August 11, 2026

MONTANA STATE UNIVERSITY
NORM ASBJORNSON College of ENGINEERING

MONTANA INBRE

How hand gestures can support communication for those with Autism, ADHD, and/or Language Impairments

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MONTANA STATE UNIVERSITY
Undergraduate Scholars Program

BRAIN & BEHAVIOR RESEARCH FOUNDATION
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MONTANA STATE UNIVERSITY
Biomedical Innovation for Research and Development Hub

PLAN FOR TODAY

- Warm-up – what brings you here today?
- Acknowledgements
- Language is amazing! A biolinguistic approach
- Background on Neurodiversity
- Background on Gestures
- Research highlights
- Conclusions

WHAT BRINGS YOU HERE TODAY?

- Type a keyword into Q and A – is it curiosity? Personal experience? What else?
- Please take 30 seconds to share in Q and A.

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MONTANA INBRE

WHY STUDY LANGUAGE?

- Human communication system is unique in the animal kingdom
  - Vocabulary (meaning)
    - Chair, desk, Bill, Mary
  - Sentence structure (grammar)
    - Boy chases dog vs. Dog chases boy
  - Language is a distinct part of cognition (memory, attention, thinking)

Hauser, Chomsky, Fitch (2002)

WHY STUDY LANGUAGE?

- Whale song: mostly structure

  Notes repeated in small sequences of ten sounds; sequences repeat a few times. Song shifts to a completely different set of sounds, the sequence of which repeats…

- Vervet monkey: mostly vocabulary

  Monkeys produce different alarm calls for different predators with relevant responses: Eagles, Snakes, Leopards

  No structure – saying "Snake Leopard" does not change meaning from "Leopard Snake"

THE BIOLINGUISTIC VIEWPOINT

- Language is a biological phenomenon.
- Approaching language as an aspect of the brain/mind is crucial to the understanding of language.
- Much of language development is a process of genetically-guided growth (in addition to the obvious existence of learning processes).
- Children acquire the language they hear by using their brain and interaction with others: both nature and nurture
- Eric Lenneberg's classic Biological Foundations of Language (1967) and Wexler (2002).

THE BIOLINGUISTIC VIEWPOINT

- Language acquisition in children is more like growing teeth than learning to ride a bike
- Growing teeth – need calcium from the environment, but if genetics aren't there –> incorrect teeth numbers. Reinforcement/feedback doesn't help. Most people grow teeth naturally.
- Learning to ride a bike – a lot of reinforcement in environment, no "predisposition", no "genes" for bike riding. Many people do not learn to ride bikes.

THE COMPARATIVE STUDY OF LANGUAGE DEVELOPMENT AND IMPAIRMENTS

- Investigating Language Development and Impairments
- Helps to understand the system of language and how it develops or breaks down
- Potentially of large help in understanding the brain and genetic bases of language
- Can contribute to development of practical interventions to support communication, children, families, and communities

NEURODIVERSITY

- All of us are neurodiverse (all people think differently and that's ok!).
- Some of us are neurodivergent (brain differences that may cause extra challenges, e.g., autism, dyslexia, ADHD (attention deficit/hyperactivity disorder), mental health, acquired brain damage, etc.).
- A crayon analogy from Dr. Jennifer DuBois of MSU chemistry

Increasing awareness that people are of all types

11

1961

1992

2020 – skin and hair

WHAT IS NEURODIVERGENCE?

- Neurodiversity describes the idea that people experience and interact with the world around them in many different ways; there is no one "right" way of thinking, learning, and behaving, and differences are not viewed as deficits. ~Harvard Health Publishing
- Neurodivergence includes a set of sometimes interrelated sensory, attentional, executive, social, and motor differences that present barriers to learning and living in conventional environments
- Neurodivergence is considered to be genetic, with evolutionary benefits, but not in modern 9-5 western society
- Terminology:
  - Identity-first language (autistic child) (more lived experience)
  - Person-first language (a child with autism) (more clinical)

EXAMPLES OF NEURODIVERGENCE WITH LANGUAGE IMPAIRMENTS

- ~ 7% of children have Developmental Language Disorder (DLD, aka receptive language impairment, mostly typical thinking and social skills, severe language deficits). Between 50-100% of youth offenders in prisons have DLD. Challenges continue in adults.
- ~3% of children have Autism Spectrum Disorder (ASD, challenges with repetitive behaviors, sensory, social interaction, often communication and thinking). Challenges continue in adults.
- ~10-20% of all people have Attention Deficit/Hyperactivity Disorder (ADHD, challenges with controlling attention, sometimes language challenges).
- DLD & ASD & ADHD often overlap in the same individuals and within families.
- These challenges are often under-diagnosed, especially in minorities, females, and rural areas.
- These impairments can lead to negative social, economic, and academic prospects.
- Living in Rural areas adds challenges with access to speech/language and other vital services.
- With support and therapy, these individuals can do better!

WHY ARE GESTURES IMPORTANT?

Gestures are hand-body movements that go with speaking

Gestures can be used by babies and people who have a hard time speaking

Non-communicative gesture

Iconic gesture (looks like the concept)

Pictures courtesy of Elsa Austin

GESTURES SUPPORT LANGUAGE

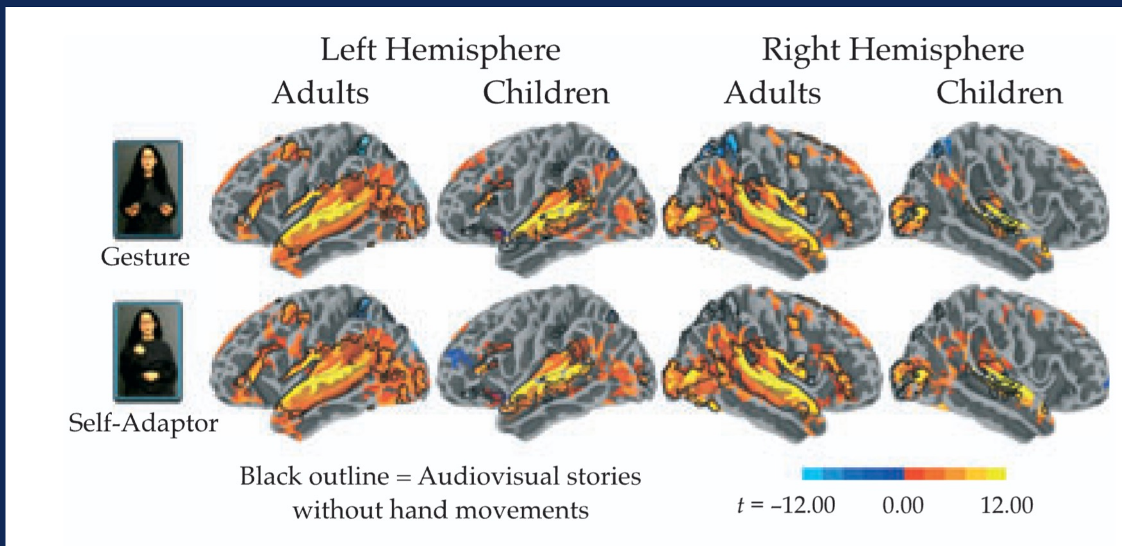
- Official sign language signs, used as gestures, support communication of young children without teaching of sign language grammar
- Children can learn unofficial signs like "made-up" signs. (Vallotton)
- How children use gestures predicts their later verbal language
- Children with DLD and ASD were successfully trained on gestures (sign equivalents of verbal words) to improve their comprehension of pronouns like "they" and prepositions "on" two-fold, with gestures becoming communicative "prosthetic devices" (Konstantareas, 1984)

