Baby Rhythm

9-10 May

ERC "BABYRHYTHM" PROJECT CLOSING WORKSHOP

Abstract Book

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European Research Council
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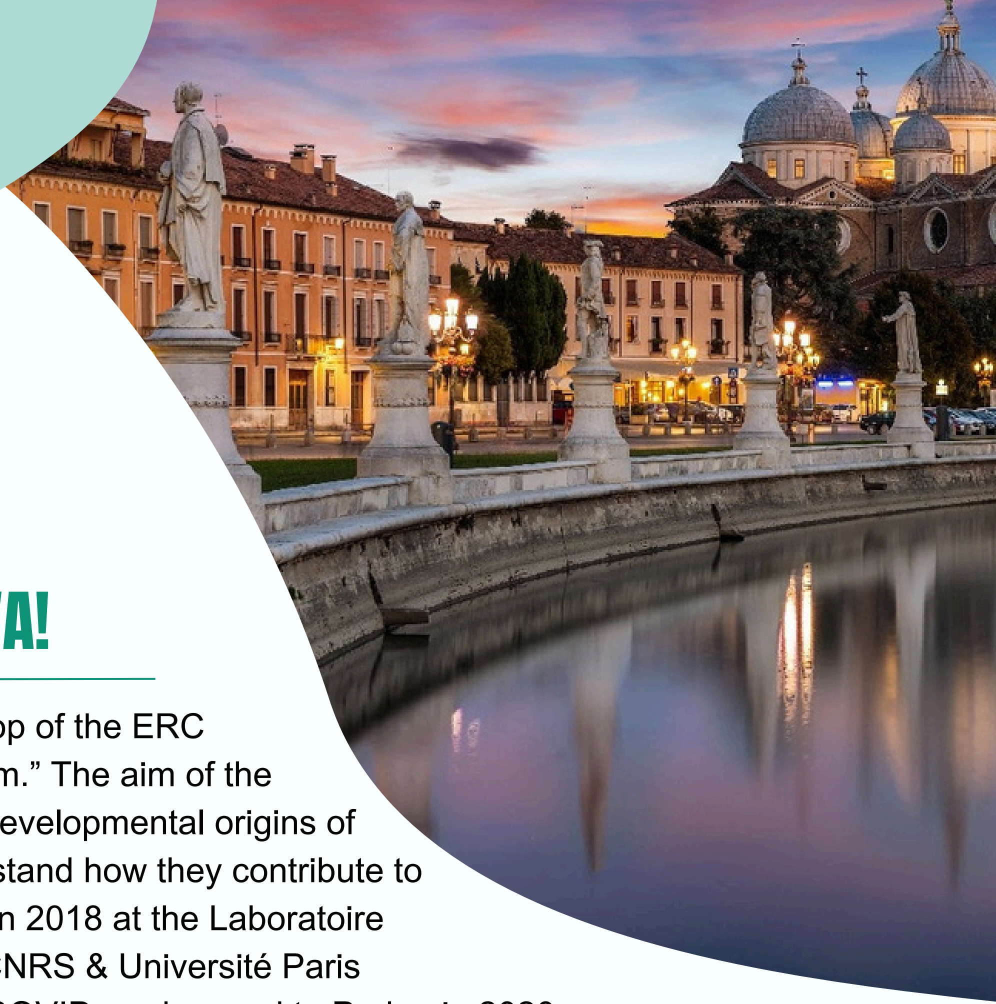


WELCOME TO PADOVA!

Welcome to the closing workshop of the ERC Consolidator Grant "BabyRhythm." The aim of the grant has been to uncover the developmental origins of neural oscillations and to understand how they contribute to language acquisition. It started in 2018 at the Laboratoire Psychologie de la Perception (CNRS & Université Paris Descartes) in Paris, "survived" COVID, and moved to Padua in 2020. It ends in May 2024.

We decided to organize this small-scale, informal, friendly, but hopefully exciting and thought-provoking workshop to showcase what we have understood about neural oscillations and what more we have done. Our aim was to "think globally, but act locally," inviting some of the internationally most important scholars of neural oscillations and language development as keynote lectures, presenting our own work as talks (and posters), and having the local (and less local) community exhibit their research as posters.

The program is designed to leave ample time for lively scientific discussions, informal chats, and relaxed social exchange (don't miss Friday night's social event complete with a DJ!).

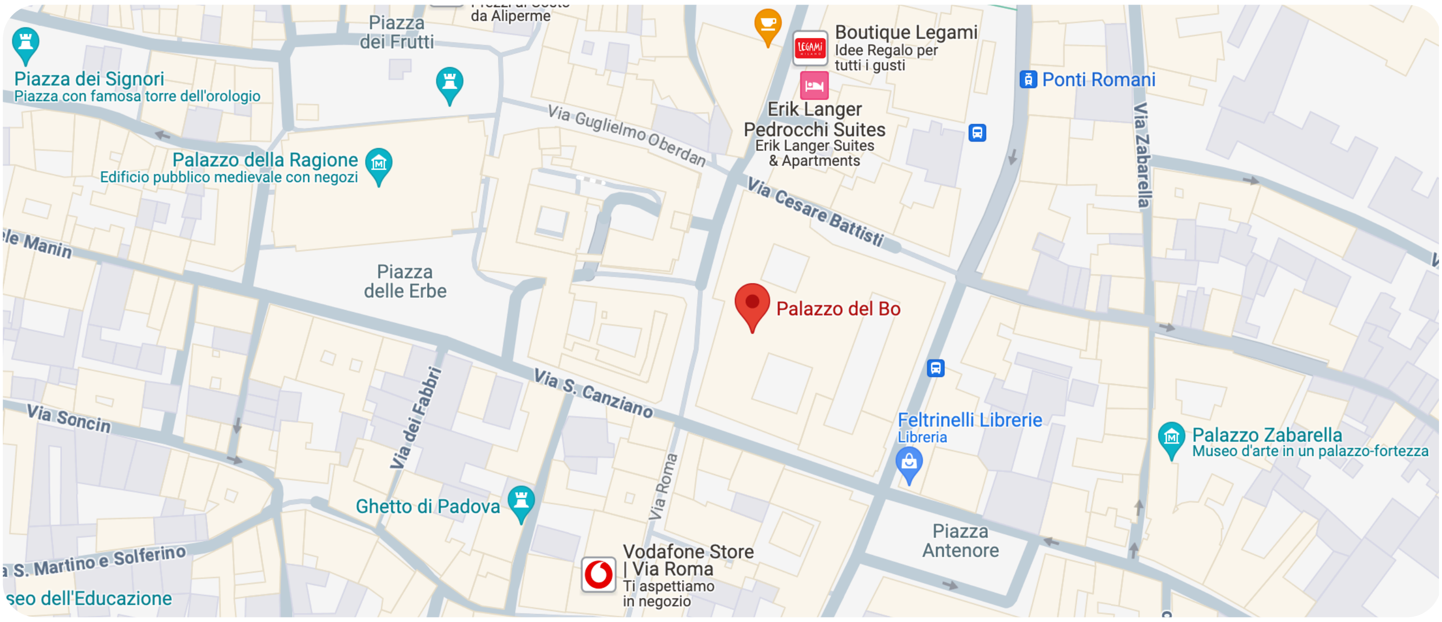
Our hope is that you will enjoy the workshop and have fun!

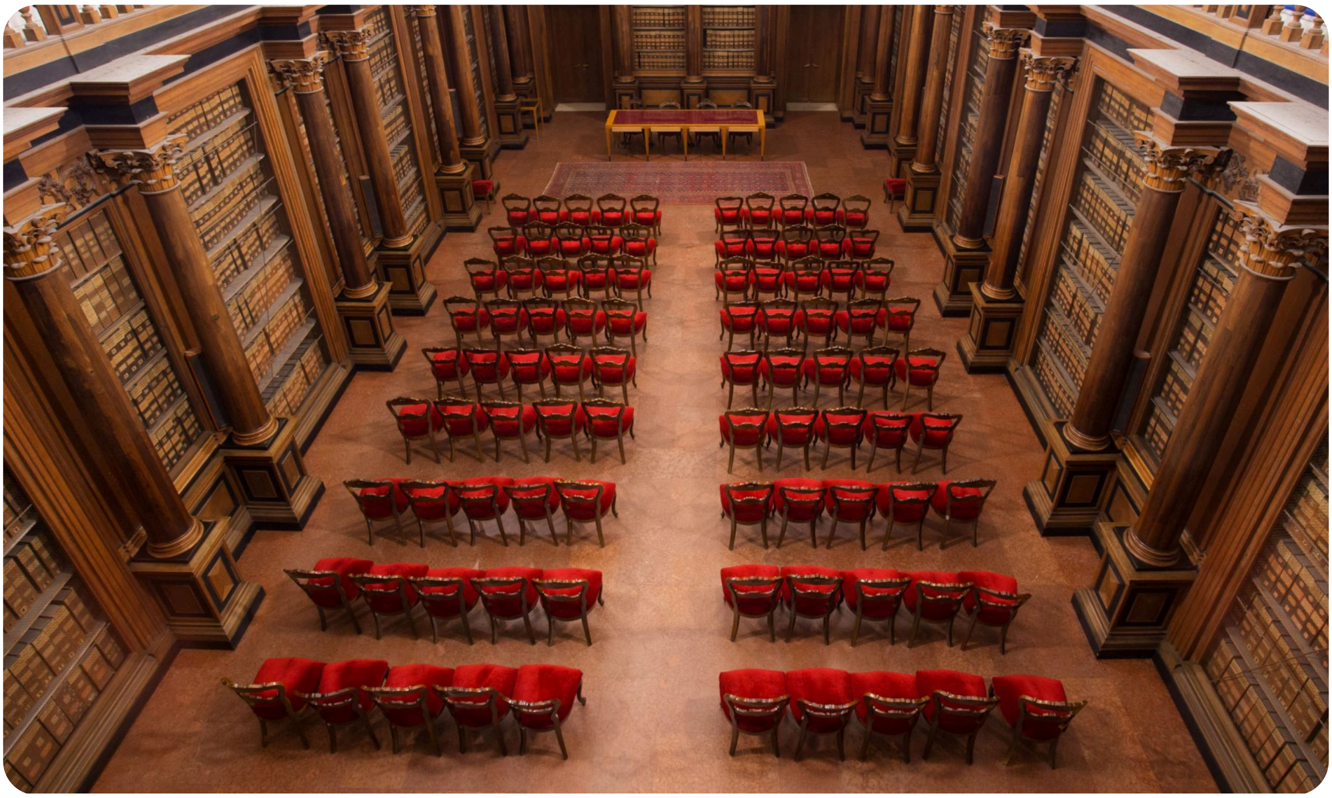
Judit
Benedetta
Caroline
Caterina
Gaia
Jessica
Martina
Silvia
Zeynep

