

PROBLEM:

sample heterogeneity +
small samples +
poor measurement =

non-reproducible scientific results

# Opportunities

- Natural language interaction
  - Highly nuanced outward signal of internal brain activity
  - Fundamentally social

- Most children with ASD acquire language;
  nearly all vocalize

- Can HLT and Big Data methods
  help us identify ASD more reliably
  and understand it better?

# Language in ASD

- Variable vocalization throughout development:
  - Differences evident in infancy
  - Language delay as toddlers/preschoolers
  - Difficulty being understood & understanding humor, sarcasm
  - Conversational quirks
    - unusual word use
    - turn-taking
    - synchrony
    - accommodation
- Real-life effects of pragmatic language problems:
  - Difficulty forming/maintaining friendships
  - Increased risk of being bullied
  - Difficulty with romantic relationships
  - Difficulty maintaining employment

# Early vocalization in ASD

- **4 mo:** fewer complex pitch contours during cooing (Brisson et al., 2014)
- **6 mo:** Higher and more variable $F_0$ in cries, poorer phonation (Orlandi et al., 2012; Sheinkopf et al., 2012)
- **9 mo:** Fewer well-formed babble sounds (Paul et al., 2011)
- **12 mo:** Less waveform modulation and more dysphonation in cries, compared to TD and DD (Esposito & Venuti, 2009)
- **16 mo:** fewer responses to parent vocalizations, especially when directing to people (Cohen et al., 2013)
- **18 mo:** Higher $F_0$ in cries, compared to TD and DD (Esposito & Venuti, 2010)

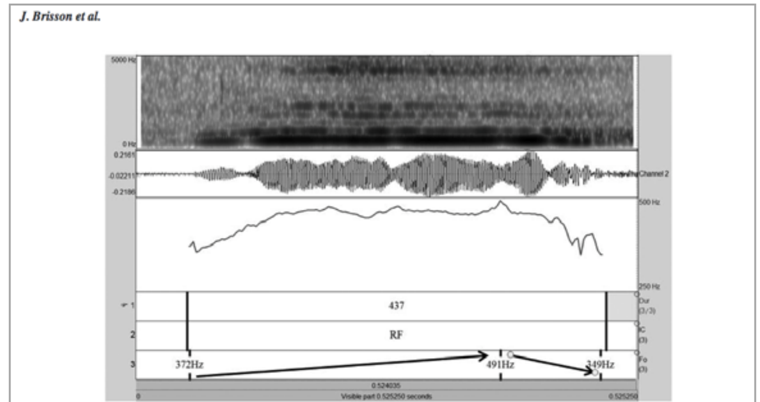
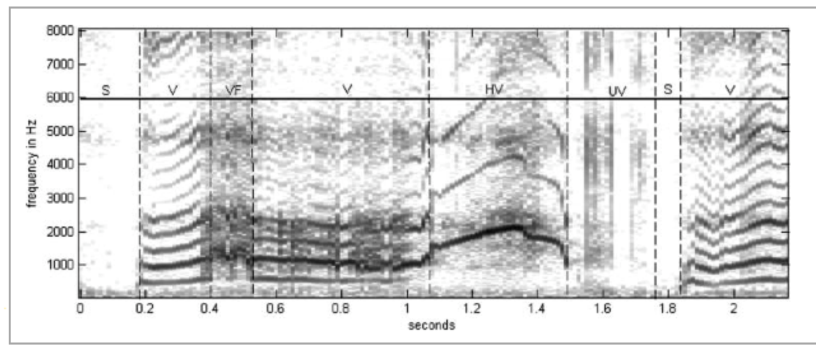


FIGURE 1. Infant vocalization analysis (duration = 437 ms, contour = rising from 372 Hz to 491 Hz, then falling from 491 Hz to 349 Hz).



# Characterizations

- ASD speech communication:
  - Many small variations accumulate to create an odd impression
  - Difficulty to determine what exactly differs
  - Difficult to recognize

Linguistic Data Consortium

# Characterizations

CAR Center for Autism Research

Too slooow

Robotic

Flat

Stilted

Pedanti
c

Too quiet

Disorganize
d

Too loud

Too fast

"Little Professor"

Sing-
song
y

# The truth?

- The generalizations in the literature are mostly impressions (or stereotypes….)
  - There are few empirical studies
  - Sample sizes are generally very small
- In fact:
  - The ASD phenotype is very diverse
    in speech communication as in other ways
  - The truth is probably neither a point nor a “spectrum”
    but a complex multidimensional multimodal distribution
    in a space that we all live in
- We don’t really know the dimensions of this space
  and figuring it out
  will take careful analysis of lots of data