EXAMPLES OF GESTURES

Dimitrova et al., 2017

Gesture type	Communicative modality type				Picture choices	
	Gesture only	Reinforcing gesture + speech	Supplementary gesture + speech	Speech only	Correct	Incorrect
Deictic	Point at sofa	"Sofa" + point at sofa	"Sitting" + point at sofa	"Sofa"		
Iconic	Bent elbows flapping as if hen	"Hen" + bent elbows flapping as if hen	"Looking" + bent elbows flapping as if hen	"Hen"		
Conventional	Index finger placed on mouth meaning 'quiet'	"Quiet" + index finger placed on mouth meaning 'quiet'	"Girl" + index finger placed on mouth meaning 'quiet'	"Quiet"		

GESTURES IN THE LIVING BRAIN Dick et al., 2012



Gesture conditions: iconic gestures accompanying storytelling
Self-Adaptor condition: self-grooming gestures

"Whole-brain analysis results for each condition compared to Baseline for both adults and children.
The individual per-vertex threshold was $p < .01$ (corrected FWE $p < .05$). The black outline represents activation of audiovisual story comprehension without gestures relative to a resting baseline."

"activation in frontal, inferior parietal, and temporal regions (for processing language), and deactivation in posterior cingulate, precuneus, cuneus, lateral superior parietal cortex, and lingual gyrus"

"Areas active without hand movements are a subset of those active with hand movements"

QUESTIONS OR COMMENTS ON BACKGROUND INFO?

FEEL FREE TO TYPE INTO Q AND A A KEYWORD YOU REMEMBER ABOUT BACKGROUND INFO AT THIS POINT

OUR KEY RESEARCH QUESTION

- How to support development of language with gestures in neurodiverse children and adults?
- Can gestures, made by speakers, help listeners?

OUR LONG-TERM OBJECTIVES

- To effectively help families of children with ASD/DLD/ADHD understand how to communicate with their children based on scientific methodology, evidence, and experience
- To contribute to the prevention/mitigation of communication challenges in these individuals as they develop, via in-home / telehealth interventions

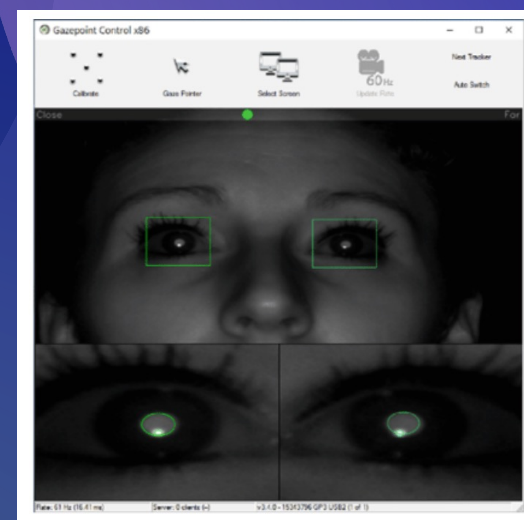
KEY METHOD

- Testing participants' comprehension of language with and without gestures
- Participants did not make gestures (which can be hard due to fine motor challenges)

OUR METHODS: EYE TRACKING AS A MEASURE OF ATTENTION

- Methodological leap of faith – people tend to think about things they are looking at
- More attention/looks to an object on a computer screen – more attention and thought there
- Can be difficult for participants who struggle to sit still
- Many companies exist – Tobii, SmartEye
- We used Gazepoint (cost effective) – a bar under computer screen that uses infrared light to track pupils

Sibley et al., 2017



FOCUS ON DETERMINERS

- "Determiners" = words like "the" and "another"
- "the" is the most common word in the English language, but many children struggle with understanding
- Coreference – mentioning something in sentence one, and mentioning it again in sentence two. Talking about the 'SAME' object as before.
  - "Fishy touches an apple, and then Turtle touches the same apple "
- Disjoint reference – mentioning a different object in the second sentence. Talking about 'DIFFERENT' objects.
  - "Turtle touches an egg, and then Fishy touches another egg"

GESTURES (SIGNS) WE SHOWED TO PARTICIPANTS

[different]

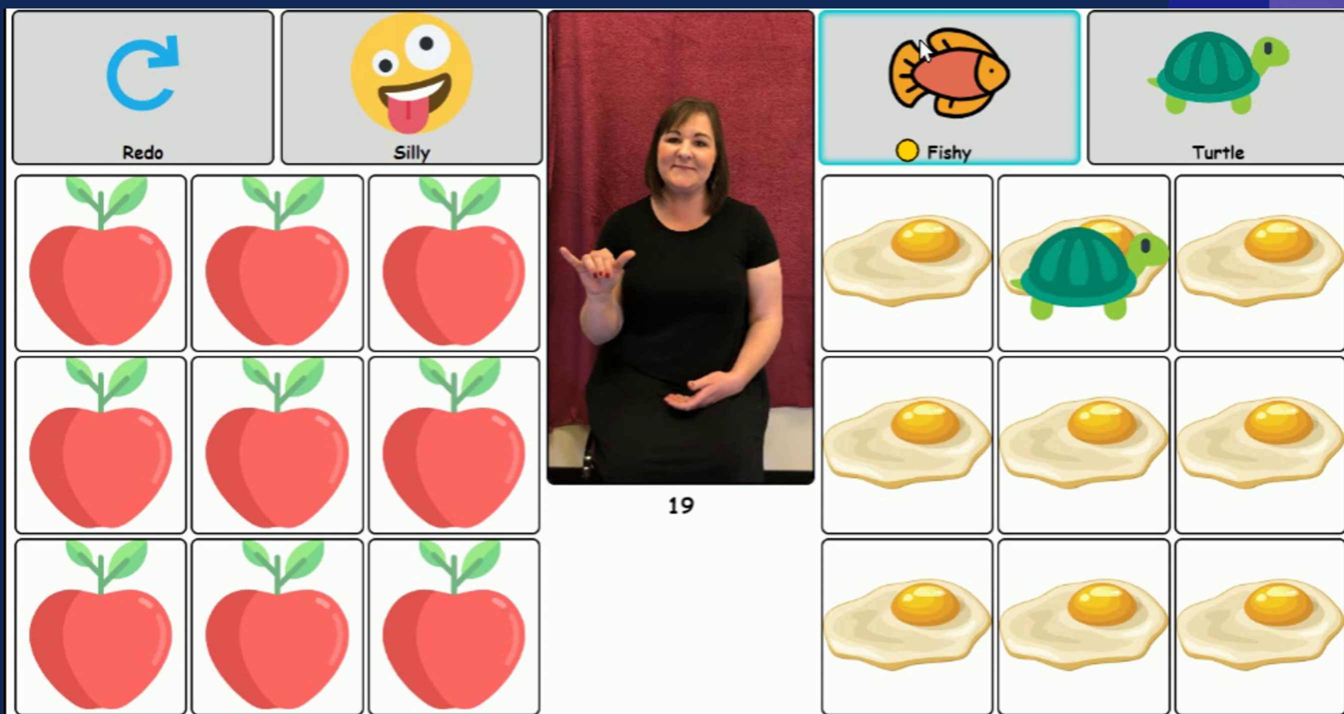
[same]

[any]

Gestures adapted from American Sign Language can support interpretation of determiners!!