VENUE

Palazzo Bo, Archivio Antico

Via VIII Febbraio, 2, 35122 Padova PD





PROGRAM IN GLANCE

8:30-8:45	Registration	
8:45-9:00		
9:00-9:15	Welcome and Opening Remarks	
9:15-9:30		
9:30-9:45	Invited Speaker: Anne-Lise Giraud	Invited Speaker: Irene de la Cruz-Pavía
9:45-10:00		
10:00-10.15		
10:15-10.30		
10:30-10.45	Oral Session 1	Oral Session 5
10:45-11:00		
11:00-11:15	Coffee Break	Coffee Break
11:15-11.30		
11:30-11:45	Invited Speaker : David Poeppel	Invited Speaker: Marcela Peña
11:45-12:00		
12:00-12:15		
12:15-12:30		
12:30-12:45	Oral Session 2	Oral Session 6
12:45-13.00		
13:00-13:15	Lunch Break	Lunch Break
13:15-13:30		
13:30-13:45		
13:45-14:00		
14:00-14:15	Poster Session 1	Poster Session 2
14:15-14:30		
14:30-14:45		
14:45-15:00		
15:00-15:15	Invited Speaker: Sonja Kotz	Invited Speaker: Janet F. Werker
15:15-15.30		
15:30-15:45		
15:45-16:00		
16:00-16:15	Oral Session 3	Oral Session 7
16:15-16:30		
16:30-16:45	Coffee Break	Coffee Break
16:45-17:00		
17:00-17:15	Oral Session 4	Oral session 8
17:15-17:30		
17:30-17:45		Concluding Remarks
17:45-18:00		
18:00-18:15		
18:15-18:30		
18:30-18:45		
18:45-19:00		
19:00-19:15		
19:15-19.30		
19:30-		Social Dinner

FULL PROGRAM

Thursday, 9th May, 2024

Welcome & Opening Remarks: 09:00-09:30

Fabio Zwirner, Vice-Rector for Research, University of Padua
Judit Gervain, University of Padua, CNRS & Université Paris Cité

Invited Speaker: 09.30 - 10.30

09:30 — **Anne-Lise Giraud**, Institut de l'Audition, Paris, France
Leveraging the auditory oscillatory function to treat speech and language disorders

Session Chair: Jessica Gemignani

Oral Session 1: 10:30 - 11:00

10:30 — **Maria Ortiz Barajas**, IKER, CNRS, Bayonne, France
How neural oscillations support language acquisition

Session Chair: Jessica Gemignani

Coffee Break: 11:00 - 11.30

Invited Speaker: 11:30 - 12:30

11:30 — **David Poeppel**, Ernst Strüngmann Institute for Neuroscience, Frankfurt, Germany & New York University, NY, USA
What the mouth says about the ear: Understanding the auditory system through the speech-motor system

Session Chair: Ramón Guevara

Oral Session 2: 12:30 - 13:00

12:30 — **Benedetta Mariani**, University of Padua
Prenatal experience with language shapes the brain

Session Chair: Ramón Guevara

Lunch Break: 13.00 - 14.00

Poster Session 1: 14:00-15:00

PS1_01 – *Ageing impacts the temporal processing and prediction of sensory input in the acoustic environment*
Antonio Criscuolo, Maastricht University

PS1_02 – *Neural entrainment to statistical regularities across multiple features of speech at birth*
Ana Fló, Université Paris-Saclay

PS1_03 – *The reproducibility of infant fNIRS studies: a meta-analytic approach*
Jessica Gemignani, University of Padua

PS1_04 – *The neural foundations of sound symbolism in prelinguistic infants: An fNIRS study*
Annika Junker, University of Padua

PS1_05 – *Rhythmic discrimination of languages in infants with hearing loss - CI application*
Gaia Lucarini, University of Padua

PS1_06 – E*arly language experience modulates the cortical tracking of speech*
Jose Pérez-Navarro, Basque Center on Cognition

PS1_07 – *Linking vestibular, tactile, and somatosensory rhythm perception to language development in infancy*
Sofia Russo, University of Padua

PS1_08 – *Different speakers promote separate word memories at birth*
Emma Visibelli, University of Padua

FULL PROGRAM

Thursday, May 9th, 2024

Invited Speaker: 15:00 - 16:00

15:30 — **Sonja Kotz**, Maastricht University, Maastricht, The Netherlands
Comparative and translational reflections on cortico-subcortical circuities in time and rhythm processing

Session Chair: Gaia Lucarini

Oral Session 3: 16:00 - 16.30

16:00 — **Caterina Marino**, University of Padua
Culture-specific experience with music: Effects on rhythmic perception, motor engagement & synchronization,

Session Chair: Gaia Lucarini

Coffee Break: 16:30 - 17:00

Oral Session 4: 17:00 - 17:45

17:00 — **Ramón Guevara**, University of Padua
Communication with neural and acoustic signals: Efficient principles constraint rhythmic properties

17:15 — **Silvia Polver**, University of Padua
Unveiling the dynamics: Anticipatory processes and conversational turns in early language acquisition

17:30 — **Jessica Gemignani**, University of Padua
Investigating newborns' representations of language prosody with NIRS-EEG

Session Chair: Caterina Marino

FULL PROGRAM

Friday, May 10th, 2024

Invited Speaker: 09:30 - 10:30

09:30 — **Irene de la Cruz-Pavía**, University of Deusto, Bilbao, Spain
The role of spectral and temporal information in lexical processing and speech comprehension

Session Chair: Silvia Polver

Oral Session 5: 10:30 - 11.00

10:30 — **Martina Turconi**, University of Padua
The neural correlates of word order in pre-lexical infants: A frequency-tagging approach

10:45 — **Zeynep Aydın**, University of Padua
Word Frequency Is a Cue to Word Order for Adults: Validating an Online Method with Speakers of Italian and Turkish for More Inclusive Psycholinguistic Testing

Session Chair: Silvia Polver

Coffee Break: 11:00 - 11:30

Invited Speaker: 11:30 - 12:30

11:30 — **Marcela Peña**, Pontifica Universidad Catolica de Chile, Santiago de Chile, Chile
Brain rhythms and language acquisition

Session Chair: Martina Turconi

Oral Session 6: 12.30 -13.00

12:30 — **Gaia Lucarini**, University of Padua
Rhythmic discrimination of languages in infants with hearing loss

Session Chair: Martina Turconi

Lunch Break: 13:00 - 14:00

Poster Session 2: 14:00-15:00

PS2_01 – *Newborn verbal memory predicts early language skills at 5-7 months?: An ongoing longitudinal study*
Tamara Bastianello, University of Padua

PS2_02 – *The development of Italian vocabulary, morphology and syntax: An observational study*
Benedetta Colavolpe, University of Padua

PS2_03 – *Neural correlates of speech rhythm processing in Arabic, French monolingual and bilingual infants*
Marielle Hababou-Bernson, Université d'Aix Marseille

PS2_04 – *Exploring the Link Between Early Rhythm Ability and Grammar Development*
Enikő Ladányi, University of Potsdam

PS2_05 – *Pupillary entrainment to natural speech reveals the development of bottom-up and top-down processes in speech perception*
Alan Langus, University of Potsdam

PS2_06 – *How does my voice sound: the role of babbling in language acquisition*
Gaia Lucarini, University of Padua

PS2_07 – *Infant cognitive and language development at the age of 12 months - Impacts of baseline gamma power and its relationship to maternal sensitivity*
Lena Metternich, University of Salzburg

PS2_08 – *Rhythm in numbers: An explorative study on numeric processing in toddlers*
Annamaria Porru, University of Padua

FULL PROGRAM

Friday, May 10th, 2024

Invited Speaker: 15.00 - 16.00

15:00 — **Janet F. Werker**, University of British Columbia, Vancouver, Canada
Timescales in infant speech perception development: Critical periods and continuous learning

Session Chair: Zeynep Aydın

Oral Session 7: 16:00 - 16.30

16:00 — **Caroline Nallet**, University of Padua
Newborns' brain responses to speech, cries, and laughter,

Session Chair: Zeynep Aydın

Coffee Break: 16:30 -17:00

Oral Session 8: 17:00 - 17:30

17:00 — **Caterina Marino & Jessica Gemignani**, University of Padua
Do newborns detect prosodic violations in an unfamiliar language at birth?