# Clinical Computational Linguistics

- Natural language:
  - Nuanced signal (marriage of cognitive and motoric systems)
  - Few practice effects

- Can automatically identify and extract features (“linguistic markers”)

- Specific linguistic features associated with:
  - Depression
  - Dementia
  - PTSD
  - Schizophrenia

  - …Autism

# Prior Research

On average, individuals with ASD have been found to:

- Produce idiosyncratic or unusual words more often than typically developing peers (Ghaziuddin & Gerstein, 1996; Prud'hommeaux, Roark, Black, & Van Santen, 2011; Rouhizadeh, Prud'Hommeaux, Santen, & Sproat, 2015; Rouhizadeh, Prud'hommeaux, Roark, & van Santen, 2013; Volden & Lord, 1991)
- Repeat words or phrases more often than usual (echolalia; van Santen, Sproat, & Hill, 2013)
- Use filler words "um" and "uh" differently than matched peers (Irvine, Eigsti, & Fein, 2016)
- Wait longer before responding in the course of conversation (Heeman, Lunsford, Selfridge, Black, & Van Santen, 2010)
- Produce speech that differs on pitch variables; these can be used to classify samples as coming from children with ASD or not (Asgari, Bayestehtashk, & Shafran, 2013; Kiss, van Santen, Prud'hommeaux, & Black, 2012; Schuller et al., 2013)

# Collaboration

- Center for Autism Research (CAR)
  - autism expertise
  - data samples
- Linguistic Data Consortium (LDC)
  - corpus building methods
  - expertise in linguistics analysis

# ADOS Pilot Project

- Process and analyze recorded language samples from **Autism Diagnostic Observation Schedule** (“ADOS”; Lord et al., 2012)
  - Conversation and play-based assessment of autism symptoms
  - Recorded for reliability and clinical supervision, coded on a scale, then filed away
- 600+ at CAR alone,
  thousands more across the U.S. and in Europe;
  never compiled
- Associated with rich metadata that includes family history, social, cognitive, and behavioral phenotype, genes, and neuroimaging

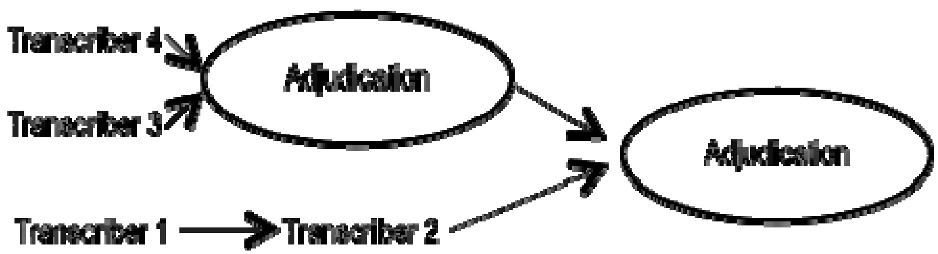
# Pilot

## Goals

- Assess feasibility
- Identify and extract linguistic features
- Machine learning classification
  and/or discovery of relevant dimensions
- Correlate features with clinical phenotype

# Transcription

- Time aligned, verbatim, orthographic transcripts (~20 minutes of conversation per interview, from ADOS Q&A segment)
- New transcription specification developed by LDC, (adapted from previous conversational transcription specifications)
- 4 transcribers and 2 adjudicators from LDC and CAR produced a “gold standard” transcript for analysis and for evaluation/training of future transcriptionists




- Simple comparison of word level identity between CAR’s adjudicated transcripts and LDC’s transcripts: 93.22% overlap on average, before a third adjudication resolved differences between the two
- Forced alignment of transcripts with audio