OUR METHODS:

Interactive Language Game



- Cursor becomes character
- No click-drag, only click
- Made in JavaScript
- All words vowel initial
- Automatic recording of reaction time and location of clicks

Turtle clicks an egg (participant selects), and then Fishy clicks [same gesture] … (participant selects same or different egg)

OUR METHODS: PRETEST-TEST-POSTTEST DESIGN

- Time 0: Pretest – only determiners presented by the lady in the video, no gestures.
- Time 1: Test (mini-intervention) – determiners+gestures, and gestures by themselves, presented by the lady in the video
- Time 2: Posttest – only determiners via speech presented by the lady in the video, to see if there's any improvement relative to pretest and test.

PARTICIPANTS (N=48, 28 FAMILIES) TRANSDIAGNOSTIC APPROACH

Autism Language Impaired (ALI), 2 ADHD	Autism Language Normal (ALN), 4 ADHD	Developmental Language Disorder (DLD), 1 ADHD	Typical Development (TD)	TD siblings of neurodivergent, 1 ADHD
n=10. 4-17 years old. Chronological age = 7.5 Mental age (nonverbal IQ) = 4.6 Verbal Mental age = 4.2 Grammar age = 3.5	n=11. 6-31 year olds. Chronological age = 15 Mental age = 15.2 Verbal age = 15.9 Grammar age = 9-10	n=4. 5-9 year olds. Chronological age = 7 Mental age = 6.9 Verbal age = 5.9 Grammar age = 4-5	n=11. 3-20 year olds. Chronological age = 10 Mental age = 12.5 Verbal age = 14 Grammar age = 9.7	n=12. 1.9-21 year olds. Chronological age = 7 Mental age = 8.8 Verbal age = 8.9 Grammar age = 7.5

17 female, 31 male. Some twice-exceptional with overlapping with ADHD (attention deficit/hyperactivity disorder).
Mostly white, some American Indian. Range of education levels, mostly college educated.
RUCA (rural-urban commuting area codes): some metropolitan, some micropolitan, some rural

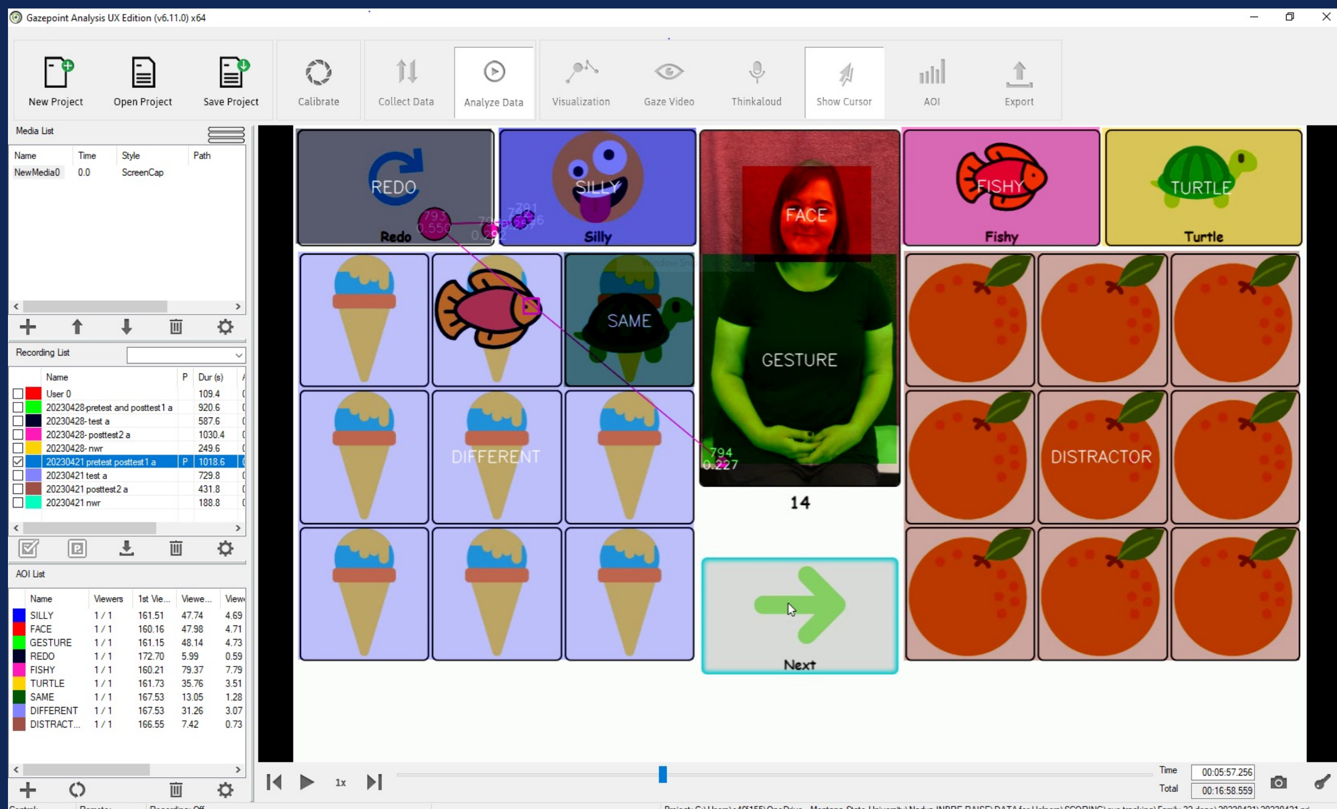
OUR BEHAVIORAL RESULTS ON COMPREHENSION OF DETERMINERS AND GESTURES – MOUSE CLICKING OR POINTING

Autism Language Impaired (ALI)	Autism Language Normal (ALN)	Developmental Language Disorder (DLD)	Older Typical Development (TD)	TD siblings of neurodivergent
Poor knowledge - Comparable to younger typical children of 3-4 years old. Many 'different' or distractor responses regardless of determiner or gesture.	Like older typical children – adult-like knowledge	Similar to ALI, overall poor knowledge	Adultlike: 'different' responses for 'an,' 'another', 'a different'… 'same' responses for 'the', 'that', 'the same', 'share'	Like typical children, with some initial challenges with 'the', improving with gestures

