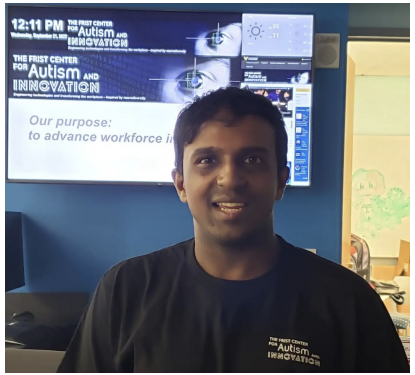
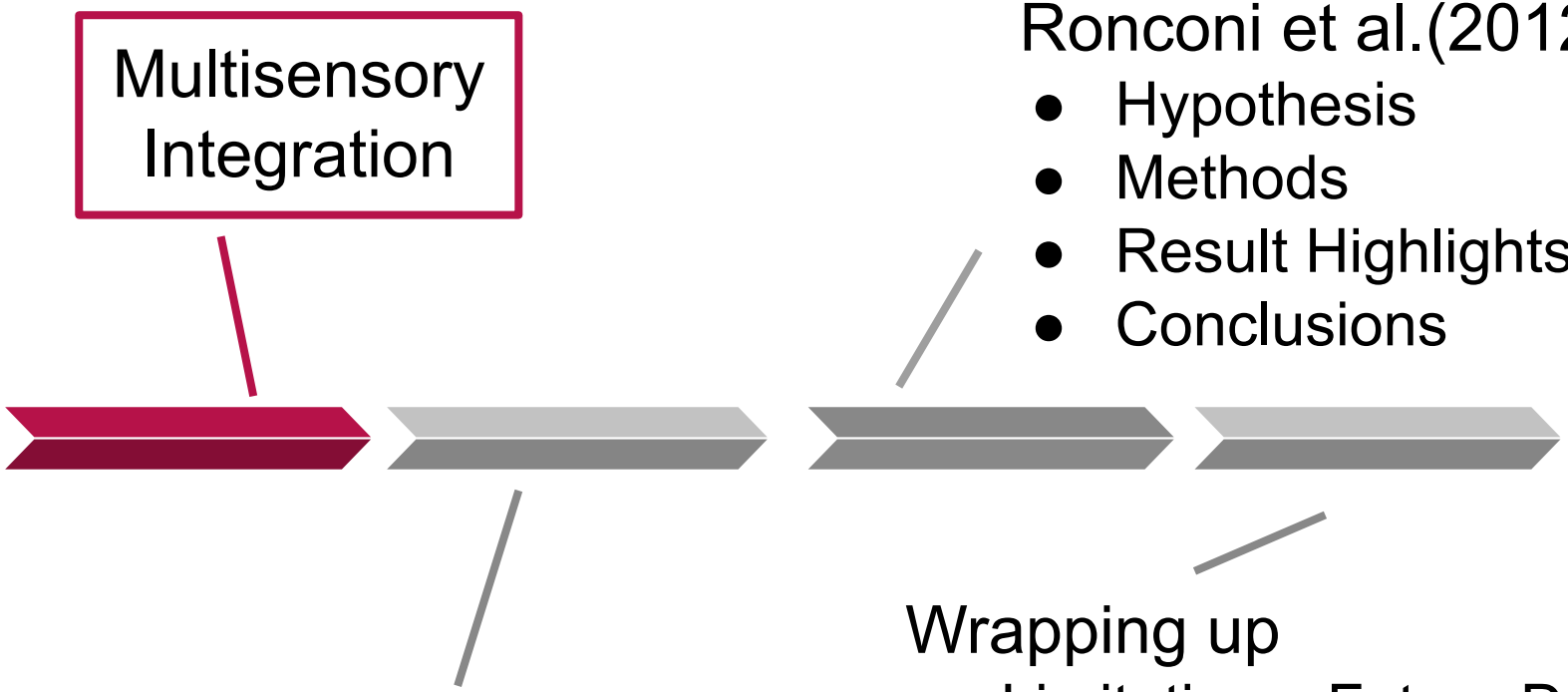
Neural dynamics driving Audio-Visual Integration in autism

Luca Ronconi, Andrea Vitale, Alessandra Federici, Noemi Mazzoni, Luca Battaglini, Massimo Molteni & Luca Casartelli (2022)



Hari Srinivasan
Nuro 8340

VANDERBILT UNIVERSITY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Multisensory Processing

- How sensory signals from different modalities are organized in our perceptual experience.
- Balancing temporal segregation & integration
  - Temporal Segregation: grouping inputs within close time periods
  - Temporal Integration: combining information over time to improve detection.

Illusion

- The mind makes educated guesses /probabilistic inferences, when environmental stimuli don’t align with conscious perception of the stimuli.