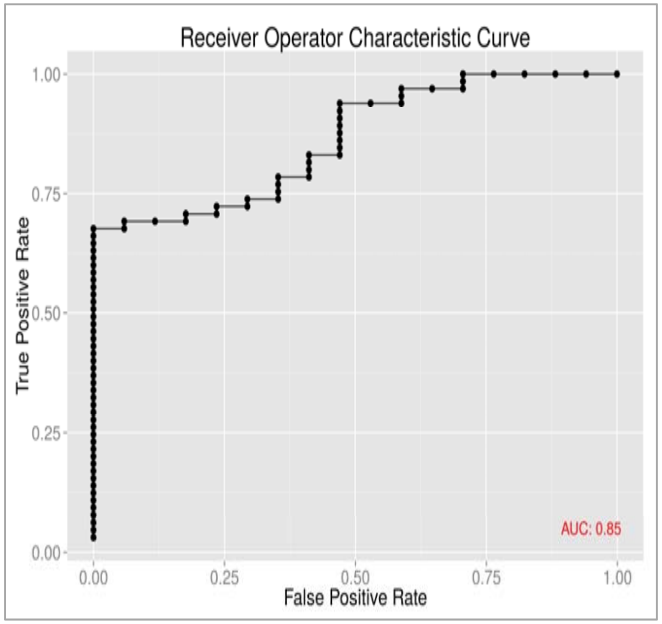
# Participants

- Pilot sample
- N=100
- Mean age=10-11 years
- Primarily male
- 65 ASD, 18 TD,
  17 Non-ASD mixed clinical
- Average full scale IQ, verbal IQ, nonverbal IQ

# Preliminary Analyses

Bag-of-words classification:

- Correctly classified 68% of ASD participants and 100% of TD participants
- Naïve Bayes, leave-one-out cross validation and weighted log-odds-ratios calculated using the “informative Dirichlet prior" algorithm (Monroe et al., 2008)
- Receiver Operating Characteristic (ROC) analysis revealed good sensitivity and specificity; AUC=85%