OUR EYE TRACKING RESULTS

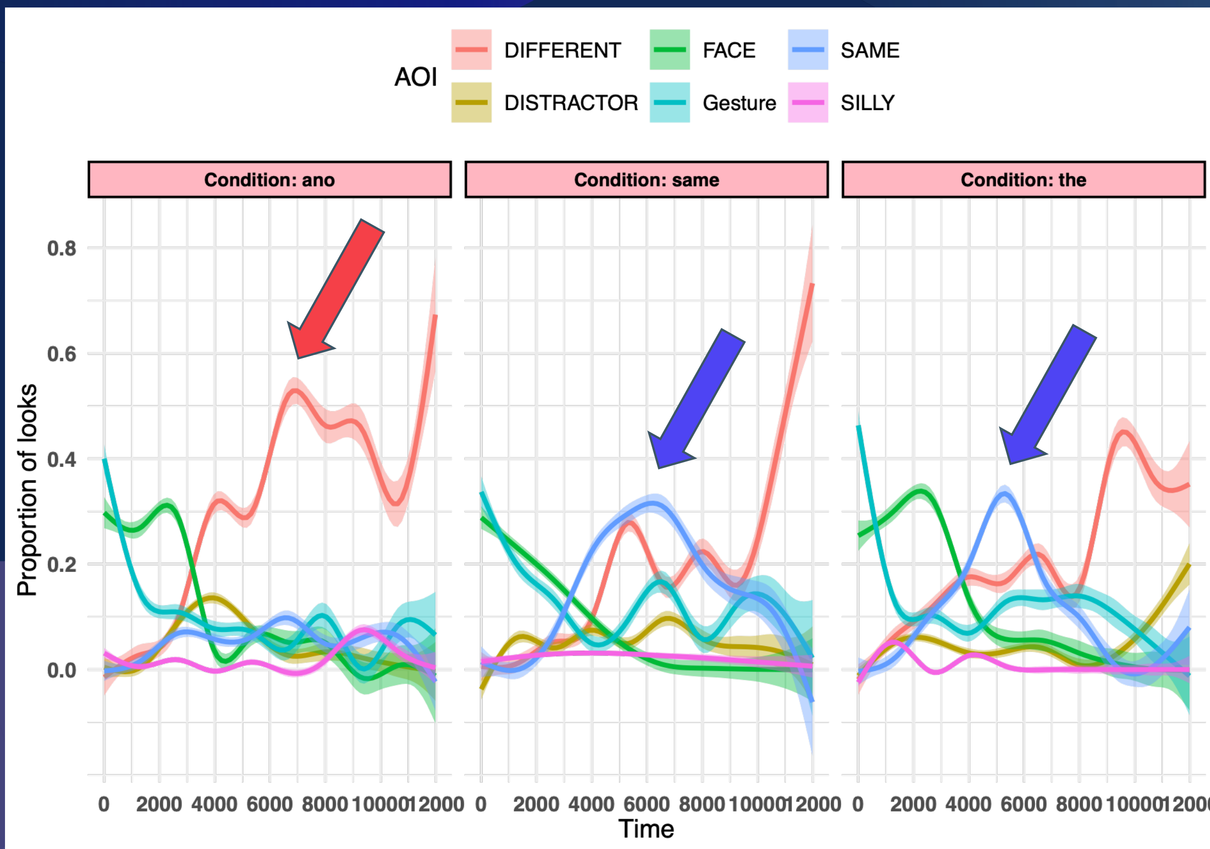
- Participants regrouped by behavioral answers (clicking, pointing) on T0 (pretest) – data driven grouping (not by diagnosis, but how they understood determiners)
- group 1 (adult-like) = mostly correct behavioral answers at pretest (T0). N=19, mean age 9.3, 3 siblings, 8 TD, 1 DLD/ADHD, 7 ALN (including 3 ADHD).
- group 0-1 (some deficit) = some mistakes in behavioral answers at pretest, especially on "the" (only 7% correct). N=9, mean age = 12.7, 2 ALI (1 ADHD), 1 ALN, 2 DLD, 1 TD, 4 Siblings (1 ADHD)
- group 0 (strong deficits) = many mistakes in behavioral answers at pretest. N=6, mean age = 7.3, 3 ALI, 2 DLD, 1 sibling. No ADHD.
- However, 9 participants, mostly younger across diagnosis groups, could not engage with eye tracking and the computer task.

SCREENSHOTS OF GAZEPOINT ANALYSES – ANNOTATION OF AOIS



AOI = area of interest

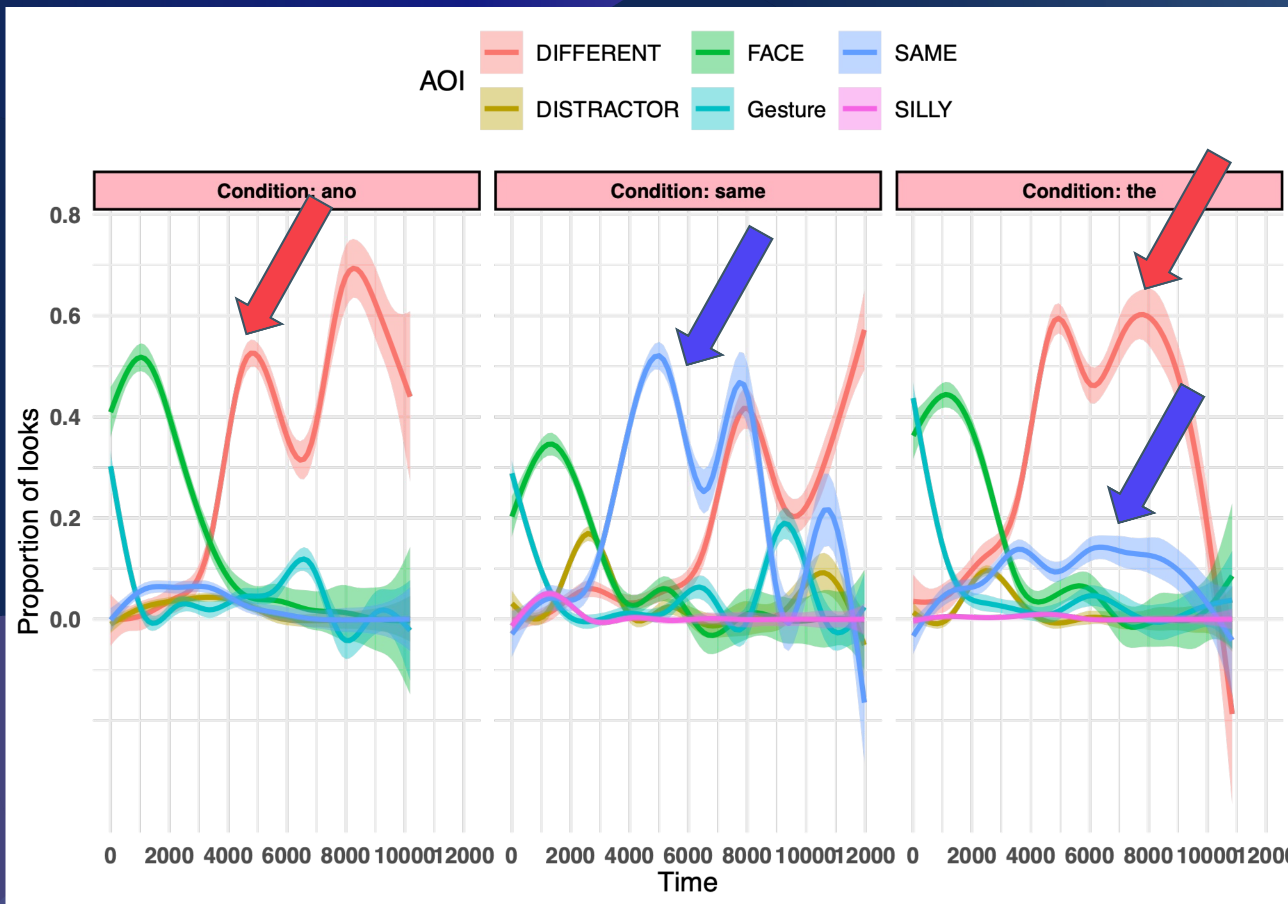
GROUP 1 (ADULT-LIKE) – EYE GAZE AS EXPECTED AT PRETEST (TIME 0)