Stream Bounce Illusion: Example

https://youtu.be/ztXwERzKEw4
https://youtu.be/ISGnGVfxhBE

Stream (https://youtu.be/ztXwERzKEw4)

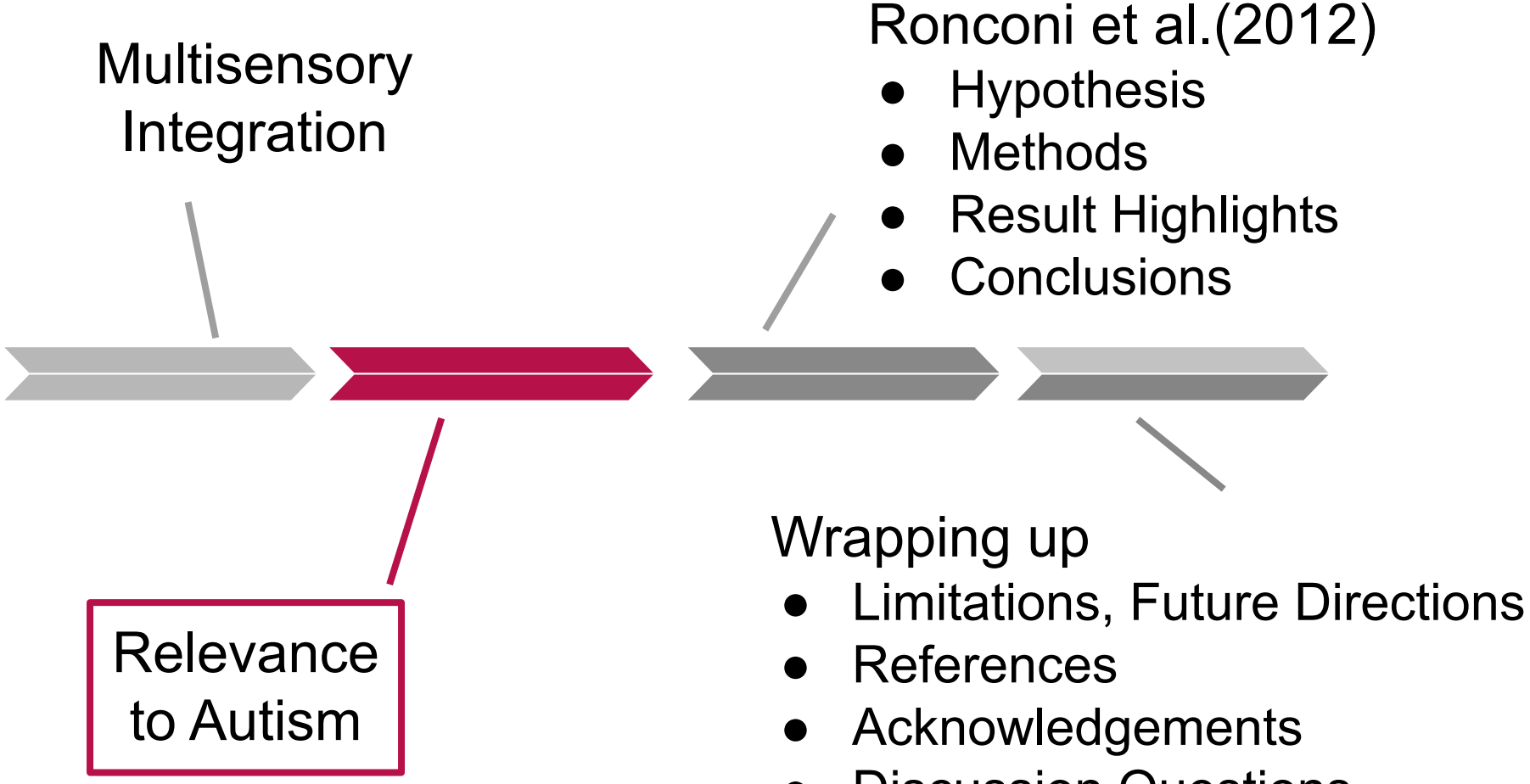
Visual (Unisensory) Input → Streaming effect
Two balls approach and seem to stream past each other

What happens if we add auditory input?

Bounce (https://youtu.be/ISGnGVfxhBE)