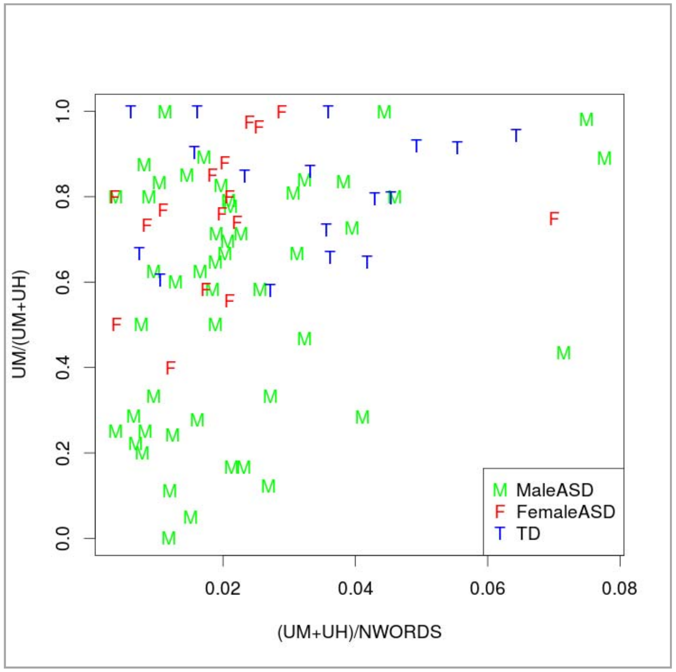


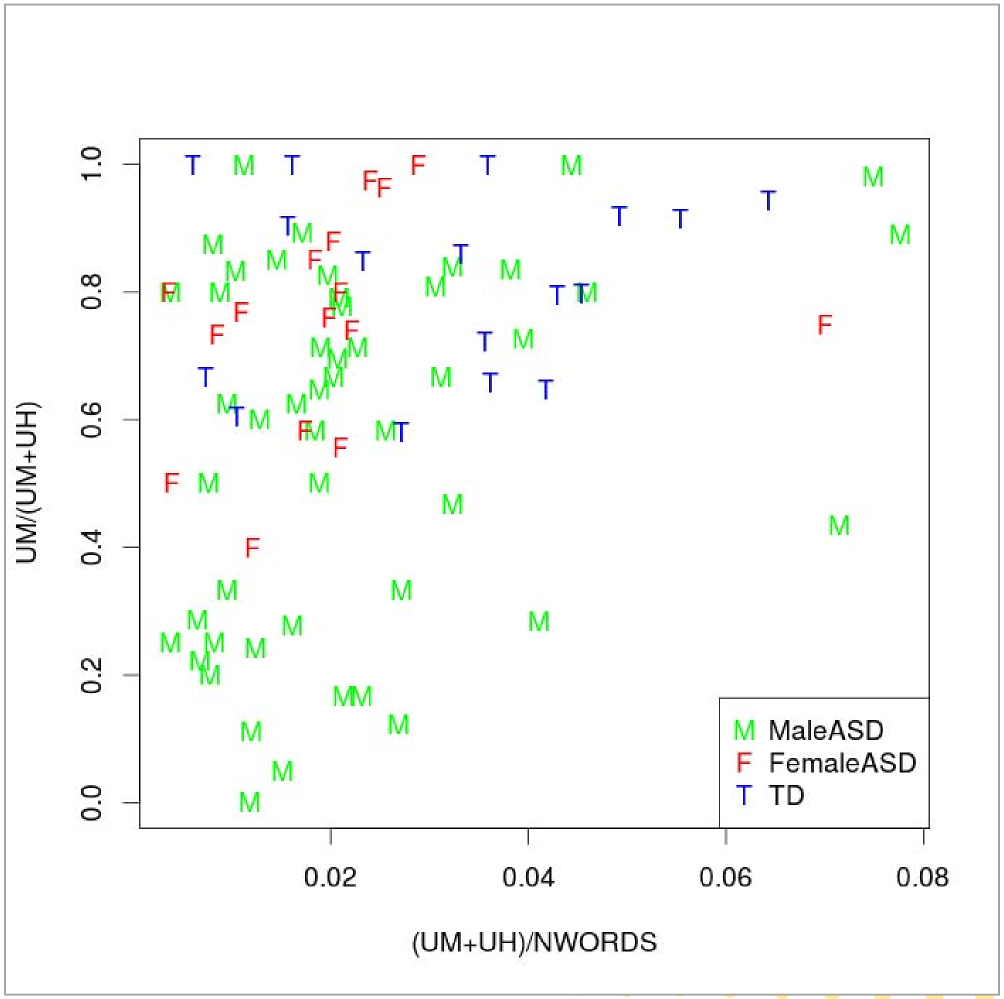
# Word Choice

- 20 most "ASD-like" words:
  - *{nsv}, know, he, a, now ,no , uh, well, is, actually, mhm, w-, years, eh, right, first, year, once, saw, was*
  - {nsv} stands for "non-speech vocalization", meaning sounds that with no lexical counterpart, such as imitative or expressive noise
  - "uh" appears in this list, as does "w-", a stuttering-like disfluency.
- 20 least "ASD-like" words:
  - *like, um, and, hundred, so, basketball, something, dishes, go, york, or, if, them, {laugh}, wrong, be, pay, when, friends*.
  - "um" appears, as does the word *friends* and laughter

# Fluency

- Rates of um production across the ASD and TD groups (um/(um+uh))
- ASD group produced UM during 61% of their filled pauses (CI: 54%-68%)
- TD group produced UM as 82% of their filled pauses (CI: 75%-88%)
- Minimum value for the TD group was 58.1%, and 23 of 65 participants in the ASD group fell below that value.