Session Chair: Caroline Nallet

Concluding Remarks: 17:30 - 18:00

19:30 - Social Event at MUSME (Museo di Storia della Medicina; Via San Francesco, 94, Padova)

ABSTRACTS

Invited Talks

Thursday, May 9th, 2024

Anne-Lise Giraud (Institut de l'Audition, Paris, France)
Leveraging the auditory oscillatory function to treat speech and language disorders

The neural computations that make oral communication possible must operate on multiple time scales, both in parallel and recursively. Neuronal oscillations at different scales and their precise coordination are a key instrument of this necessary multiplexing, a phenomenon we are exploring in humans through surface and intracortical EEG. In this presentation, I will recall the key computational principles and show how we can exploit them to address fundamental questions about neurodevelopmental pathologies and propose therapeutic solutions.

David Poeppel (Ernst Strüngmann Institute for Neuroscience, Frankfurt, Germany; New York University, New York, USA)
What the mouth says about the ear: Understanding the auditory system through the speech-motor system

The interaction between perceptual and motor systems continues to be a foundational question for the psychological and brain sciences. One issue that makes the question so compelling is that different 'coordinate systems' have to be aligned - online, fast, and seamlessly. In the case of speech, there is an auditory coordinate system, a speech-motor coordinate system, and to make matters even more interesting, a 'linguistic coordinate system' as well (since the targets of production and perception are, informally speaking, words). What are the building blocks of these different domains such that their interaction occurs so automatically and rapidly? Several experiments will highlight how we can think about this computational challenge, with special emphasis on what studies of speech motor output teach us about audition. I argue that - although the flavors of the moment are deep neural networks or Bayesian approaches - an idea from the 1950s seems the most straightforward: analysis by synthesis.

Sonja Kotz (Maastricht University, Maastricht, The Netherlands)
Comparative and translational reflections on cortico-subcortical circuities in time and rhythm processing

In a continuously changing environment, we rely on prior knowledge to evaluate actual against expected sensations ('what' and 'when' predictions) and adapt to mismatches between these sensations. Some important questions in this context are (i) whether this human capacity is something we share with other species, (ii) how specific learning contexts might enhance this capacity (music and L2 exposure), and (iii) if pathological changes in the auditory system (e.g., deafferentation in tinnitus, aberrant sensory feedback in auditory verbal hallucinations) might lead to new default predictions. I will present animal and human studies as examples of well-adaptive and altered adaptive strategies in tone, voice, and speech processing. These data showcase the critical contribution of cortico-cerebello-thalamo-cortical circuitry in maintaining and adjusting what and when predictions.

Invited Talks

Friday, May 10th, 2024

Irene de la Cruz-Pavía (University of Deusto, Bilbao, Spain)
The role of spectral and temporal information in lexical processing and speech comprehension

Spectral and temporal information are the two primary acoustic components extracted from the speech signal by the auditory system. I will present a series of studies investigating the impact of these two components in specific aspects of speech processing. First, using vocoded speech we examine if and how degradation of these fundamental components impact two central tasks in lexical processing, namely infant word segmentation and adult word recognition. We will then explore whether rhythmic restoration affects the perception of accelerated speech. Ghitza and Greenberg (2009, Phonetica) demonstrated that speech accelerated beyond comprehension becomes intelligible again to English listeners if silences are periodically inserted to restore the theta rhythm, a rhythm that matches the syllabic rate in natural speech. We examine whether this rhythmic restoration effect holds for languages that differ from English in their linguistic rhythm, and whether and if yes, how the restoration of speech rhythms associated with other linguistic units impacts comprehension.

Marcela Peña (Pontifica Universidad Catolica de Chile, Santiago de Chile, Chile)
Brain rhythms and language acquisition

The rhythms of brain activity can couple to the rhythms of external stimuli, such as speech. Many questions remain unanswered about the role of such processing on early development. In this presentation we will discuss possible interpretations and consequences of this coupling specifically for language acquisition during the first year of age. We will show data from our own and other laboratories that indicate that infant's brains can couple to external rhythmic signals, however not only to speech but also to non-linguistic sound stimuli and visual sequences. In addition, we will discuss whether cognitive processes such as phoneme processing and word learning may rely on the properties of this coupling. Finally, we will discuss the prospects of the brain-speech coupling as an indicator of early development.

Janet F. Werker (University of British Columbia, Vancouver, Canada)
Timescales in infant speech perception development: Critical periods and continuous learning

Development involves a constant interplay between the current status of the mind/brain, the kinds of experience a child has, and their available learning and/or organizing capabilities. In this talk, I will focus on the role of timing in speech perception development, focusing specifically on the infancy period to consider both critical period delimited and continuous learning mechanisms that influence the establishment of native language representations. Using the working definition of a critical period as a mechanistically defined point in development when a system is most open to environmental input, I will present evidence from work on phonetic “categories” to compare to other instances of linguistic and non-linguistic development and learning.

TALKS

T1_01 – How neural oscillations support language acquisition

Maria Clemencia Ortiz Barajas (1), Ramón Guevara (2,3,4), Judit Gervain (1,3,4)

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(1) Integrative Neuroscience and Cognition Center, CNRS & Université Paris Cité, Paris, France
(2) Department of Physics and Astronomy, University of Padua, Padua, Italy
(3) Padova Neuroscience Center, University of Padua, Padua, Italy
(4) Department of Developmental and Social Psychology, University of Padua, Padua, Italy

Neural oscillations are now well established as a key mechanism of speech and language processing in adults (e.g. Giraud & Poeppel 2012; Meyer 2018). Despite the wealth of evidence in adults, the developmental origins of neural oscillations and their contribution to language development remain largely unexplored. In an EEG study with newborns and 6-month-old infants, we have explored whether neural oscillations support speech processing from birth and how they are modulated by pre- and postnatal language experience during the first months of life. We recorded infants' neural activity during speech stimulation, as well as during silence periods before and after stimulation. We presented infants with sentences in their native language, French, as well as in a rhythmically similar unfamiliar language, Spanish, and a rhythmically different unfamiliar language, English. At birth, infants are able to discriminate two rhythmically different languages (Mehler et al., 1988), but unable to discriminate two rhythmically similar ones (Nazzi et al., 1998; Ramus et al., 2000). It is only around 4 months of age that infants start to discriminate their native language from a rhythmically similar one (Bosch & Sebastián-Gallés, 1997; Molnar et al., 2013). We hypothesize that neural oscillations might reflect these different language discrimination abilities at birth and at 6 months. We analyzed the data in two different ways. First, we assessed whether infants' brains entrain to the speech envelope, and found that at birth, entrainment is present for all three languages both in phase and amplitude, while at 6 months, infants' brains track the speech envelope in all three languages for phase, but only in English for amplitude, suggesting that phase and amplitude tracking are different mechanisms, with different developmental trajectories. Phase tracking is a universal, experience independent, possibly basic auditory phenomenon, while amplitude tracking is shaped by language experience. Second, we investigated whether delta, theta and gamma oscillations are modulated during speech processing, and if so, whether they reflect the discrimination of the native language from unfamiliar ones. We found that newborns show increase activation in the slow, i.e. delta and theta, but not fast, i.e. gamma oscillations to the native language French and the rhythmically similar unfamiliar language Spanish, but not to English, constituting the basis of early rhythmic language discrimination. As this differential response is only observed in the slower oscillatory bands, which coincide with the low frequency information also present in the prenatally heard speech signal, but not in the faster gamma band, we hypothesize that prenatal experience already plays a role in fine-tuning the slower oscillations. Furthermore, we investigated whether a measure of language discrimination at birth could predict later language skills at 12 and 18 months. We found, that the ability to discriminate the native language, French, from the rhythmically different unfamiliar language, English, as reflected by theta activity at birth predicted language comprehension at 12 months, as well as language comprehension and production at 18 months. Taken together, these results suggest that neural oscillations support speech perception and language acquisition from birth, specifically by delineating linguistic units in the continuous speech signal, such as syllables (theta) and phrases (delta), that are useful for word learning and syntax acquisition.

T2_01 – Prenatal experience with language shapes the brain

Benedetta Mariani (1,2), Giorgio Nicoletti (1,2,3), Giacomo Barzon (1,2) Maria Clemencia Ortiz Barajas (4), Mohinish Shukla (2,5,6), Ramón Guevara (1,2,5), Samir Simon Suweis (1,2), Judit Gervain (2,4,5)

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(5) Department of Developmental and Social Psychology, University of Padua, Padua, Italy
(6) Faculty of Social and Behavioural Sciences, University of Amsterdam, Amsterdam, The Netherlands

Human infants acquire language with notable ease compared to adults, but the neural basis of their remarkable brain plasticity for language remains little understood. Applying a scaling analysis of neural oscillations to address this question, we show that newborns' electrophysiological activity exhibits increased long-range temporal correlations after stimulation with speech, particularly in the prenatally heard language, indicating the early emergence of brain specialization for the native language.