- AOI = area of interest
- Graphs show how eye gaze moves across areas of interest over time in milliseconds, across conditions (determiners)

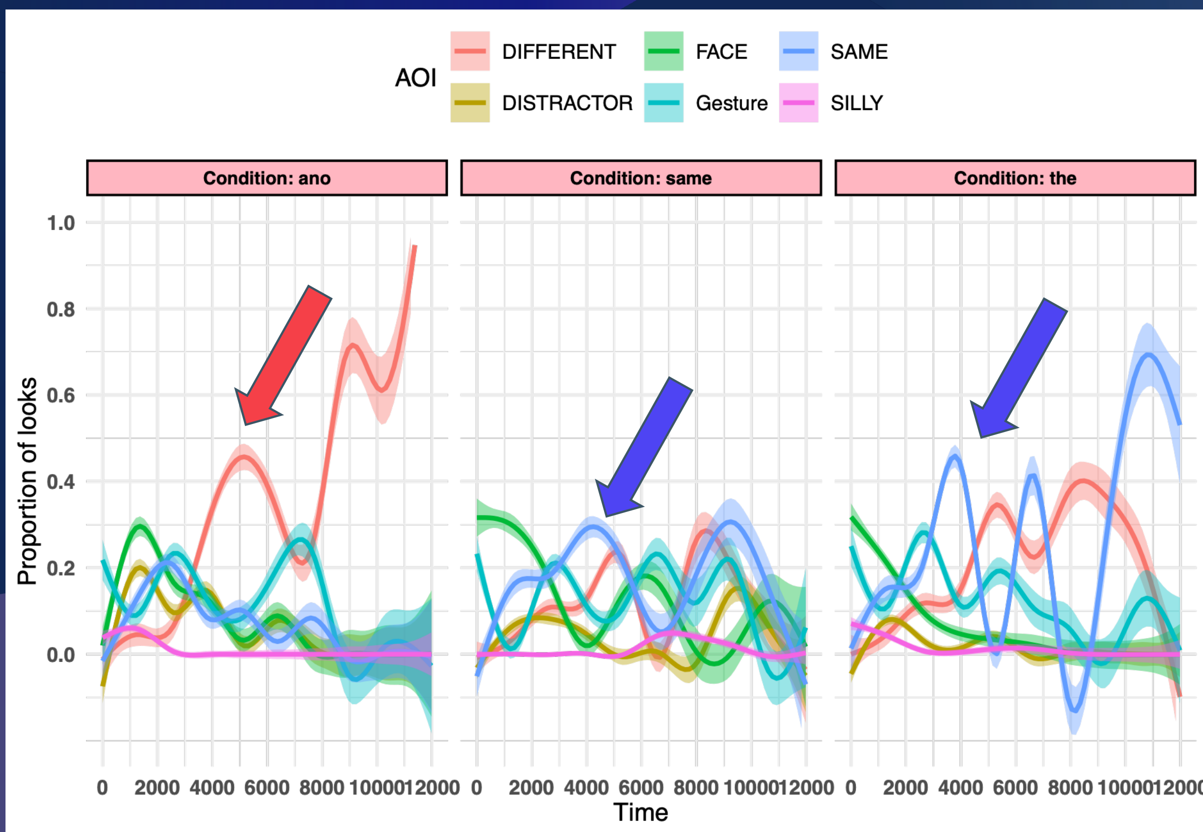
- Initial looks to the face of speaker (green)
- Followed by looks to the 'same' location (blue) or a 'different' location (red), depending on which determiner is said
- Similar pattens in test time with gestures ->gestures don't interfere!

GROUP 0-1: SPECIFIC DEFICIT WITH "THE" AT PRETEST

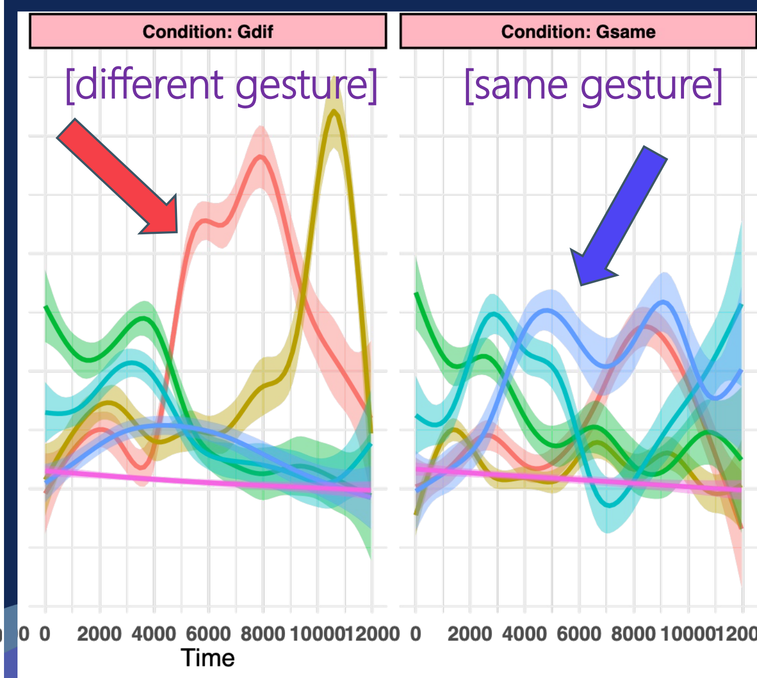


- Like group 1 – initial looks to the face
- Like group 1 – eye gaze to same or different referents with "same" and "another".
- EXCEPT FOR "THE" = 7% correct on behavior, interpreted as disjoint reference in eye gaze!!
- Potential for diagnostics, with comprehension of "the" as a biomarker for language challenges or brain differences

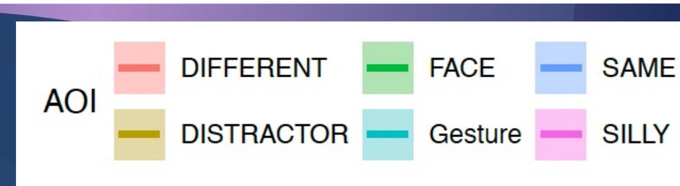
GROUP 0-1: IMPROVING AT TEST WITH GESTURES. NOTE LOOKS TO GESTURE/BODY SPACE (TURQUOISE)



"the" improves to 76% correct in behavioral answers!