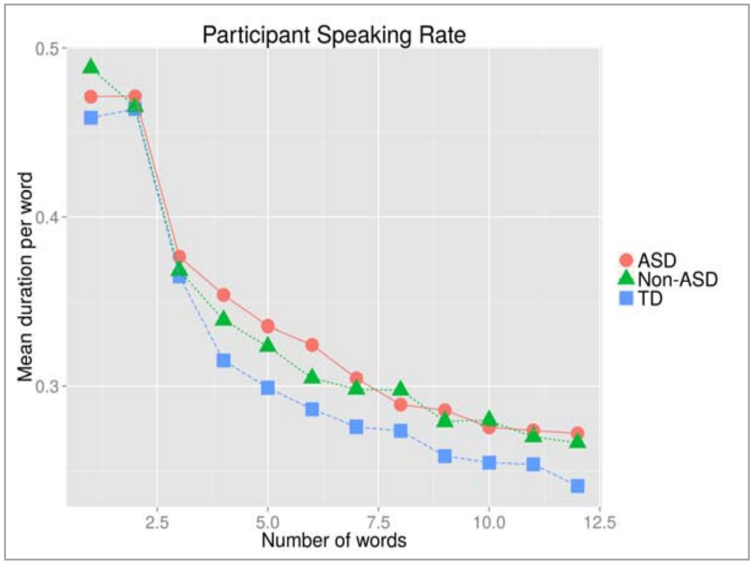


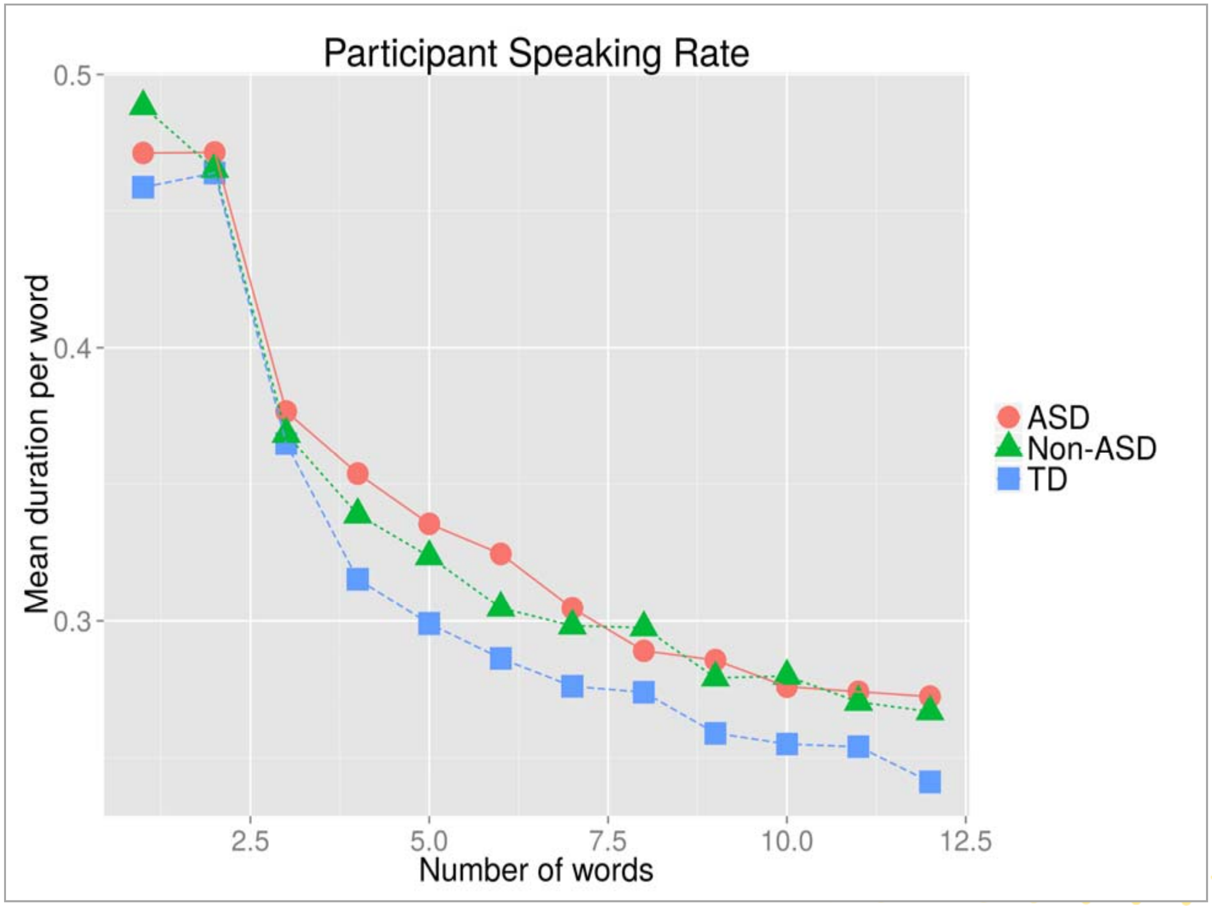


1.0
0.8
0.6
0.4
0.2
0.0
UM/(UM+UH)
0.02
0.04
0.06
0.08
(UM+UH)/NWORDS
M MaleASD
F FemaleASD
T TD

# Rate

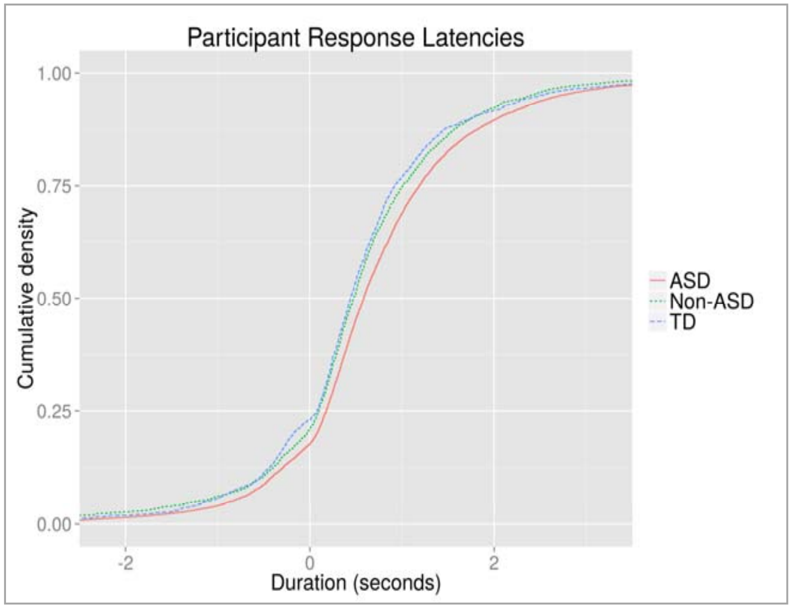
- Mean word duration as a function of phrase length
- TD participants spoke the fastest (overall mean word duration of 376 ms, CI 369-382, calculated from 6891 phrases)
- Followed by the non-ASD mixed clinical group (mean=395 ms; CI 388-401, calculated from 6640 phrases)
- Followed by the ASD group with the slowest speaking rate (mean=402 ms; CI: 398-405, calculated from 24276 phrases)