Audio-Visual (Multisensory) Input → Bounce effect

The balls seem to bounce off each other at midpoint.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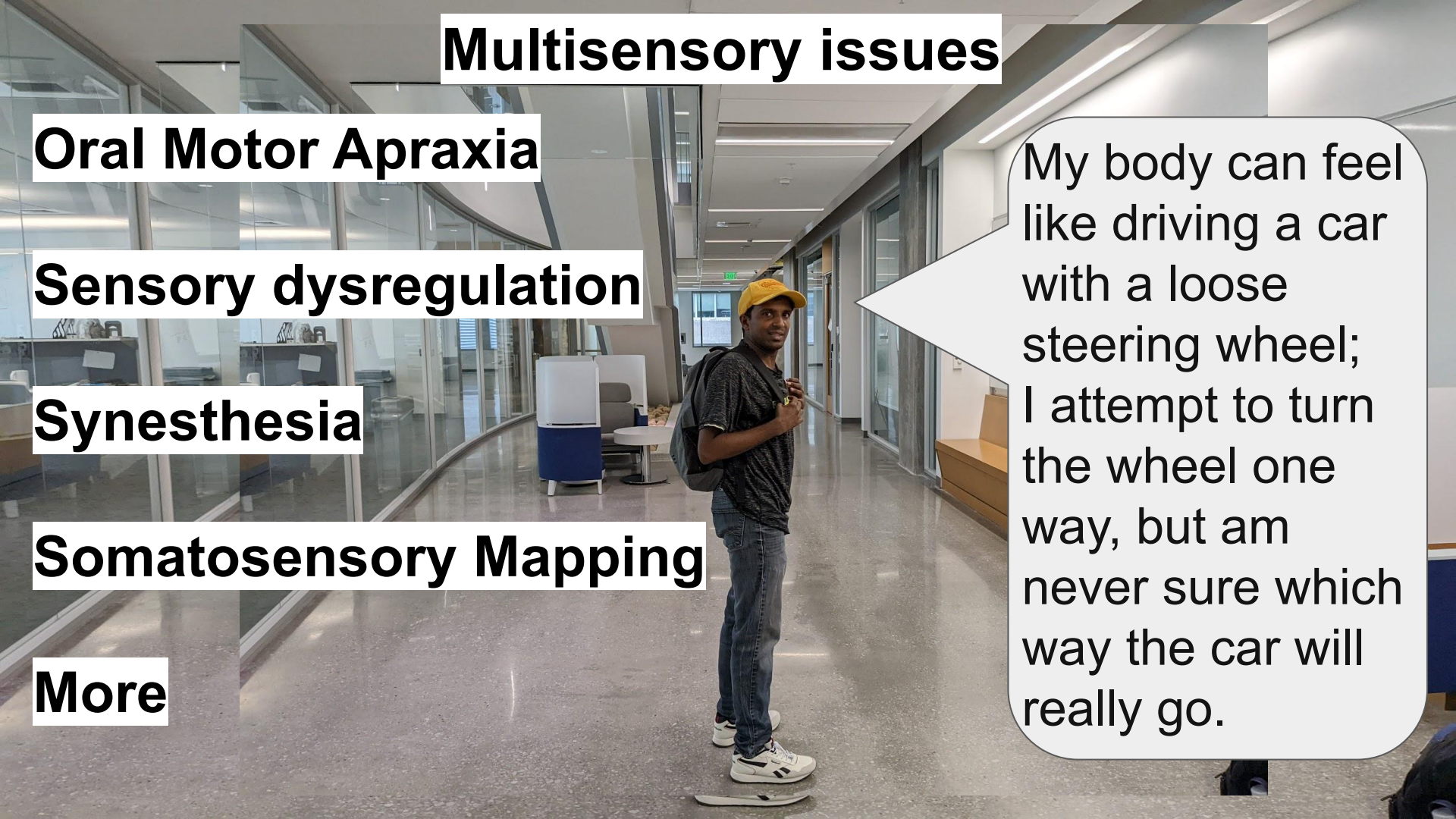
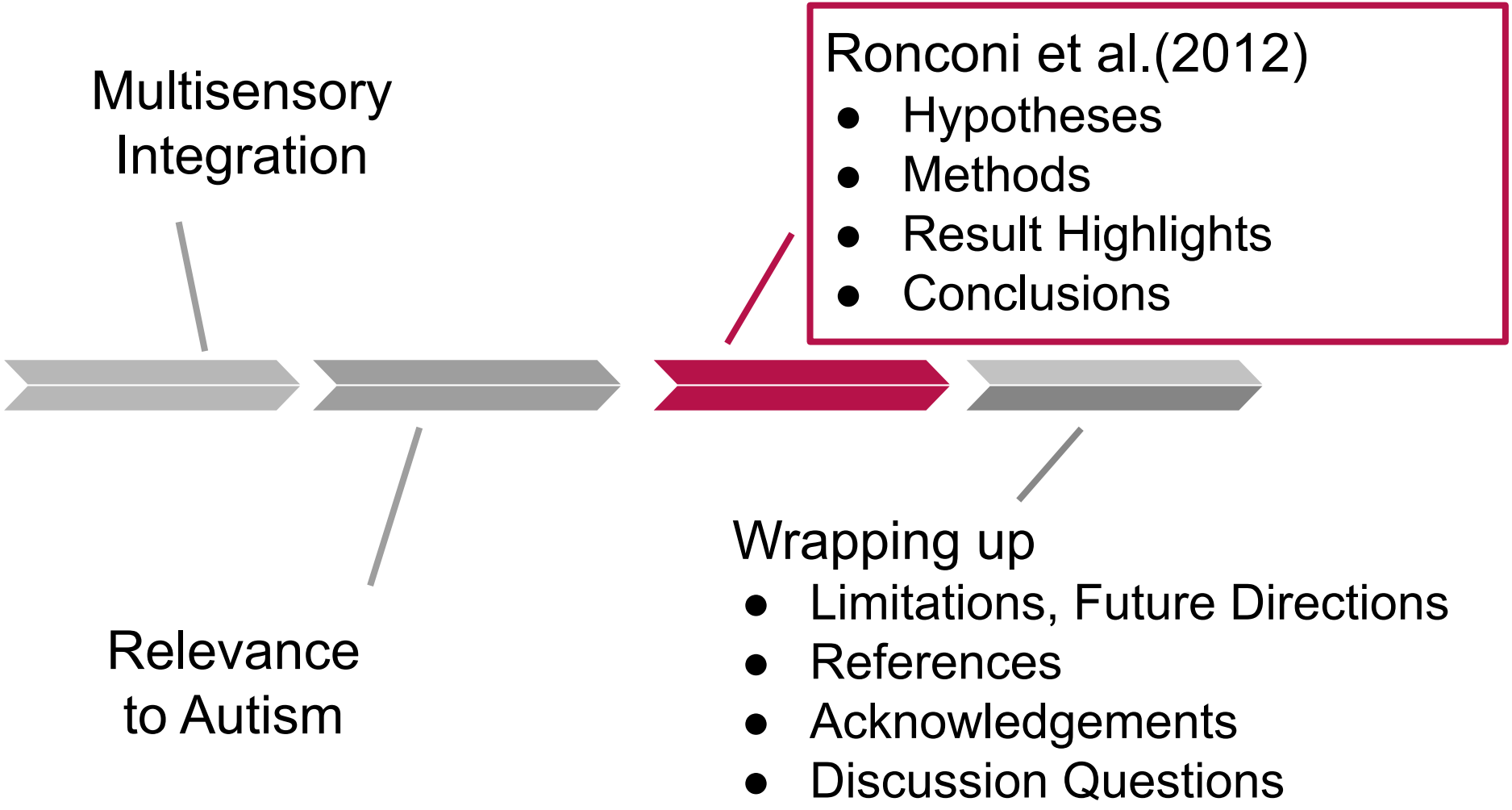
Relevance to Autism