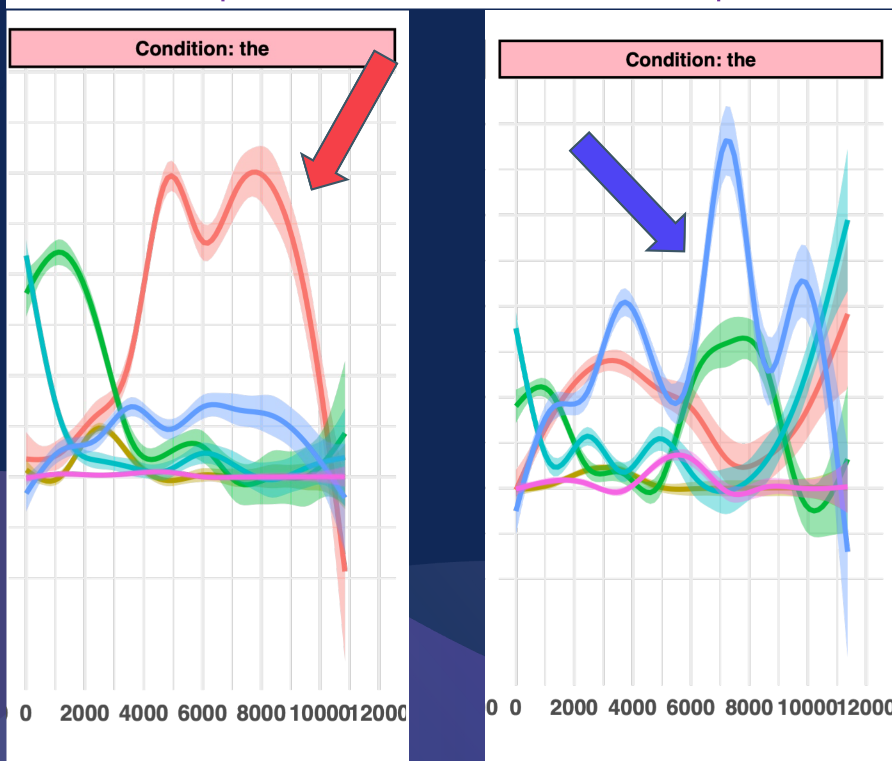


GROUP 0-1: IMPROVEMENT FROM PRETEST TO POSTTEST!



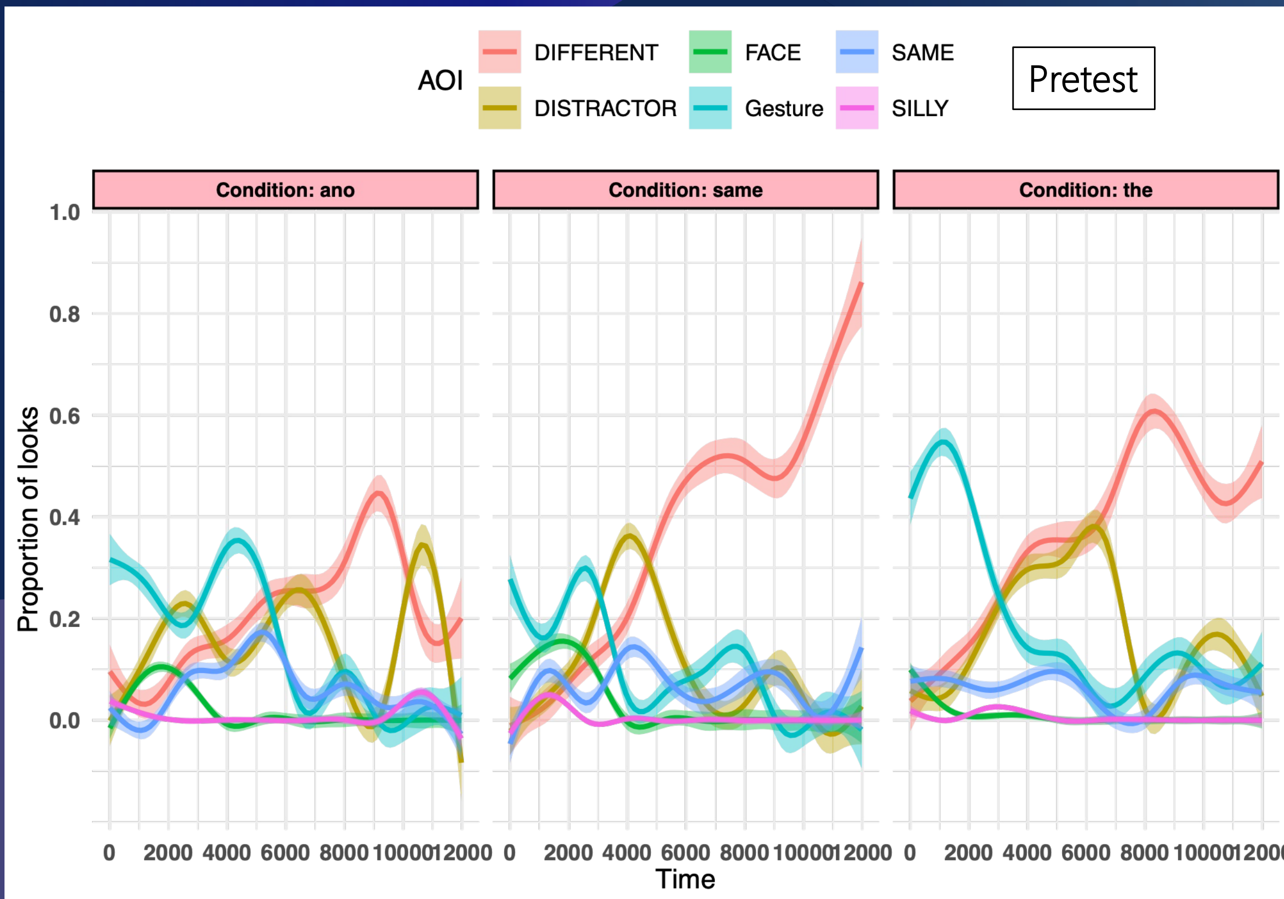
"The" - pretest

"The" - posttest



- Improvement in "the" from 7% in pretest to 58% correct on behavior following exposure to gestures.
- Caveat: no long term follow up to see if this is a lasting change
- Not diagnosis or age specific: 2 ALI, 1 ALN, 2 DLD, 1 TD, 4 Siblings

GROUP 0 – MANY CHALLENGES WITH DETERMINERS AT ALL TIMES. GESTURES DO NOT HELP.