Participant Speaking Rate
Mean duration per word
0.5
0.4
0.3
2.5
5.0
7.5
10.0
12.5
Number of words
ASD
Non-ASD
TD

# Latency to Respond

- Characterizes gap between speaker turns
- Too short = interrupting or speaking over a conversational partner
- Too long (awkward silences) interrupts smooth exchanges
- ASD somewhat slower than TD



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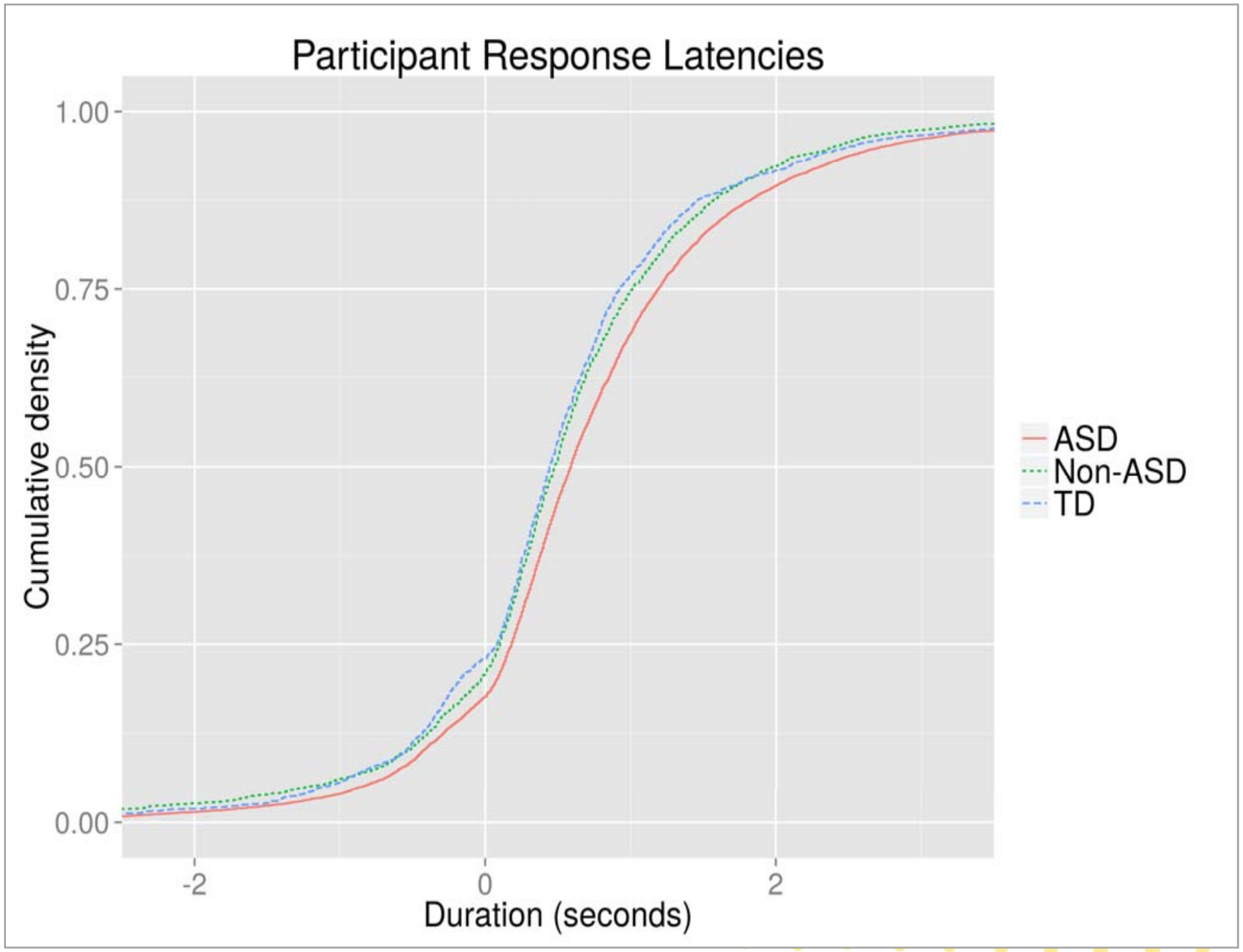
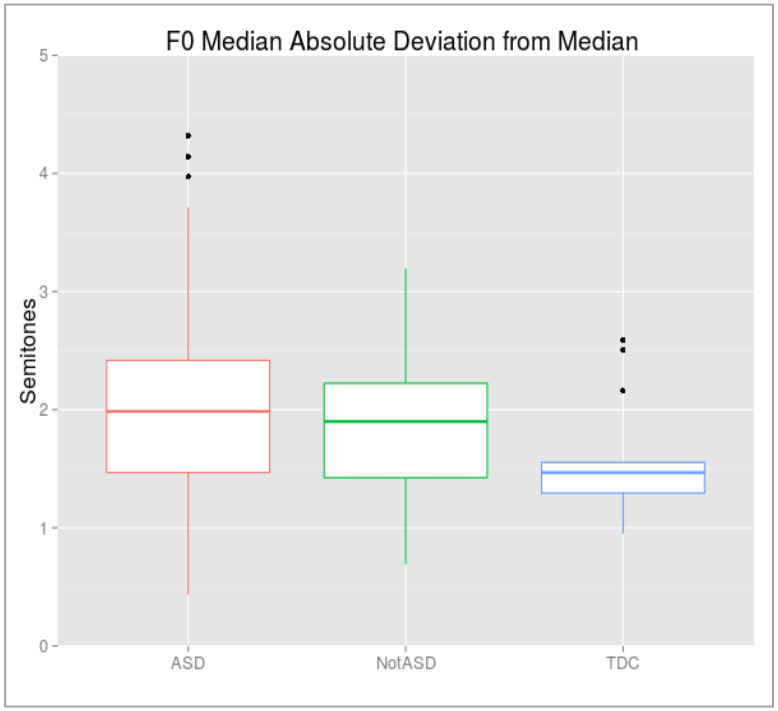
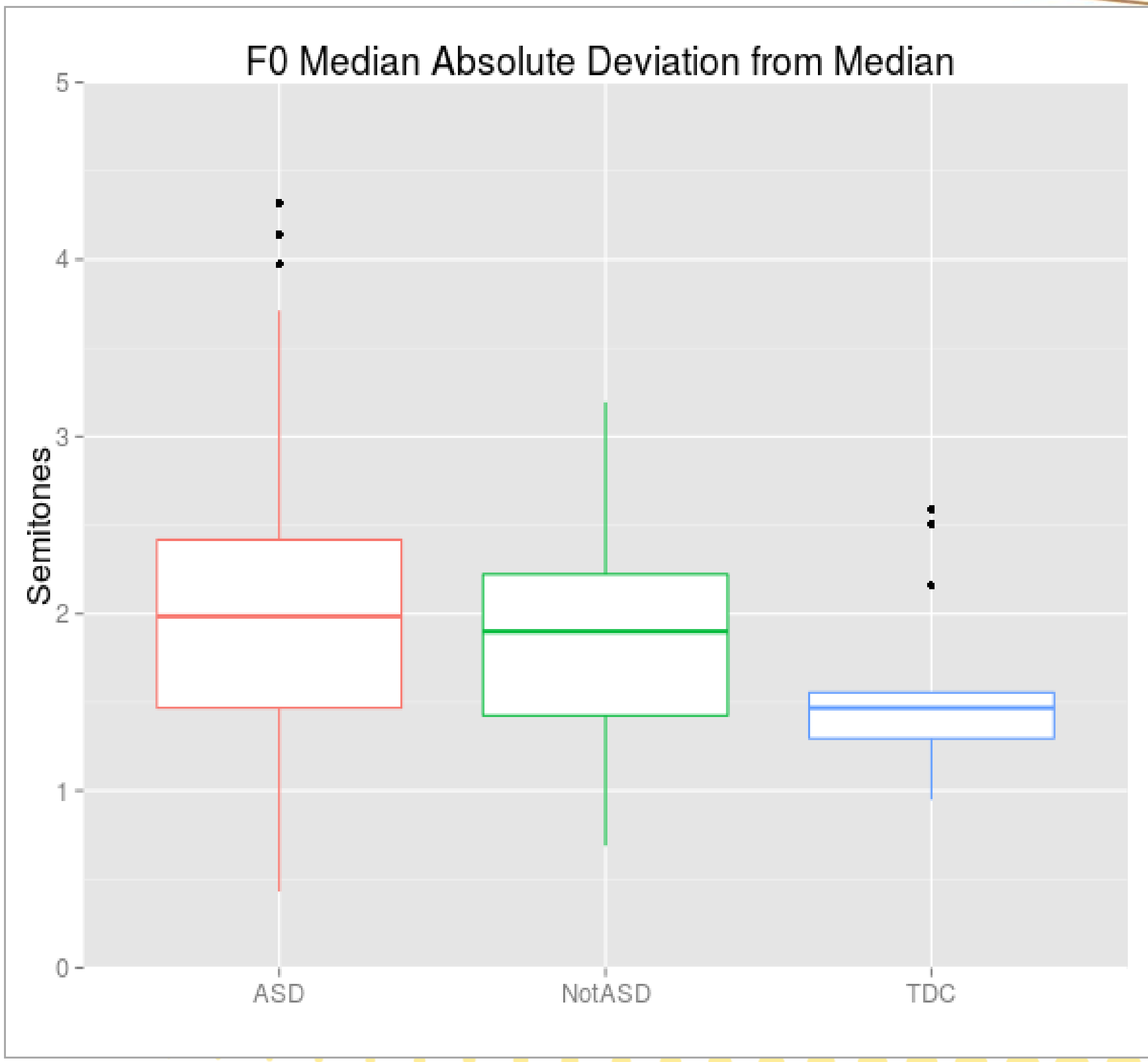