- Temporal Binding Window thought to be wider in autism.
  - Timeframe in which different stimuli input are integrated and perceptually bound together.
- Reduced susceptibility to AV illusions
- Eg: McGurk Effect, Sound Induced Flash Illusion (Feldmanetal 2018; Zhouetal 2018), Pip-pop effect (Collignon et al., 2013).
  - Example of McGurk effect (https://youtu.be/7uHDMc4TEU8)
- AV integration seen as playing crucial roles in social functioning and communication in autistics.

McGurk effect - Informal Poll

Autistic (me)	Neurotypical (friend)
Heard same sound When attention re-directed noticed lip movements could imply different sounds. But still heard only ba	Eyes open → different sounds Eyes closed → same sound


Multisensory issues
Oral Motor Apraxia
Sensory dysregulation
Synesthesia
Somatosensory Mapping
More
My body can feel like driving a car with a loose steering wheel; I attempt to turn the wheel one way, but am never sure which way the car will really go.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Ronconi et al., 2022

Assumption: Multisensory integration-segregation balance crucial for high level social functions like speech in autism.

Purpose of this paper: Investigate mechanisms behind altered multisensory processing in autism using oscillatory framework (EEG).

Hypotheses Ronconi et al, 2022

Neural signatures could be altered in autistics. Specifically:

1. Weaker link between alpha rhythms and AV integration window
   - ➢ indicates poor reliance on endogenous oscillatory activity and/or more pronounced stimulus-driven multisensory processing
2. Absence of pre-stimulus power/ phase differences between AV integration versus segregation in low-/mid-frequency oscillations
   - ➢ marginal reliance on anticipatory signals of AV co-occurrence.
3. Different impact of auditory-induced phase reset
   - ➢ atypical balancing and temporal alignment of the different unisensory signals.

Sample - Ronconi et al, 2022

- TD Group (n=17, mean age = 11.5)
- AS Group (n=17, mean age 12.47)
  - Dx with clinician & ADOS
  - Normal vision/hearing
  - **No gross behavior issues**
  - **No drug therapy**
  - **No ADHD dx**

Match Criteria

- age
- performance in Block Design subtest of WISC.

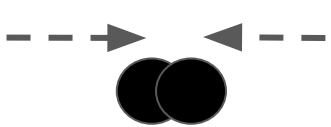
Parental (SCQ) social communication questionnaire (SCQ) indicated autistics having more challenges in social and communication domains

Methods - 3 Trial Conditions Ronconi et al. 2022

Stream-Bounce Illusion

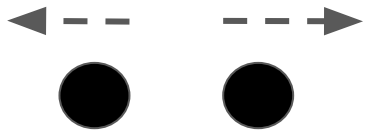
1.Pre-coincidence

150 ms before dots overlap



2. Synchronous

67 ms before dots overlap



3. Post-coincidence

184 ms after dots overlap

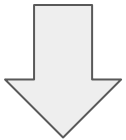
Participants indicate if STREAM or BOUNCE

Methods: Testing Integration vs Segregation

Ronconi et al. 2022

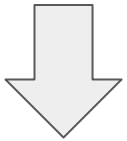
Key aspect of testing AV integration vs segregation was the sound dependent change in visual motion.

Stream Response



Segregation
of 2 modalities

Bounce Response



Integration
of 2 modalities

Methods: Three Electrode Clusters for AV Task

Ronconi et al. 2022

- Occipital (E33, E34, E36, E38)
- Right Temporal (E46, E48, E49, E52)
- Left Temporal (E22, E24, E25, E26)