T3_01 – Culture-specific experience with music: Effects on rhythmic perception, motor engagement, and synchronization

Caterina Marino (1,2), Judit Gervain (1,2,3), Jessica Gemignani (1,2), Martina Turconi (1,2) , Jesus M. Encinas Riveros (1,4), Ramón Guevara (1,2,4)

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Prosodic and rhythmic information, common to both language and music, is already perceived in the womb. Their prenatal perception enables the early specialization of brain areas supporting both speech (e.g., Peña et al. 2003, Sato et al. 2011) and music processing (Perani et al., 2010; Perani, 2012). After birth, the infant starts to accumulate rich multisensory rhythmic experience as caregivers naturally synchronise auditory input and body movements (e.g., with cradling and hopping). Recent evidence indicates that this experience contributes to influencing how infants process rhythm later in life, and thus supporting the existence of the music-cultural perceptual narrowing (e.g., Hannon & Trehub, 2005), (i.e., listeners initially exhibit sensitivity to a broad range of perceptual structures, which narrow down through exposure to the specific characteristics of their musical culture, thus leading to reduced sensitivity to unfamiliar musical patterns). In line with this evidence, this project has two main general objectives.

It first explores the neurocognitive mechanisms underlying the perception of song at birth. To this end, newborns (0-5 days of age) were tested with fNIRS while being presented with three auditory conditions: (i) spoken sentences in Italian (*Speech*); (ii) Italian sung sentences (*Song*); and (iii) Hummed song melody (*Hummed melody*). Specifically, spoken sentences carry linguistic information; sung sentences add a melodic component to speech, while hummed melody only carries the musical component, without linguistic information. By comparing brain areas elicited by Speech and Song, i.e., sharing linguistic information, and by Song and Hummed melody, i.e., sharing melodic information, this work will bring important insights in the understanding of whether music and language rely on distinct or overlapping neural mechanisms, and the extent to which this specialization depends on biological mechanisms already operating in the womb.

The project further explored the onset of synchronization abilities and if culture-specific exposure to music influences movement-to-sound responses. More specifically, it tested whether (i) culture-specific perceptual narrowing influences how infants spontaneously move in response to music of their native meters as compared to unfamiliar meters; and (ii) whether these responses are modulated by daily exposure to a specific metric pattern, which is either native or non-native to the infants' culture.

To this purpose, infants between 5 to 12 months and their parents, who are mainly culturally exposed to Western music with simple meters, were presented with songs of both simple (4/4) and complex (7/4) meters, while accelerometers recorded their motor behavior as a response to these songs. After the first testing session, they participated in a month-long musical training at home with either a 4/4- or 7/4-meter song. They then returned to the lab for a second testing session, identical to the first one. Overall, these results will bring important insights into the general understanding of the mechanisms underlying sensorimotor synchronization abilities with music, their development during the first year of life, and the role that cultural music ultimately plays in this specialization.

References:

1. Pena, M., Maki, A., Kovačić, D., Dehaene-Lambertz, G., Koizumi, H., Bouquet, F., & Mehler, J. (2003). Sounds and silence: an optical topography study of language recognition at birth. Proceedings of the National Academy of Sciences, 100(20), 11702-11705.
2. Sato, H., Hirabayashi, Y., Tsubokura, H., Kanai, M., Ashida, T., Konishi, I., ... & Maki, A. (2012). Cerebral hemodynamics in newborn infants exposed to speech sounds: A whole-head optical topography study. *Human brain mapping,* 33(9), 2092-2103.
3. Perani, D., Saccuman, M. C., Scifo, P., Spada, D., Andreolli, G., Rovelli, R., ... & Koelsch, S. (2010). Functional specializations for music processing in the human newborn brain. Proceedings of the National Academy of Sciences, 107(10), 4758-4763.
4. Perani, D. (2012). Functional and structural connectivity for language and music processing at birth. Rendiconti Lincei, 23, 305-314
5. Hannon, E. E., & Trehub, S. E. (2005). Metrical categories in infancy and adulthood. Psychological Science, 16(1), 48–55. https://doi.org/10.1111/j.0956-7976.2005.00779.x

T4_01 – Communication with neural and acoustic signals: Efficient principles constraint rhythmic properties

Ramón Guevara (1,2,3)

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(1) Department of Physics and Astronomy, University of Padua, Padua, Italy
(2) Padova Neuroscience Center, University of Padua, Padua, Italy
(3) Department of Developmental and Social Psychology, University of Padua, Padua, Italy

Neural activity conveys information, and the same is true for acoustic signals such as animal vocalizations and human speech. We analyze neural and auditory signals in terms of their rhythmic properties and conclude that such signals are fine tuned in order to maximize information content. The tuning consists of the signals being neither too random, nor too regular. We conclude that many biological signals used for communication processes are constrained by coding principles, in such a way as to balance efficiency and redundancy in the transmission of information.

T4_02 – Unveiling the dynamics: anticipatory processes and conversational turns in early language acquisition

Silvia Polver (1)

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(1) Department of Developmental and Social Psychology, University of Padua, Padua, Italy

Brain functions rely heavily on identifying patterns to anticipate future events, which in turn influence our behaviors (Auksztulewicz et al., 2018; Morillon & Schroeder, 2015). This predictive ability is thought to be fundamental for brain functioning and is observed from basic neural circuits to higher cortical regions (Auksztulewicz et al., 2018). Early in auditory processing, the brain detects repetitions, guiding attention to specific intervals in the auditory stream (Auksztulewicz et al., 2018). Notably, the predictability of sound stimuli enhances such processing in auditory regions through activity-dependent changes, aided by inputs from higher- order brain areas (Auksztulewicz et al., 2018; Morillon & Schroeder, 2015). Speech perception involves the dynamic sampling of acoustic information across different time scales simultaneously (Morillon & Schroeder, 2015), with timing predictability likely playing a crucial role in language learning (Kujala et al., 2023). Despite infants having immature auditory systems, they display remarkable ability in speech detection (Cabrera & Gervain, 2020). However, the specific factors enhancing their encoding of natural speech remain unclear (Nencheva & Lew-Williams, 2022). Moreover, since natural auditory scenes are less strictly predictable, the extent to which the brain tolerates variability while still perceiving sounds' sources signals as predictable remains unresolved (Bendixen, 2014). To explore the hypothesis that infants' early sensitivity to speech stems from their ability to perceive predictable temporal patterns, we are conducting a study with 6-month and 12-month-old infants. We present them with naturalistic conversations between two speakers while recording their brain activity using the EEG. Additionally, we included an adult sample for developmental comparisons. We manipulated the duration of pauses between questions and answers to assess the brain's integration abilities. In one condition, the pause duration matched typical conversational intervals (200 ms), while another condition introduced a 500 ms overlap between the question and the answer to disrupt predictions. An ambiguous condition prolonged the pause to 850 ms. We anticipate that 6-month-old infants will demonstrate prediction abilities by responding similarly to short and long pauses but show disrupted responses in the overlapping condition. Conversely, 12-month-old infants may exhibit disrupted predictions even in the long pause condition, akin to adults, albeit with more uncertain responses. By investigating the interplay between temporal predictability and early language processing, our study aims to contribute with novel insights to the study of neural mechanisms at play during critical periods for language development in infancy. Indeed, temporal predictability, encompassing the rhythmic and timing cues inherent in speech, may serve as a scaffolding mechanism for language learning, facilitating the segmentation of speech into meaningful units and aiding in the acquisition of linguistic structures.

T4_03 – Investigating newborns' representations of language prosody with NIRS-EEG

Jessica Gemignani (1,2) and Judit Gervain (1,2,3)

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(3) Integrative Neuroscience and Cognition Center, Université Paris Cité & CNRS, Paris, France

Functional near-infrared spectroscopy (fNIRS) and electroencephalography (EEG) are two of the most popular neuroimaging methods in the developmental neurosciences. In this work, we use them to investigate neuro-functional mechanisms of processing of prosody at birth; in fact, evidence suggests that at birth infants have a specific sensitivity to the prosody of the input signal, for example it has been shown that they can recognize a change in pitch if they already heard it prenatally, but not if they didn't (Partanen et al., 2013); that they rely on acoustic cues (duration, pitch, intensity) to group and process prosodic contours, but only for cues they heard prenatally, thus the ones typical of the language(s) spoken by the mother during pregnancy (Abboub et al., 2016); it was also shown that they can detect a change in the order of words only if the words are presented independently in a sequence with no overarching prosodic contour, but not if they are embedded within a full, native prosodic contour (Benavides and Gervain, 2017). Interestingly, they don't seem to show a preference for speech over primate vocalizations (Vouloumanos and Werker, 2010). In this project, we aim at shedding more light on this issue, i.e. on the initial representations that newborns have for prosody, with concurrent NIRS and EEG. In particular, we are interested in learning how the neuro-functional patterns of brain activity differ between standard and time-reversed prosodic contours of the native language, and whether such discrimination is in place also when hearing non-human sounds.

In the talk, NIRS-EEG data will be presented that is being collected at the maternity ward of the hospital of Padua.

Newborns are tested while being presented with two auditory conditions: (i) spoken sentences in Italian ("Speech"); (ii) baboon vocalizations ("Vocalizations"), using a montage including 16 NIRS channels, distributed bilaterally on the temporal and temporo-parietal areas, and 6 EEG electrodes (F3-Fz-F4-C3-Cz-C4), similarly to the arrangement employed in Cabrera & Gervain (2020) .For each condition, 5 blocks are presented (mean duration of 65 s; inter-block interval 20-30s), each containing 25 repetitions of the same sentence or vocalization, 20 of them presented with either a standard prosodic contour ("Standard"), while 5 of them presented with a time-reversed prosodic contour ("Deviant").