- Mostly 'different' responses regardless of which determiner or gesture is said/shown.
- A known 'default' response strategy
- Note many looks to distractor pictures which were not mentioned
- Note almost no looks to the face of speaker. Looks to body space in absence of gestures.

TAKE AWAYS FROM EYE TRACKING

- Eye tracking shows that when participants do not understand "the apple" in behavioral answer, they really do <u>not</u> think that it can mean "same", unlike "the same apple".
- Specific deficit with “the” vs. other determiners (which require similar cognitive efforts) supports a language-specific explanation, not general cognitive one
- Eye tracking does not work for everybody, nor does an interactive task, so we need <u>neuroimaging and passive-viewing tasks</u>

QUESTIONS OR COMMENTS ON EYE TRACKING RESULTS?

FEEL FREE TO TYPE INTO Q AND A
A KEYWORD YOU REMEMBER
ABOUT RESULTS AT THIS POINT

NEXT RESEARCH DIRECTIONS

ongoing

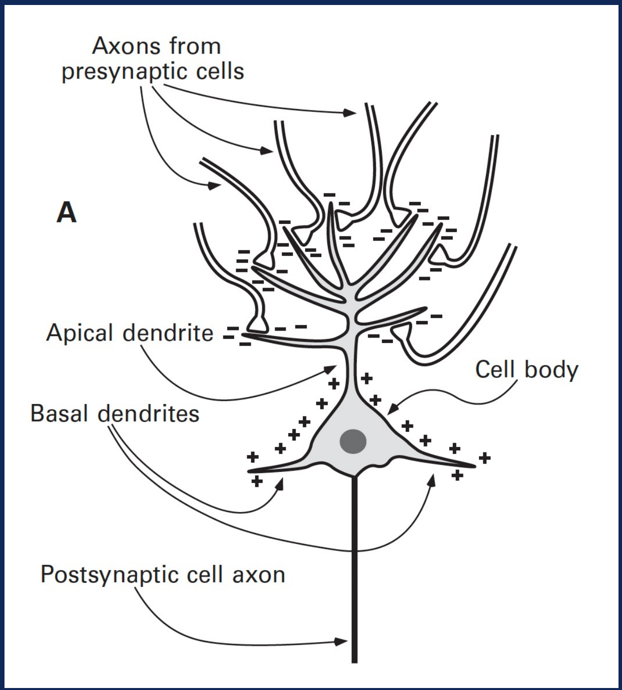
Bio ReD Hub

BIOMEDICAL INNOVATION FOR RESEARCH AND DEVELOPMENT HUB

- By Dr. Bernadette McCrory and team
- The BioReD Hub's vision is as a translatable research interface between the brain (neurobiology), cognition (neuroscience) and human behavior (human factors engineering).
- Leveraging Interdisciplinary Partnerships
- state-of-the-art instrumentation, research practices and innovative ideas to address biomedical systems engineering design, healthcare system improvement, and clinical practice advancement. This collaboration … positively impacts lives and society, especially for Montanans.

EEG (ELECTRO-ENCEPHALO-GRAPHY)

Enobio 20



Representation of a neuron

- Recording electrical brain activity in microvolts over time
- ERP: event related potentials
- P1: Positive wave in microvolts 100 milliseconds after start of information (picture or word) – sensory perception – "I see it!"
- N400: Negative wave in microvolts, 400 milliseconds after onset of stimulus – semantic integration – indication of 'surprise' when information mismatches – "I know what it is!"

OUR METHODS: ANIMATION-GESTURE-WORD

- EEG (electroencephalography) used to record ERPs (event related potentials) during tasks
- Gestures adapted from signs from American Sign Language
- Passive Viewing: Match / Mismatch task

  Animation – Gesture – Word combinations

  Participants passively watch a series of videos

Neutral gesture (noncommunicative)

Animation

Communicative gesture

Mismatching spoken word

COMMUNICATIVE GESTURE VS. ANIMATION VS. SPEECH

Animation (gif) "Bouquet"

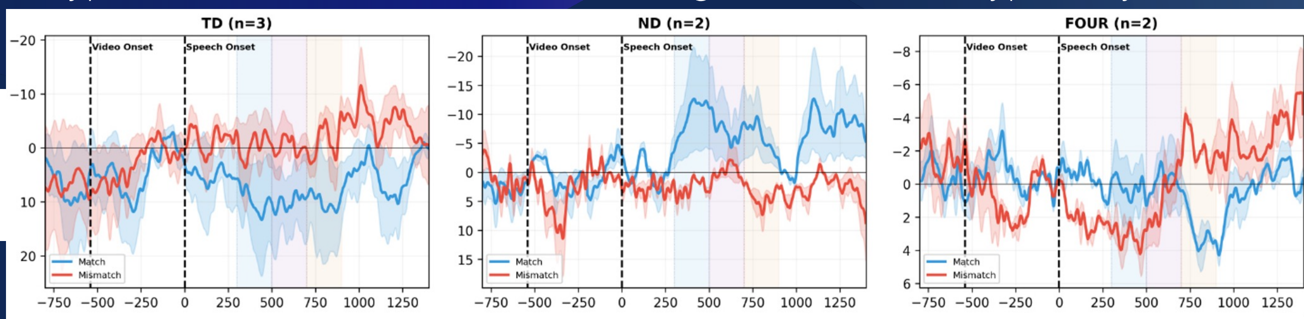
Communicative gesture (video) [Bouquet]

Spoken word (video) "Cat"

OUR PRELIMINARY RESULTS FROM CHILDREN:

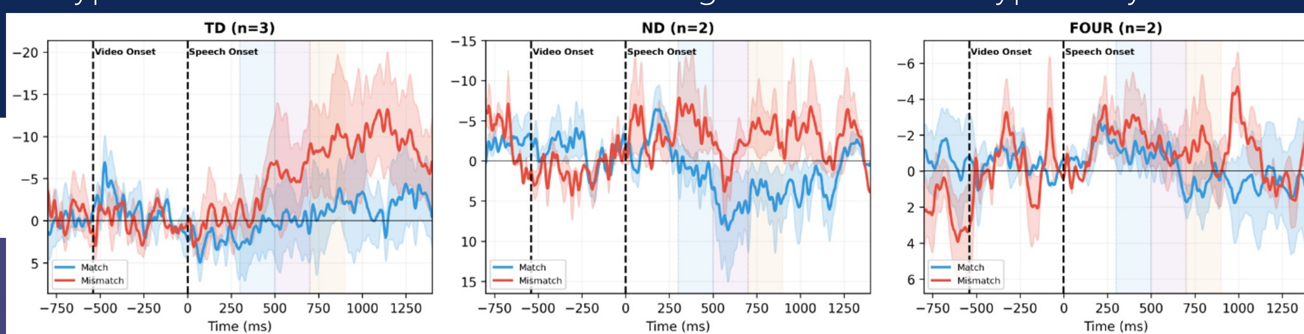
Typical tweens | Neurodivergent tweens | Typical 4 year olds

Animation



Typical tweens | Neurodivergent tweens | Typical 4 year olds

Gesture



Aviles Zuniga et al., 2026

For animation-speech, FOUR-year old typical children and tweenager typical children (TD) show comprehension (semantic integration of animation and speech) – red line of Mismatch is above the blue line of Match (the "N400" effect).