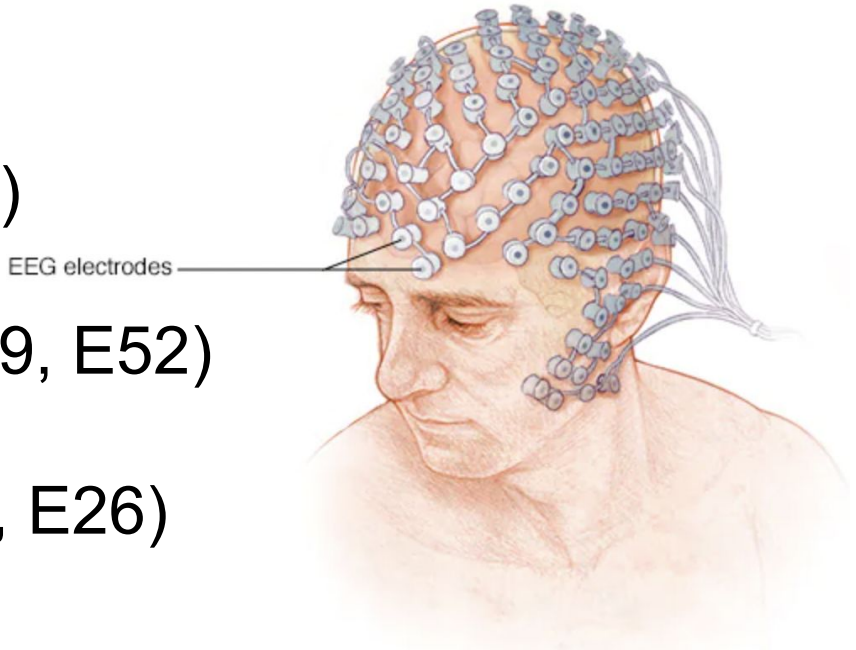


Image source: https://www.mayoclinic.org/tests-procedures/eeg/about/pac-20393875

Discussion of Results Ronconi et al. 2022

- Behavioral Results

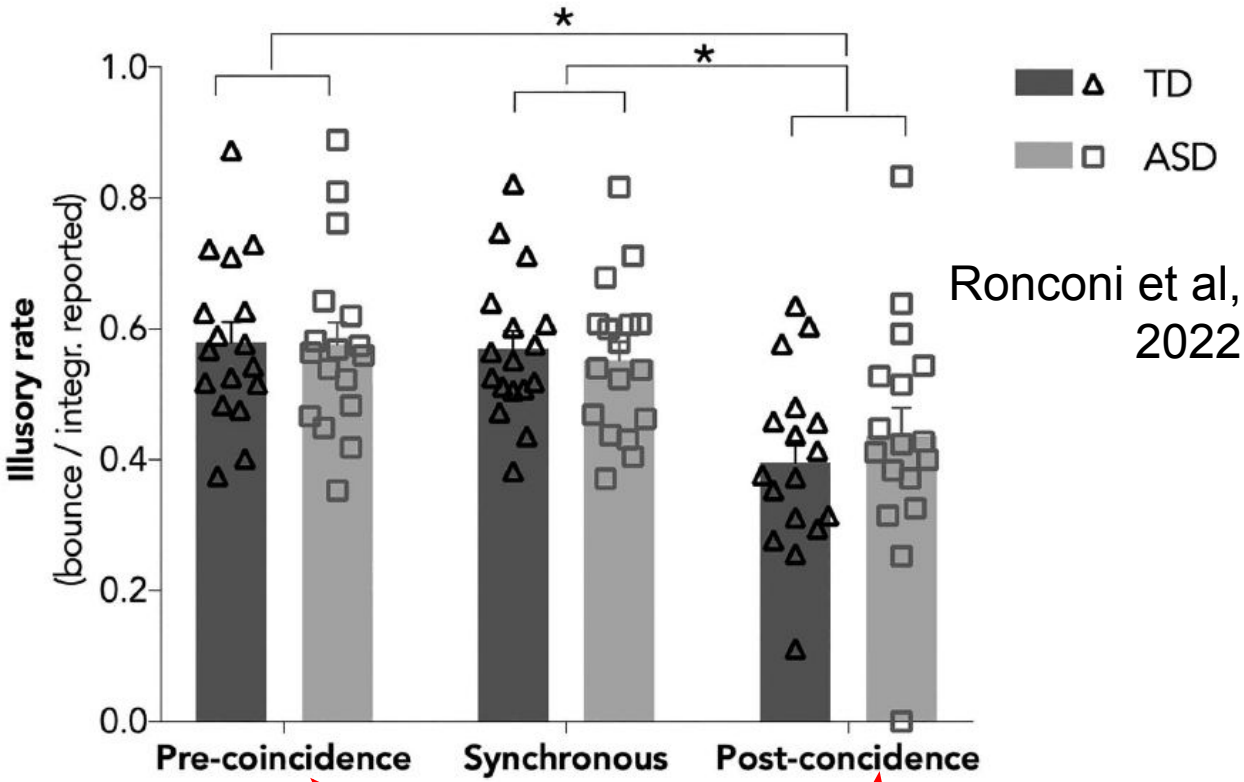
- EEG Findings

TD children reflected earlier findings in TD adults
Differences seen in AS group.

  - Alpha Rhythms and AV integration window
  - Anticipatory Signals of AV co-occurrence
  - Impact of Auditory-Induced Phase Reset

Result 1: Behavioral Performance

Main effect of factor condition



Ronconi et al, 2022

Perception in more than ½ of trials

bounce integration

stream segregation

Result 2: Alpha Rhythms and Integration Window

- Awake-relaxed. **8–12 Hz**
- Cortical inhibition. Suppression & selection (Klimesch , 2012). Gating of irrelevant sensory stimuli
- IAF = Individual Alpha Frequency.
- In TD:
- Resting state alpha, key for temporal sampling within/ across modalities (Keil & Senkowski, 2018; Bauer et al, 2020)
- ie: IAF determines width of cross modal binding window.
- Lower alpha peak frequency