Our first goal is to characterize neuro-functional patterns of brain activity in response to the standard and deviant presentation of either condition, Speech and Vocalization. Secondly, we aim at developing an innovative analysis framework that leverages features from EEG as well as both hemoglobin components of the NIRS signal and uses them in a multivariate pattern analysis (MVPA) fashion to discriminate brain patterns elicited by the different sounds, when presented with a standard as well as with a deviant prosodic contour.

Overall, the project aims at contributing to bringing insight into the initial neural representation of prosody that babies have of their native language at birth, and more broadly on the prenatal prosodic bootstrapping hypothesis, while introducing methodological advancements for the analysis of concurrent infant NIRS-EEG data.

T5_01 – The neural correlates of word order in pre-lexical infants: A frequency-tagging approach

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Infants learn their native language quickly and effortlessly and follow the same developmental path regardless of culture. Although infants have an immature peripheral and central auditory system, they show exquisite speech perception abilities from birth. Indeed, the fetus' auditory system is functional by about 150 days after gestation. So, even before birth, they are exposed to the acoustic external environment, which is, however, muffled by the mother's body. According to the "bootstrapping hypothesis" (Morgan and Demuth 1996) infants are able to acquire abstract and structural properties of their language by detecting and using perceptually available surface cues present in the speech input. One of those properties seems to be word order: a pivotal basic element of language acquisition. Indeed, a series of behavioural studies have repeatedly demonstrated that young learners exhibit some knowledge of basic word order from their earliest multiword utterances (Brown 1973; Guasti 2002; Gervain *et al.* 2008; Bernard and Gervain 2012; de la Cruz et al. 2021). To understand how the surface cues of speech inputs are perceived, neuropsychological and brain imaging works have been conducted in recent years. Their results suggest that language acquisition involves neural commitment (Ahissar *et al.* 2001; Luo and Poeppel 2007; Buiatti *et al.* 2009; Ding *et al.* 2015; Chen *et al.* 2020): neural phase-locking to speech rhythm seems to track speech comprehension in a reliable way.
Using a frequency-tagging approach we aimed to explore the neural mechanisms underlying the perception of word order thanks to the surface cue of the relative position of functors and content words in pre-lexical infants. EEG was recorded in infants of 6 to 8 months of age listening to a monotonous acoustic stream composed of two alternate basic units presented periodically at a specific temporal frequency that mimic the relative frequency of functors and content words in natural languages (*aXbY*, see Gervain *et al.* 2008). We hypothesize that the presentation of these structured units, composed of regularly concatenated syllables, would give rise to a peak of power at the frequencies of syllable occurrence. Consequently, if after some exposure, syllables are bound to adjacent syllables and ultimately grouped in quadrisyllabic words, we expected to record a peak of power at the frequency of two or four syllables.

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T5_02 – Word Frequency Is a Cue to Word Order for Adults: Validating an Online Method with Speakers of Italian and Turkish for More Inclusive Psycholinguistic Testing

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Learning the relative order of function and content words is a fundamental aspect of language acquisition, and previous studies show that infants develop prelexical representations of this word order. As functors are more frequent than content words, they serve as anchors with respect to which the positions of other words can be readily encoded. This frequency-based bootstrapping strategy has been shown to be used both by infants and adults. However, only a handful of languages, mainly spoken in Western countries, have been tested so far. One hurdle to more inclusive testing is the lack of laboratory facilities in some geographical areas of the world. Online testing is a useful tool to overcome this difficulty. The current study, therefore, implements and validates an online version of an artificial grammar learning paradigm originally developed for laboratory use to test the frequency-based anchoring effect on adults in typologically different languages, Italian and Turkish. Italian has functor-initial word order, while Turkish is functor-final. First, we test whether previous lab-based results by Gervain et al. (2013) with Italian adults are replicable using online testing. Second, we leverage online testing to assess a hitherto understudied language, Turkish, which has opposite word order properties compared to Italian. Our findings indicate that online testing can efficiently reproduce laboratory-based results. Indeed, Italian adults in our online study show similar word order preferences to those tested in the laboratory earlier, while Turkish participants have opposite word order preferences, as predicted. These findings pave the way for testing the frequency-based bootstrapping hypothesis on a more inclusive and diverse sample of languages than previously available.

T6_01 – Rhythmic discrimination of languages in infants with hearing loss

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At birth, newborns show sensitivity to the rhythm of their native language, i.e. the language they heard prenatally, being able to discriminate it from a rhythmically different language (Peña et al., 2003, May et al., 2018). A current hypothesis (Gervain, 2018; Nallet & Gervain, 2021) suggests that prosody provides the basis of early speech perception and helps infants discover other linguistic units after birth, when the full-spectrum speech signal is available. Prenatal experience is thus hypothesized to be foundational for language learning. But what happens when the prenatal experience is disrupted? To investigate this, we tested the ability of 0-12-month-old infants with different degrees of hearing loss (HL) to discriminate their native language (Italian) from a rhythmically different unfamiliar language (English).

54 HL infants were tested in a simple block design paradigm. Sentences in both languages were presented forward and backward. Backward speech, with perturbed temporal features, is a standardly used non-linguistic control (Peña et al., 2003). A control group of 69 age-matched normal hearing (NH) infants was also tested. Infants' brain responses were recorded using functional near-infrared spectroscopy (fNIRS) in the frontal, temporal, and parietal regions, bilaterally. After pre-processing and data rejection, 31 HL and 45 NH subjects were kept for subsequent statistical analysis.

In the talk, we will present how two factors influence brain responses: the familiarity with the language (native Italian vs unfamiliar English) and the direction of presentation (forward vs backward). In the HL group, the impact of the hearing thresholds will be analyzed as a continuous variable.

T7_01 – Newborns' brain responses to speech, cries, and laughter

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Newborns already show a preference for listening to speech over various non-human auditory stimuli (Colombo & Bundi, 1981; Glenn, Cunningham and Joyce, 1981; Vouloumanos & Werker, 2004; 2007; Vouloumanos et al., 2010). However, previous results suggest that infants do not show preference between listening to speech and to monkey vocalizations before the age of 3 months (Vouloumanos et al., 2010). Does this mean that, at birth, the "speech" category is broad and includes all primate vocalizations, and that some months of experience with language is required to narrow down this category to speech only? To better understand what constitutes the category "speech" at birth, we tested newborns' brain responses to speech and various other human auditory stimuli that are speech-like in various ways. Specifically, we chose two stimuli, cries and laughter, that are communicative, produced by the human vocal tract and that even young infants are able to produce.

In Experiment 1, we measured the brain responses of 25 French newborns to speech (French sentences) and newborns cries (non-pain-related cries recorded from French newborns) using functional near-infrared spectroscopy (fnirs). In Experiment 2, a new group of 15 French newborns was recruited and exposed to speech (same stimuli as in Exp.1), infant laughter and adult laughter. If the category broadly includes all primate vocalizations, then we hypothesized that listening to cries and laughter will elicit similar neural responses as listening to speech in the newborn brain.

Our results highlight a greater and bilateral activation in response to the cries and the laughter conditions compared to speech. On the other hand, the brain responses to speech were left-lateralized (Exp.1) and modulated by the context (Exp.2). Indeed, while the exact same sentences were presented in the two experiments, speech triggered flat/inverted responses in experiment 2. We suggest that this pattern of results might be explained by the presence of a second adult vocalizations condition with a strong emotional content (adult laughter), as opposed to the neutral valence of the speech condition.

Taken together, our results thus suggest that speech in the native language already triggers specialized (left-lateralized) brain responses at birth, different from non-linguistic, but communicative sounds such as cries and laughter.

Newborns' representation of speech is thus already specific enough not to include these categories of sounds, despite the fact that they are acoustically similar, communicative and can be produced by the infants themselves. The greater and broader brain activation in response to the two emotional stimuli (cries and laughter) compared to speech suggest that emotional vocalizations play an important role in the infants' early perception of human vocal productions.

T8_01 – Do newborns detect prosodic violations in an unfamiliar language at birth?

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Experience with language starts prenatally, as fetuses can already hear during the last trimester of gestation and the intrauterine environment allows speech prosody to get through. Prosody is a universal organizing principle of spoken language, and its prenatal perception seems to play a crucial role in establishing the foundations of later language development. Recently, Martinez-Alvarez and colleagues (2023) demonstrated that, at birth, infants readily detect utterance-level prosodic violations in the language they heard prenatally, French. In remains unknown, however, whether this discrimination ability requires prenatal experience with a given language or whether newborns have a universal sensitivity to the shapes of prosodic contours. To answer this question, we tested infants exposed prenatally to Italian with the same French stimuli as in Martinez-Alvarez et al.'s (2023) study. Like in the original study, we used near-infrared spectroscopy (fNIRS) to measure newborns' brain responses in the bilateral frontal, temporal, and parietal areas. We found that Italian-exposed newborns discriminate between standard and deviant prosodic contours in French, activating right hemispheric areas specialized for the processing of prosody in adults. Importantly, however, the time course and the localization of the effect were slightly different from those found in French newborns. This suggests that a universal sensitivity to prosodic contours may be modulated by prenatal experience at birth.