The neurodivergent group, ND (including ALN and ADHD) does not show this.

For gesture-speech, all groups show comprehension, with red line (mismatch) above the blue line (match).

Take away: ALN, ADHD, and younger TD children can understand gestures with speech!

OUR NEXT STEPS: fNIRS

- fNIRS: functional near-infrared spectroscopy
- Measuring changes in hemoglobin with brain activity, gives location in the brain
- Story telling by caregiver with and without gestures measured with motion capture gloves (designed by engineering capstone students at MSU)
- Recording brain activity in child/adult listener

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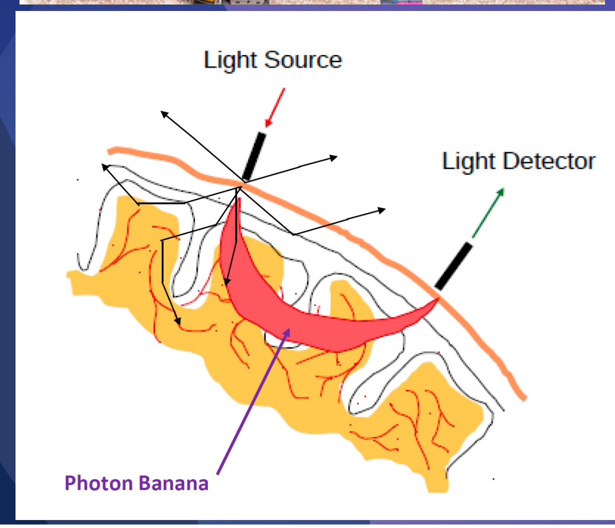


RAISE: Rural Autistic Individuals – Supporting Expression

UNIQUE APPROACH: EEG WITH fNIRS

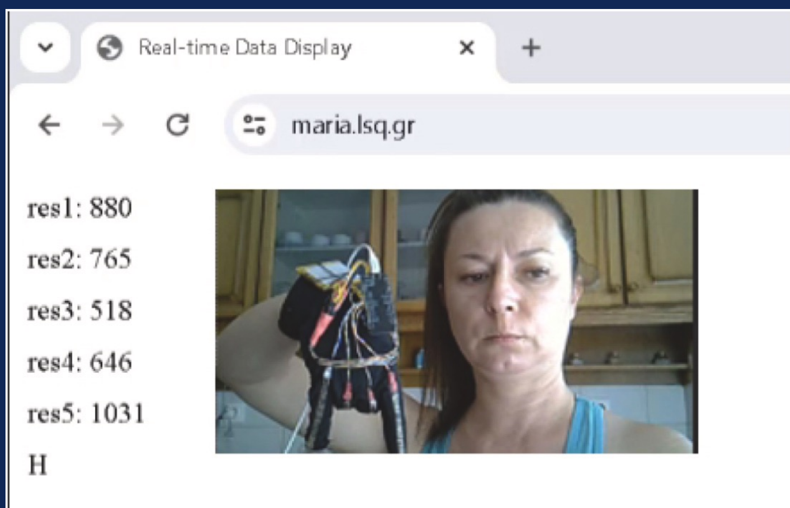
Photo courtesy of Elsa Austin and Luke Winchell

Our unique approach:

- EEG (white knobs) gives timing of brain response
- fNIRS (black knobs) gives location of brain response
- Leads to more precise information on language and gesture comprehension!
- This is ongoing work in our lab

RESEARCH ON AUTOMATIC TRANSLATION OF SIGN LANGUAGE AND GESTURES

Papatsimouli et al., 2026



Greek letter "H"

"Modern technological advancements have enabled the development of sign language recognition systems designed to bridge the communication gap between deaf and hearing individuals, while the continuous innovation in this field holds great potential for reducing social isolation and fostering new social, educational, and economic opportunities for deaf and hard-of-hearing communities. "

CONCLUSIONS

Gestures do Help!

- Speaker gestures do help some children, teenagers, and adults with Autism, ADHD, and/or language impairments understand language better

Multimodal communication!

- Verbal/auditory words + hand gestures by speakers ➢ more clear meaning
  - ➢ better communication

For Caregivers, Teachers, Providers, and Children!

- Translating findings into training/support with gestures for both children and caregivers/co-communicators
- Especially in Rural areas

Future research to support other patients

- Would gestures help or hurt communication? The research is inconclusive…
- For example for Alzheimer's, Parkinson's, Down syndrome, etc.

REFERENCES

<u>Our group:</u>

Aviles Zuniga et al. 2026. Investigating Semantic Integration of Gestures with Nouns in Neurodiverse Individuals via Event Related Potentials. *Proceedings of the 2026 International Symposium on Human Factors and Ergonomics in Health Care*.

Erickson et al. 2025. Inferring comprehension of social interaction from eye tracking in neurodiverse individuals in rural settings. *Proceedings of the 2025 International Symposium on Human Factors and Ergonomics in Health Care, 14* (1), 198-203.

Modyanova et al. 2024. Improving Language Comprehension via Hand Gestures in Children with Autism Spectrum Disorders and/or Language Impairment in Rural Montana. *Proceedings of the 2024 International Symposium on Human Factors and Ergonomics in Health Care*. *13*(1), 191-196.

Wexler, K. 2002. Lenneberg's dream: learning, normal language development, and specific language impairment. *Developmental Language Disorders: From Phenotypes to Etiologies*, 52.

<u>Other sources:</u>

Dick, Goldin-Meadow, et al. 2012. Gesture in the developing brain. *Developmental Science*, *15*(2), 165–180.

Dimitrova et al. 2017. Do Verbal Children with Autism Comprehend Gesture as Readily as Typically Developing Children? *Journal of Autism and Developmental Disorders*, *47*(10), 3267–3280.

Hauser, Chomsky, Fitch. 2002. The faculty of language: What is it, who has it, and how did it evolve? *Science*, *298*(5598), 1569–1579.

Konstantareas. 1984. Sign language as a communication prosthesis with language-impaired children. *Journal of Autism and Developmental Disorders*, *14*(1), 9–25.

Lenneberg, E. 1967. Biological Foundations of Language.

Papatsimouli, et al. 2026. IoT-powered assistive technology for real-time translation of sign language. *International Journal of Cognitive Computing in Engineering*, *7*, 582–595.

Sibley et al., 2017. Practical considerations for low-cost eye tracking: An analysis of data loss and presentation of a solution. *Augmented cognition. Neurocognition and machine learning.*

<u>Vallotton, C. Signing with Babies and Children: A Summary of Research Findings for Parents and Professionals. *Two Little Hands Productions*</u>. https://www.deafchildrenaustralia.org.au/signing-with-babies-and-children-a-summary-of-findings/

THANK YOU !

Contact:

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QUESTIONS? COMMENTS?

Resource (unaffiliated):

https://signingtime.com/

“Babies, toddlers, and young children can learn to sign before they can talk. Reduce frustration and start communicating sooner with our beloved video series, available on any device.”