  → more integration → higher illusory rate

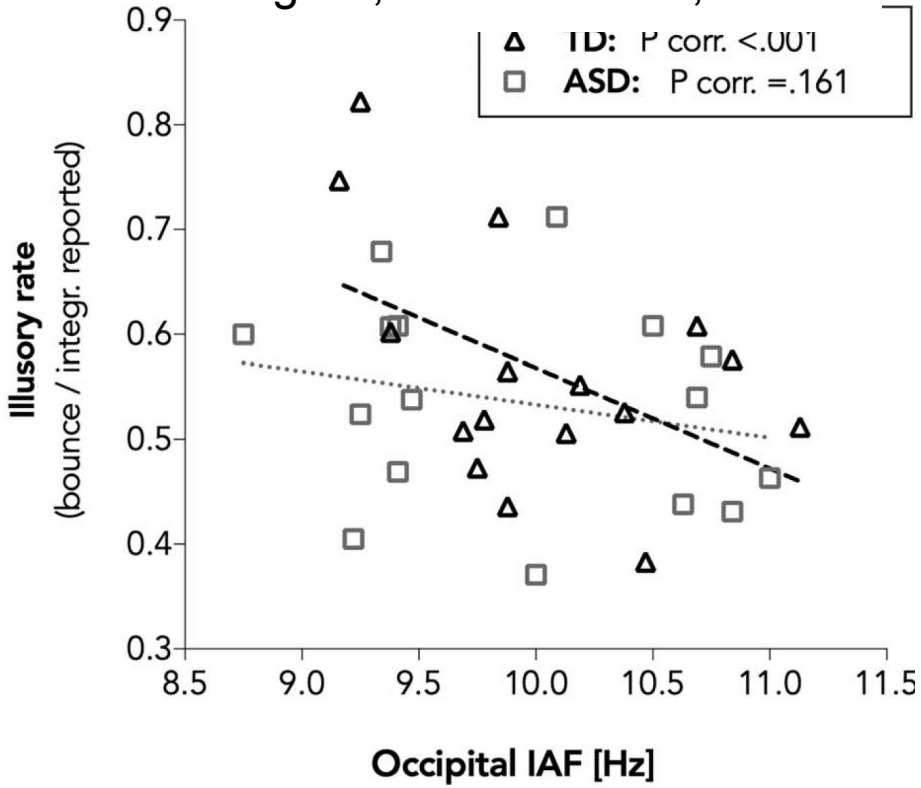
  → temporal widening of AV binding window

Result 2: Alpha Rhythms and Integration Window

TD: **Negative correlation** between IAF and Illusory Rate in **occipital** cluster

AS: **Lack of correlation** → Suggests a noisier cortical alpha sampling.

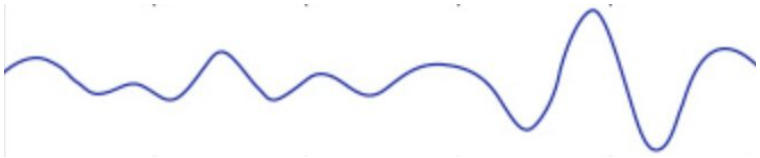
Fig 4A, Ronconi et al., 2022



Result 3: Theta Anticipatory Mechanisms

- (4-8 Hz)
- In TD

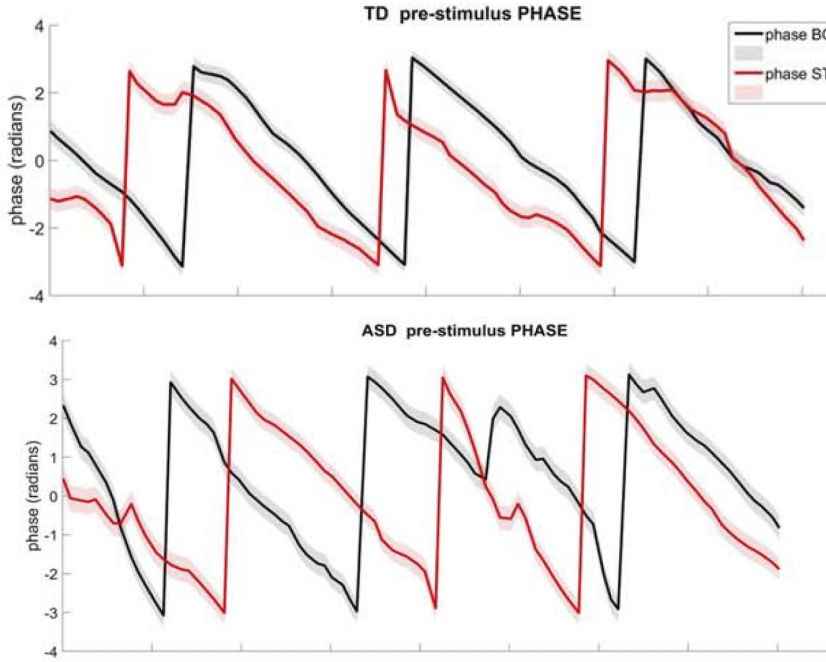
  Theta oscillations predict upcoming auditory stimulus based on visual dynamic info.



Result 3: Anticipatory mechanisms

Fig 3E-F, Ronconi et al., 2012
Black: Bounce, Red: Stream
(x-axis: Time)

TD: Increased occipital **theta** oscillations cluster around a common phase angle for bounce (integration) percept trials
→ **anticipatory activity predicting AV integration**



AS: **absence** of significant **different phase concentration** for bounce or stream trials.