POSTER PRESENTATIONS

PS1_01 – Ageing impacts the temporal processing and prediction of sensory input in the acoustic environment

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A cascade of biochemical, neuro-functional and -anatomical changes take place during ageing. Deterioration in the peripheral and central auditory systems are particularly common in older adults and might lead to hearing difficulties and speech comprehension deficits. While compensatory mechanisms exist to partially overcome these limitations and prevent isolation, electrophysiological evidence demonstrates altered neural responses to speech input along the entire auditory pathway, from the brainstem, to auditory cortex and spreading across the speech network. Furthermore, ageing seems to impact the temporal dimension of speech processing: neural activity fails to precisely encode and lock to the onset of speech sounds, leading to variable and delayed responses, and ultimately impacts speech comprehension even in normally hearing individuals. Thus, several questions emerge: is the deficit in temporal processing impacting speech processing? Can ageing individuals encode temporal regularity in acoustic sequences, and can they employ it to efficiently generate predictions about future events?

Here, we addressed these questions by recording EEG in healthy older and young individuals while they listened to simple isochronous auditory tone sequences. A comprehensive analysis pipeline tested the amplitude, latency, and variability of event-related responses (ERP) to each tone onset along the auditory sequences. Next, Fourier and Inter-Trial Phase Coherence (ITPC) analyses tested if and how participants encode the temporal regularity in the acoustic environment. Older participants showed larger, more variable, and faster N100 responses as compared to younger participants. Similarly, they showed a larger peak in the Fourier spectrum at the stimulation frequency (Sf) and a positive correlation between this amplitude peak and the variability in the ERP amplitudes and latencies. However, the ITPC at the Sf was reduced in the older participants, indicating less precise encoding of the temporal regularity of sound events.

Overall, our observations demonstrate altered temporal processing and reduced capacity to use predictions to time-lock and adaptively suppress neural responses to predictable and repeated tones within auditory sequences. We propose that deterioration in timing and predictive processes may underlie speech processing deficits observed in ageing. As timing and predictive functions play a fundamental role in other cognitive domains (e.g., attention, perception, and action), the current results motivate future research on the impact of timing deficits on cognition in ageing and across the lifespan.

PS1_02 – Neural entrainment to statistical regularities across multiple features of speech at birth

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Statistical learning (SL) is a crucial mechanism supporting language acquisition in human infants. At the same time, SL is ubiquitous across species and domains (Santolin et al., 2018; Saffran et al., 1999; Fiser et al., 2002; Kirkham et al., 2002), prompting the importance of understanding how SL articulates with other processes and how it operates across different dimensions of the input to understand its role in language acquisition. In a previous study using electroencephalography and neural entrainment, we showed that after a couple of minutes of familiarization with an artificial language built by the random concatenation of trisyllabic words, the neonate's brain oscillated in phase not only at the syllabic rate but also at the word rate, revealing that sleeping neonates tracked the regularities. Moreover, event-related potentials (ERP) to sequences in isolation during a post-learning phase suggest that neonates extracted the words from the stream (Flo et al., 2022). These results revealed that infants statistically analyze the linguistic input from birth.
The current study investigates whether SL is limited at birth to phonetic regularities or operates as well on an equally complex and essential but non-linguistic dimension of speech, namely, voices. We exposed neonates to artificial languages constructed by concatenating syllables simultaneously varying in their phonetic content and the voice uttering them (i.e., pitch and timbre). We used six consonant-vowel syllables produced by six voices (36 possible tokens). The experiments included (1) a Random stream with phonetic and voice content varying randomly, (2) a Structured stream built by concatenating three bi-syllabic items defined by the transition probabilities between the phonemes (voices), while the voices (phonemes) varied randomly, (3) isolated duplets adhering or not to the structure. In Experiment 1 (N=33), the Structured stream had regularities based on the phonetic content. In Experiment 2 (N=32), the Structured stream had regularities on the voices. It is worth noticing that the duplets presented in the two experiments were identical; thus, any effect must be due to the familiarization. During the experiment, we recorded high-density EEG (128 electrodes). We measured brain synchrony at the syllabic and regularity rate while presenting the Random and Structured streams and ERPs to the duplets in isolation in the post-learning phase.
We observed neural entrainment at the frequency of the regularity (2 Hz) with comparable activation patterns for both familiarization streams (inter-trial-coherence bigger than at adjacent frequency bins, $p < 0.05$, one-sided t-test, FDR corrected). Significant neural entrainment at 2 Hz emerged in both experiments at around 2 min after the onset of the familiarization stream.

After familiarization, the ERPs to correct (words) and incorrect (part-words) duplets differ in both experiments (cluster-based permutation analysis, $p<0.05$). Additionally, we found an ERP component consistent with an N400 only for Experiment 1 duplets (cluster-based permutation analysis, $p<0.05$). The entrainment at 2 Hz and the difference in ERPs between words and part-words show that neonates are equally sensitive to regularities based on phonetic or voice dimensions of speech, even in the presence of a non-informative feature, revealing that neonates have a powerful tool to create associations between recurrent events on probably all dimensions in which stimuli are factorized in the auditory cortex. The lack of advantage for the linguistic dimension points to the universality of statistical learning mechanisms. Based on the ERP component found only after familiarization with an artificial language with structure over the phonetic content, we hypothesize that phonetic regularities might provide lexical entries. Thus, the language networks might get differently involved depending on the dimension presenting the regularity.

PS1_03 – The reproducibility of infant fNIRS studies: A meta-analytic approach

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The use of fNIRS has grown remarkably over the last three decades, especially in developmental cognitive neuroscience. As the volume of fNIRS research has grown, so has the concern for the reproducibility of its findings. Meta-analytic approaches are a powerful tool to assess the robustness of empirical findings and support theory building, but have been so far little applied to fNIRS data. In this work we describe a framework to aggregate across experimental findings to reveal the robustness of the effect of rule learning in infants (de la Cruz-Pavía & Gervain, 2021; Marcus et al., 1999) in the left temporal lobe and to investigate its sources of variability across studies, e.g. different laboratories, countries, NIRS machines etc., and across individuals.

To this end, we aggregated 19 fNIRS studies conducted in different laboratories (k=4), testing brain responses of infants to auditory stimuli presented as trisyllabic sequences, representing repetition- (e.g. ABB: *ba-ge-ge*) and diversity-based (e.g. ABC: *mu-ba-ge*) linguistic rules. The final sample included 355 newborns, 104 6-month-olds, 13 7-month-olds and 15 9-month-olds. After pre-processing all NIRS raw data with the routine described in Gemignani & Gervain (2021), effect sizes were computed for three effects of interest: brain responses to repetition-based rules vs. baseline (R vs 0), diversity-based rules vs. baseline (N vs 0) and repetition- vs. diversity-based rules (R vs N). The analysis was narrowed to responses measured from the left temporal lobe, given the well documented relevance of this area for speech processing and for the effect under investigation (Gervain, 2008; Gervain et al., 2012). The average magnitude of brain responses was compared to their between-subject variation to obtain meta-analytic effect sizes, and to their inter-trial variation to obtain infant-level effect sizes. In both cases, we explored how effects are moderated by the factors Laboratory, Age of the Participants and Rule Type, using meta-analytic and linear mixed effects models (Viechtbauer, 2010).

The overall magnitude of the effect was 0.27 (95% CI=[0.144, 0.398], z=4.20, p<0.001) for the R vs 0 comparison, 0.18 (95% CI=[0.03, 0.33], z=2.35, p<0.05) for the N vs 0 comparison and 0.08 (95% CI=[-0.06, 0.22], z=1.14, ns) for the R vs N comparison. No analysis revealed a significant effect of Laboratory. Age was a significant moderator: responses to repetitions were larger in 6-month-olds than in newborns, then decreased for 7- and 9-month-olds.

In conclusion, in this work (Gemignani et al., 2023) our meta-analysis quantified effect sizes of infants' responses to repetition- and diversity-based rules in the left temporal area. The analysis revealed no significant variability attributable to Laboratory, indicating that effects were overall robust and reproducible across different Labs (in different countries and with different NIRS devices). Further, we found differential developmental trajectories for the two types of rules, thus demonstrating the value of employing meta-analytic techniques to identify theoretically relevant moderators and thus contribute to stronger theory-building on phenomena of interest.

PS1_04 – The Neural Foundations of Sound Symbolism in Prelinguistic Infants: An fNIRS Study

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Sound symbolism can be described as the non-arbitrary relationship between speech sounds and meaning. Associations between nonwords such as "bubu" and "kiki" with round and angular shapes, respectively, have been found systematically in adults and toddlers, and even prelinguistic infants of 4 months. This phenomenon could facilitate the emergence of infants' first vocabulary and provide insight into how language evolved. While the existence of sound symbolism is almost unanimously accepted, it is still unclear how sound symbolism is processed in the infant's brain. To date, only one study has attempted to identify the neural correlates of sound symbolism using near-infrared spectroscopy (NIRS) in 11-month-old infants. The study reported significant differences between symbolically matched and unmatched stimuli in the right posterior superior temporal sulcus, which is thought to process sound symbolism in adults. However, because adults and older infants have had significant experience with the language mappings that exist in their environment, it is unclear whether these findings are the result of language exposure or the product of an initial proclivity.