# Fundamental Frequency

- Mean absolute deviation from the median (MAD)
  - Outlier-robust measure of dispersion in F0 distribution
  - Calculated in semitones relative to speaker's 5th percentile




- MAD values are both higher and more variable within the ASD and non-ASD mixed clinical group than the TD group
  - ASD: median: 1.99, IQR: 0.95
  - Non-ASD: median: 1.95, IQR: 0.80
  - TD: median: 1.47, IQR: 0.26


F0 Median Absolute Deviation from Median
Semitones
0
1
2
3
4
5
ASD
NotASD
TDC

# Next Steps

- **Expand sample sizes**
  - Improve classification metric
    - Focus on *specificity* (differentiate ASD from its cousins)
  - Identify relevant dimensions of variation
  - Hone HLT for pediatric clinical population

- **Emerging collaborations include more ADOS evals with phenotypic data, neuroimaging, and genetics**
  - Large body of shared data
  - Goal: gene-brain-behavior mapping

- **Enlarge age range**
  - Goal: downward extension to infancy
  - Identify clusters of acoustic markers
  - Chart growth to pinpoint critical points of divergence (targets for intervention)

# PUBLICATION

- We have subject consent and IRB clearance for publication of anonymized transcripts and audio
- Larger ADOS sample from CAR in process
- Possible multi-site project (like ADNI) to pool very large collection of existing ADOS interviews processed and analyzed to the same standard
- BUT
  - New ADOS interviews require expensive, time-consuming in-person collection
  - **NEED**: *Scalable, inexpensive methods to collect natural language from large, diverse samples*

# Future Directions

- **Phone bank**
  - Inexpensive student worker asks ADOS questions
  - Child and parent language samples, questionnaires, online IQ
  - Nationally representative cohort
  - Longitudinal samples

- **Computerized Social Affective Language Task** (C-SALT)
  - Self-contained laptop-based audio/video collection
  - Records language and social affect in schools, clinics and homes
  - Controlled recording is conducive to automated approaches (reduces need for transcription)

- **Combine data sources** to **improve predictive power:**
  - Motor, language, medical records, parent/teacher report, clinical judgment, performance tasks, imaging, genetics

CAR and LDC are eager to collaborate:

looking for novel analytic approaches and outside-the-box ideas!

# Applications

- **Support clinical decision-making and improve access**
  - Low-cost, remote screening
  - Direct behavioral observation: record in clinics, integrate into EHR
  - Inform identification efforts and assist in differential diagnosis

- **Identify behavioral markers → of underlying (treatable) pathobiology**
  - Profiles of individual strengths and weaknesses link to biology = personalized treatment planning and improved outcomes
  - Granular assessment of response to intervention – dense sampling

- **Give participants and families more information about themselves**
  - Online feedback
  - Monitor growth trajectories

# Acknowledgements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  - Autism Science Foundation
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