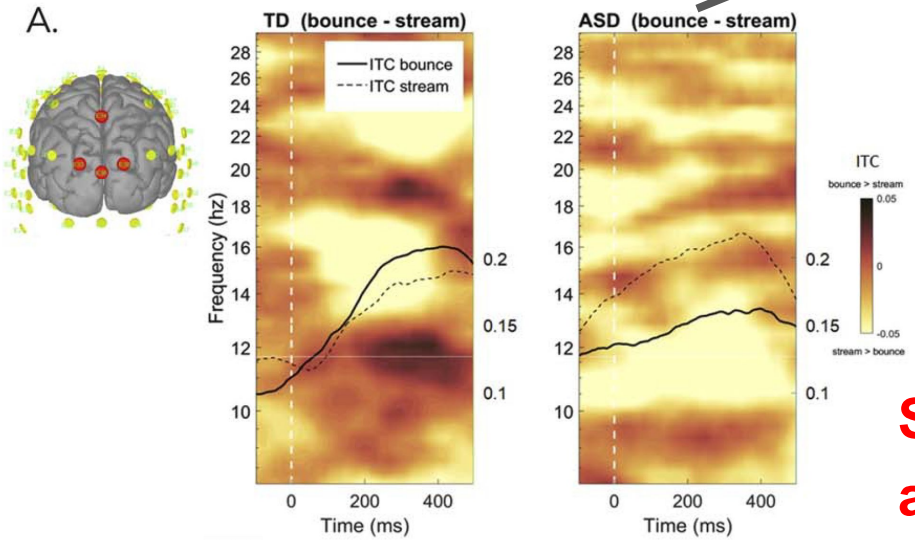
⇒ Not rely on anticipatory mechanisms that track dynamic visual events.

Result 4: Auditory Induced Phase Reset

In TD: reset in visual cortex important for opening a temporal window where AV **integration** can occur.

In AS: reset causes **segregation** of AV stimuli, breaking the AV integration & Illusory outcome.

Fig 3A, Ronconi et al., 2012



Highest phase concentration strictly dependent on auditory timing event.

Suggests stronger reactivity to auditory inputs

Conclusions Ronconi et al., 2021

AV integration-segregation present but different in AS

Distinct computations supporting multisensory processing weighed differently in AS.

Marginal reliance on anticipatory signals of AV co-occurrences
counterbalanced by
Greater impact of post stimulus neural dynamics.

Conclusions Ronconi et al., 2021

AV integration not predicted by
speed of alpha rhythms or by amplitude

Instead, a different neural processing of the sound and a differential post-stimulus sound-induced realignment of visual cortical oscillations could explain AV integration v. segregation.

Conclusions Ronconi et al., 2021

These results show how multisensory integration depends on different endogenous, anticipatory, and stimulus-driven factors, which seem selectively altered in AS.

Aligning results with my lived experience

Alpha rhythms gate sensory stimuli.

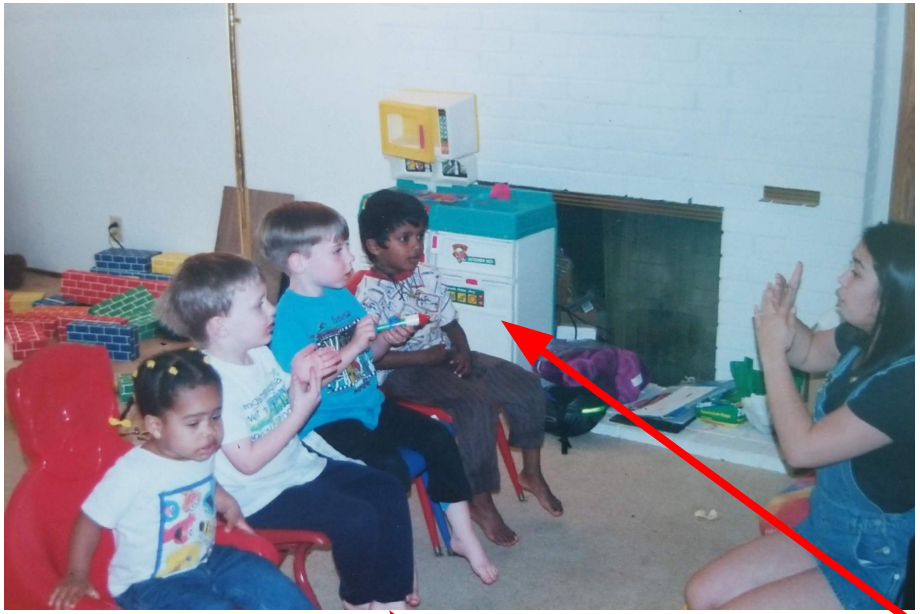
- Overwhelmed with sensory stimuli.

Theta Rhythms and anticipatory mechanisms

- High alert body, in constant anticipatory mode.
- Autism + ADHD interaction?
  - *“Altered AV interaction signature … comorbid phenotype shared by ASD and ADHD, possibly due to alterations in attentional selection systems.” (Norcia et al., 2021)*

Auditory-Induced Phase Reset.