The current study investigates the neural mechanisms of sound symbolism in one-to-three-month-old prelinguistic infants with significantly less exposure to language compared to the previous study. 22 one-to-three-month-old infants will be tested in a silent room with an infant-controlled cross-modal matching paradigm (Cohen's d = 0.8, power = 0.95). In each trial, participants will be presented with one image paired with one sound. The visual stimuli will consist of 20 rounded and 20 spiky, which will be presented at the center of the screen and can be paired with an auditory stimulus of either the nonword "bubu", congruent with the round shape, or the nonword "kiki", congruent with the spiky shape. There will be 20 blocks, 10 per condition (i.e. congruent and incongruent), each block lasting around 12 s. The order of the blocks will be pseudo-randomized so that there cannot be more than two subsequent blocks of the same condition. Whether the first trial is congruent or incongruent will be counterbalanced across infants. Each block will contain 4 different visual stimuli (either round or spiky), each of them lasting 3 s. Auditory stimuli have been recorded with a female Italian voice. They will appear 200 ms after visual stimulus onset and last for 400 ms. Blocks will be separated by pauses of 25-30 seconds, in which infants will be presented with an attention-getter. A video camera will be mounted above the monitor to record the infants and allow for both online and offline coding of their behavior. Data collection will start soon.

A NIRSport machine with a 36-channel configuration will be used to measure brain activity over bilateral temporal regions (including the primary auditory area), as well as parietal and visual brain areas, including the temporal-parietal-occipital (TPO) junction, which plays a role in multisensory integration. We hypothesize a larger increase in Oxy-hemoglobin in the superior temporal area of the right hemisphere compared to the left hemisphere for the congruent condition, but not the incongruent condition. Significant differences in brain activation between the two conditions will demonstrate that very young, prelinguistic infants have the ability to spontaneously map cross-modal sound-symbol pairs and provide evidence for the hypothesis that sound symbolism has its origins in early infancy.

PS1_05 – Rhythmic discrimination of languages in infants with hearing loss – CI application

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Despite the enormous potential of cochlear implants (CI) to improve hearing, social integration and life quality for implanted individuals, outcomes vary considerably, and some CI users never develop functional oral language skills, even when implanted early in life, during the critical period for language development. By bringing together interdisciplinary expertise from otorhinolaryngology, speech therapy, developmental psychology and neuroscience, our project identifies how individual variation in neuroplasticity early in development impacts the restoration of auditory and speech perception after implantation. We are testing infants before cochlear implantation with NIRS and follow them up afterwards to assess the predictive relationship between individual-level neural variables and later language and cognitive/behavioral outcomes.

PS1_06 – Early language experience modulates the cortical tracking of speech

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The cortical tracking of speech is the temporal alignment of continuous brain activity to the information present in the speech signal. Cumulative evidence during the past decade has shown its relevance for supporting speech comprehension, as well as its atypical maturation in developmental language disorders (e.g., dyslexia). This neurocognitive mechanism is also in place and developing during infancy and childhood. However, no studies to date have addressed the question of whether accumulated language experience shapes the cortical tracking of acoustic and linguistic information from the speech signal. This was our main goal: to test whether bilingual children with considerably unbalanced experiences within each of their languages show different strategies for the cortical tracking of speech for each language respectively. We collected EEG data from 35 Basque-Spanish bilingual children (6 y.o.) with a markedly unbalanced bilingual profile (>70 % exposure to Basque, L1 hereafter; <30 % to Spanish, L2). Children listened to continuous speech in the form of two 14-minute stories (one in each language), which allowed us to assess their cortical tracking of speech at the acoustic temporal (speech envelope), lexical (lexical frequency), and semantic (sentence-level semantic distance) levels respectively. As indexes of the cortical tracking of speech, we computed speech-brain coherence and multivariate temporal response functions (mTRF). While speech-brain coherence measures the phase alignment between two signals (speech envelope and EEG activity), mTRF models the linear mapping between speech features (speech envelope, lexical frequency and semantic distance in our case) and changes in the continuous EEG signal. Through cluster-based permutation tests, we found significant speech-brain coherence in L1 and L2 within the delta frequency band (0.5 - 1.5 Hz), which aligns with prosodic phrasing in both languages. Despite robust speech-brain coherence in both languages, there were no significant between-languages differences regardless of the markedly bigger exposure to L1 than to L2. Nonetheless, the cortical mapping (mTRF) of the speech envelope yielded a significant between-languages difference. Namely, the cortical encoding of the speech envelope in L2 was more robust than in L1. There was also a strong significant between-languages difference in the temporal response to semantic distance. In this case, children showed a more sensitive early (70-230 ms) cortical tracking of semantic information in L1 than L2.

We also found that, only in L1 (Basque), the cortical tracking of speech at the envelope level predicted phonological abilities; and the cortical tracking of lexico-semantic information predicted vocabulary knowledge. Our findings initially point at a tradeoff from relying on acoustic temporal (envelope) information (L1 < L2) and on more abstract linguistic (semantic) information (L1 > L2) that is dependent on the accumulated experience within a language during the early years of life. The specific relationships between the cortical tracking of speech and different language abilities highlight the behavioral relevance of the maturation of this neurocognitive mechanism for speech comprehension. The present study can inform developmental cognitive neuroscience and neurobiology of bilingualism by bringing to context the relevance of accumulated linguistic experience for the maturation of brain processing of language during childhood.

PS1_07 – Linking vestibular, tactile, and somatosensory rhythm perception to language development in infancy

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First experiences with rhythm occur in the womb, with different rhythmic sources being available to the human fetus. Among sensory modalities, vestibular, tactile, and somatosensory perception (VTS; Provasi et al., 2014) plays a crucial role in early processing (Phillips-Silver and Trainor, 2005; Tichko et al., 2021). However, a limited number of studies so far have focused on VTS rhythms in language development. In this work, VTS rhythmic abilities and their role in language development are explored through two Experiments with 45 infants (21 females; M age = 661.6 days, SD = 192.6) with middle/high socioeconomic status (Russo et al., 2024). Specifically, VTS rhythmic abilities are firstly assessed through a vibrotactile tool for music perception (Experiment 1). In Experiment 2, the link with linguistic abilities is evaluated by testing phonological and prosodic processing in the same cohort of infants. Discrimination abilities for rhythmic and linguistic stimuli across experiments are inferred from changes in pupil diameter to contingent visual stimuli over time, through a Tobii X-60 eye-tracker (Hepach and Westermann, 2016; Mathôt, 2018; Calignano et al., 2023). The predictive effect of VTS rhythmic abilities on linguistic processing and the developmental changes occurring across ages were explored by means of generalized, additive and linear, mixed-effect models (Baayen et al., 2008; van Rij et al., 2019). Results show that: i) infants are able to discriminate between different rhythms based on their underlying meters perceived via VTS sensory modalities; ii) increased rhythm discrimination abilities are found for infants familiarized with double meters, in line with previous findings on musical enculturation processes in auditory development (Trainor & Hannon, 2013); iii) the way in which infants react to unpredicted changes occurring in the underlying meter of musical rhythms is related to the way in which they respond to unpredicted changes in the phonological and prosodic features of linguistic stimuli along development. This suggests that an overlapping set of basic rhythmic abilities might serve the processing of a vast range of signals across domains (i.e., music to language) but also across sensory modalities (i.e., touch to hearing). This result is particularly informative within the growing literature on the link between basic rhythmic skills in language acquisition (e.g., Fiveash et al., 2021; Goswami, 2011) and cross-sensory perception (e.g.,Karam, Nespoli, et al., 2009; Karam, Russo, & Fels, 2009). Specifically, current frameworks and theories on rhythm in language development called for a detailed investigation into the link between cross-domain and

cross-sensory abilities underlying rhythm processing in musical and linguistic domains. Accordingly, the present Study brings significant insights into the extent to which rhythm processing suggests a general cognitive ability serving the processing of different temporal signals across modalities, with considerable impacts for typical and atypical development.

PS1_08 – Different speakers promote separate word memories at birth

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Introduction: Language development requires the storage of linguistic content. While several studies show that young infants already have brain areas specialized for speech processing (Dehaene-Lambertz et al., 2002; Peña et al., 2003; Perani et al., 2011), little is known about the mechanism underlying verbal memory in infants. Understanding which factors determine forgetting or consolidation of verbal memories is crucial for understanding the principles governing language acquisition early in life.
Benavides-Varela et al. (2011, 2017) used functional near-infrared spectroscopy (fNIRS) to investigate verbal memory formation at birth. Newborns habituated to a 2-syllables pseudoword recognized it after 2 minutes if no interference or music were present immediately after encoding, i.e., in the retention interval between the encoding and the recognition test. Interestingly, recognition did not persist when neonates heard another word with the same CVCV structure produced by the same speaker during the 2-minute retention period (Benavides-Varela et al., 2011).
At a first sight, this suggest that verbal short-term memory in neonates is limited to a single instance. However, in Benavides-Varela et al. (2011) study a single identical word was repeated many times, whereas natural language varies in its phonological content, prosody, and speakers and previous evidence suggests that acoustic variability promotes word learning (Benavides-Varela et al., 2017; Rost & McMurray, 2009, 2010; Estes & Lew-Williams, 2015). Therefore, we hypothesized that interference at birth could be overcome if the word presented immediately after learning acoustically differs from the initially encoded word. In particular, the current study investigates newborns' ability to recognize the sound of a word after an interfering word is uttered by a different speaker.
Methods: 32 newborns (age range: 2-5 days) were tested in a 27-minute habituation-interference-test protocol (Benavides et al., 2011, 2012, 2017). During habituation, one speaker uttered one word and during the retention, another speaker pronounced another word. The two speakers were a female and a male voice, thus drastically differing in acoustic features. Pseudowords (CVCV structure) were presented in a block design with each phase (habituation, interference, test) lasting 3 minutes (5 blocks of 6 words each, ISI 0.5-1.5 s, inter-block interval 25-35 s). These words were controlled to have the same duration and intensity. A within-subject design was implemented by having two sessions separated by 9 minutes of silence: one condition in which neonates heard the same word during habituation and test and another with a novel word presented during the test phase.