Auditory Induced Phase Reset

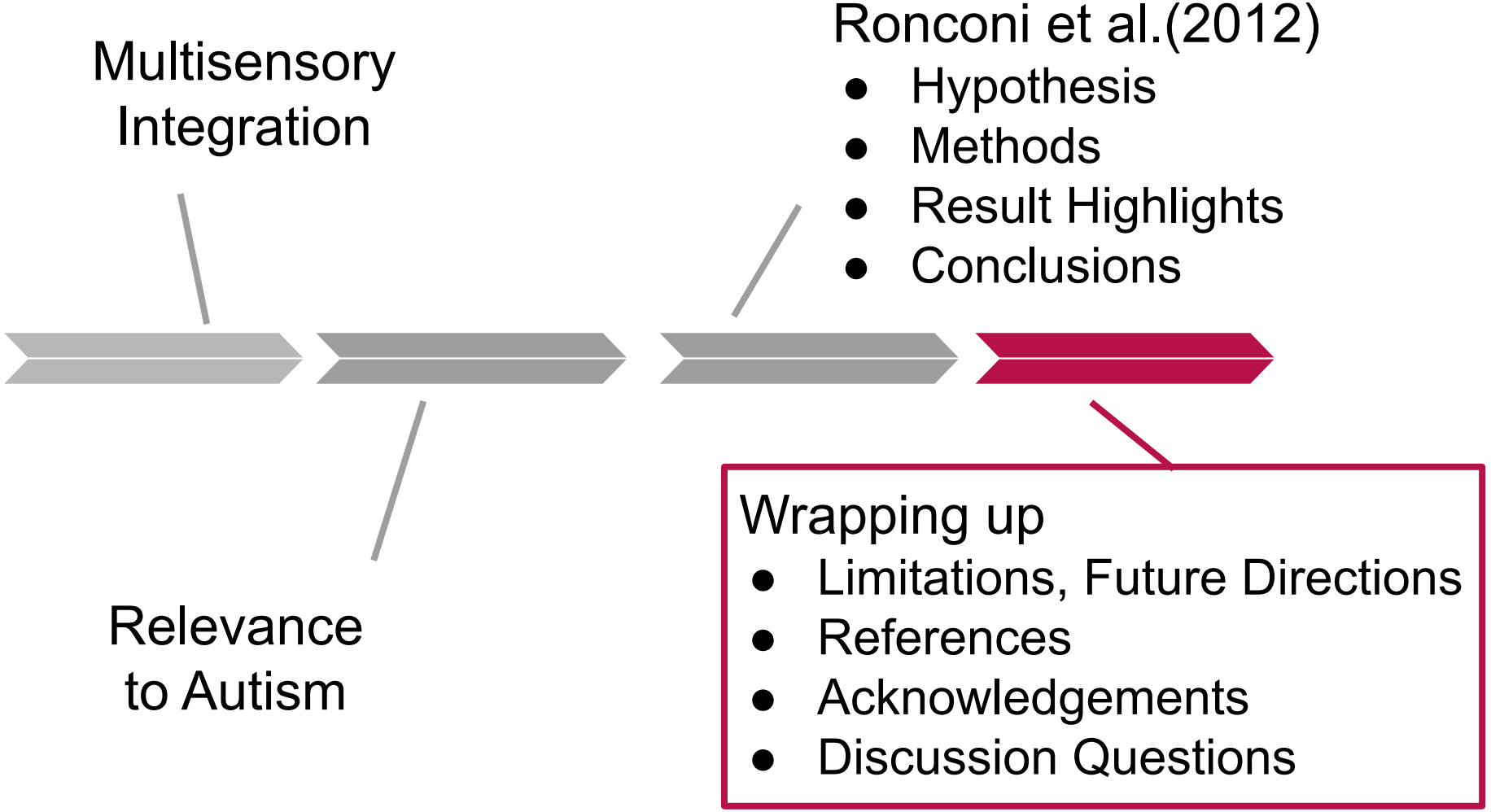


Typical peers synchronous instruction following.

Me just looking at therapist

40-15 hrs/week of 1:1 therapy, ages 3 -12

A life of therapy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Limitations & Future Directions

Applicability of results.

- Heterogeneity of autism.
- Co-occurring could impact sensory experience
  - ADHD: 50-70% (Hours et al., 2022)
  - Epilepsy: 10% (Liu et al., 2022)
- Drug therapy. 30-50% (Feroe et al., 2021)

Future Direction

Limitations & Future Directions

Two Modalities ≠ Multisensory

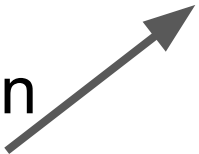
- Majority of studies: Audio + Visual
- Audio + Somatosensory (Russo et al., 2010)
  - Lower integration in AS
- Audio+Visual, Olfactory+Visual (Stickel et al., 2019)
  - No group difference. Similar neural mechanisms.
    - AV integration → superior temporal activation
    - Olfactory visual integration → amygdala activation

Future Direction ⟶ 3 or more senses

Limitations & Future Directions

Measurements

- Current study used only EEG
  - Need many measurements (fMRI etc) in same sample
- Which produces stronger reaction?. Audio or Visual?
  - Current study: implies Auditory Dominance. Personal observation → Visual dominant

Future Direction 

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Thank you

Thilo Womelsdorf & Leah Mann
for giving me confidence and assistance.

Thank you everyone.
For your patience as I navigate my
atypical mode of presenting.

I will attempt to answer any short questions.
I may have to email longer responses.

PS:

Very curious about your audio-visual integration with the computer generated audio which lacks intonation/nuances of human speech.

Did you need more words or less words on screen for integration?

Will the computer voice change make a difference to your integration.

Discussion Questions

1. How do we address the issue of heterogeneity in autism so that research results are more meaningful.
2. How would we experimentally design a study that can incorporate three or more senses to truly reflect multi-modal.
3. More humane language to present scientific results about fellow humans.
    - “peculiar/anomaly” when dx is upto 1:44?
    - Differences, not deficits
    - Co-occurrence, not comorbid.

Progress of Science and Humanity