The order of the conditions and the words used in the different phases were counterbalanced across participants. During the test phase, brain hemodynamic responses to the familiarized word (Same-word condition) and a completely novel word sound (Novel-word condition) were assessed by recording neural cortical activity over frontal, temporal, and parietal regions using a 42-channel fNIRS system (NIRx NIRSPort, wavelength = 760 and 850 nm) with 16 sources and 15 detectors.

Results: A linear mixed-effects model (act ~ -1 +block + block:cond + (1 | sbj)) showed higher activation for the novel word compared to the familiar word in the second block (β= 10.04 p=2x10-6). If the regions of interest were included in the model (act ~ -1 + block:roi + (block:roi:cond) + (1 | sbj)) the effect was significant in the second block over inferior frontal gyrus left (β=10.19, p=0.049) and right (β=10.65, p=0.037), left superior temporal gyrus (β=16.93, p=0.001), and marginally significant over left parietal lobe (β=8.50, p=0.09) and right superior temporal gyrus (β=8.92, p=0.08), suggesting newborns recognized the familiarization word.

Conclusions: In the current study, we investigated whether separated memory traces of linguistic stimuli can be generated when two acoustically different words are presented close in time. Our findings reveal that acoustic feature variations between the habituation and the interference word facilitate memory consolidation at birth, possibly by promoting memory trace separation.

PS2_01 – Newborn verbal memory predicts early language skills at 5-7 months?: An ongoing longitudinal study

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Introduction: Recent longitudinal studies have provided insights into how brain structure relates to early language development. For instance, Corrigan and colleagues (2022) demonstrated that brain myelination at 7 months predicts language development at 24 and 30 months of age. Additionally, Huber et al. (2023) revealed that language experience at 6, 10, 14, 18, and 24 months predicts white matter myelination at 2 years of age, indicating the bidirectional relationship between linguistic competence, exposure, and brain structure. However, up to date, no study longitudinally investigated how neural mechanisms for language processing at birth relate to future outcomes.
This ongoing study aims to filling this gap by examining brain response associated with verbal memory, i.e., ability to recognize the sound of a novel word versus a familiar one at birth (Time-1), child's language abilities at 5-7 months (Time-2) and the extent to which parental input at Time-2 counts in shaping individual language differences.
Methods: At Time-1, 32 healthy newborns (age range: 2-5 days) were tested with a memory-test protocol (Benavides et al., 2011, 2012, 2017) while neural cortical activity over frontal, temporal, and parietal regions was recorded using fNIRS. Pseudowords (CVCV structure) were presented in a block fashion during habituation and test. In addition, a within-subject design was implemented by having two sessions separated by 9 minutes of silence: one condition in which neonates heard the same word during habituation and test and another with a novel word presented during the test phase.
At Time-2 (ongoing), the same children (age range: 5-7 months, N=7) were assessed for receptive and expressive vocabulary through standardized assessments (Bayley test, Ferri et al., 2015; Italian version of the MB-CDI, Caselli et al., 2015) and 12 hours of naturalistic language and environment recordings (LENA technology, LENA Colorado). From the latter recordings, the number of vocalizations produced by children (CVC), the number of words produced by parents (AWC), the number of conversational turns (CTC), and their percentile scores were retrieved. The percentage of meaningful speech (i.e., speech segments produced the child can hear near and clear) was then considered. Based on previous evidence, we expect that the number of vocalizations produced by children will be positively related to the percentage of adult meaningful speech they hear during a typical day (Ferjan Ramírez et al., 2019) and that the more frequent the conversational turns in which they are involved in, the more talkative they will be (Ferjan Ramírez et al., 2020).

Preliminary results: Time-1. A linear mixed-effects model on the memory-test showed higher activation for the novel word compared to the familiar word in the second block (β= 10.04 p=2x10-6) over left and right inferior frontal gyrus and left superior temporal gyrus, suggesting that newborns recognized the familiarization word from the novel one.
Ongoing study (Time-2). The preliminary results suggest that neural activation at birth could be related to later expressive (Bayley scale scores, β= -0.31, p= .08; and CVC, β= -16.29, p= .009) and receptive (Bayley scores, β= -0.97, p= .04) vocabulary skills at 5-7 months of age. Moreover, infant's receptive and expressive skills appear to relate to the quantity (AWC, β= 1.30, p= .008) and the quality (CTC, β= 0.72, p< .001; and meaningful speech, β= 2.53, p= .002) of parental input received during a typical day in the same week of the testing.
Conclusions: Our preliminary results provide some suggestive evidence that both language experience at home and brain activity at birth have an influence early language skills. A more exhaustive array of analyses may shed light on the individual contribution of each of these factors in predicting children's cognitive development. Despite the results being very preliminary at this stage, the study represents a relevant and original contribution to developmental psychology by collecting data longitudinally from birth, potentially highlighting individual differences, and measuring children's linguistic output and input using a natural and direct approach, which guarantees ecological validity of the study.

PS1_08 – The development of Italian vocabulary, morphology, and syntax: an observational study

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The acquisition of Italian, a Verb-Object, morphologically fusional language, remains understudied. To fill this gap, we longitudinally document and analyze the language development of a cohort of 7 typically-developing Italian-learning toddlers. Our aim is to track vocabulary growth, morphological development, the emergence of syntax and the interactions between them, as well as to contribute a new Italian corpus to the CHILDES database.

Toddlers were first assessed between 18 and 29 months and followed longitudinally over 8 months. Spontaneous productions were recorded every two weeks and transcribed into CHAT format [1]. To assess syntactic development, we calculated the MLU in words and in morphemes. The frequency of major lexical categories, non-prototypical word order and the emergence of subordinate clauses were also marked. Additionally, the Italian version of the MacArthur-Bates CDI [2] and an adapted version of the Wug Test [3] were administered.

All children were within the norm for their age on the CDI. All achieved 100% correct responses on the Wug Test. Nominal suffixes for gender and number were also correctly produced in spontaneous speech [4]. MLUs scores increased considerably over the 8-month-period, and we documented the emergence of combinatorial syntax. Open-class words were more frequent than functors and nouns were predominant at younger ages, while verbs prevailed from 30 months onwards [5].

Our study documents the emergence of early productive language in Italian, an understudied language. The results support a model of language acquisition whereby different levels, e.g. morphology, syntax and vocabulary, develop in parallel, possibly interacting with one another.

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PS2_03 – Neural correlates of speech rhythm processing in Arabic, French monolingual, and bilingual infants

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To what extent does the native language shape the encoding of continuous speech in early development? This study aims to better understand the impact of prosody on neural responses across different rhythm class languages, specifically stress-based (Arabic) and syllable-based (French) in monolingual and bilingual infants.

Studying developmental differences across languages is critical given the predominant focus of language acquisition research on Western, Educated, Industrialized, Rich, and Democratic (WEIRD) Languages. We will compare infants at two different stages of development, 6 and 20 months, and adults. Adult data will allow exploring the mature encoding of prosodic cues in continuous speech across languages and linguistic contexts (monolingual versus bilingual). Twenty-month-olds represent an interesting stage of perceptual narrowing for relevant prosodic features of the native language, and this narrowing should be enhanced in monolinguals compared to bilinguals (Graf Estes, et al., 2015). Six-month-old infants already tend to show an attuned perception toward the acoustic features of their native language (Friederici, et al., 2007), using some of them as cues for word segmentation, recognition, and syntactic categorization (Gervain & Werker, 2013). For instance, they are thought to rely heavily on lexical stress and transition probabilities between adjacent syllables for word recognition (Kooijman, et al., 2009; Romberg & Saffran, 2010). Besides the developmental issues addressed in this study, cross-linguistic comparisons will allow us to assess whether neural specialization in the encoding of rhythmicity in speech evolves language-specific. Language acquisition research also benefits from studies on bilingual populations in understanding the role of rhythm, as it has been demonstrated that 3.5-month-old bilingual infants are already more sensitive to within rhythmic class variations than monolinguals (Molnar, et al., 2014). This behaviorally tested sensitivity to rhythm in bilinguals might reveal early differences in cortical encoding of speech between monolinguals and bilinguals. Here, we wonder to what extent learning multiple languages at once affects the developmental pattern of speech processing.

To assess how neural specialization to the native rhythm develops in monolingual and bilingual infants, we will use mTRF applied to EEG data collected while infants are presented with 10-minute-long stories. We will use naturalistic, continuous speech stimuli recorded in Infant-directed speech (IDS) in French and spoken Moroccan Arabic to account for prosodic variation in infants' natural input.

To encompass the different rhythmic cues that might be relevant for language acquisition at different developmental stages , we will extract several predictor variables from the stimuli including acoustic and linguistic features (i.e., speech envelope, spectral variation, relative pitch, lexical stress, syllables and words onset, word comprehension of each individual among others). Then, we will evaluate the accuracy of speech-to-cortical response matching based on the extracted variables.

We expect younger infant's brain activity to respond more to the timing of acoustic regularities in speech while older infants' brain activity will depend more on linguistic variables. According to the literature, lexical stress carries lexical information in Arabic (Shahin, et al., 2016; Boudelaa & Meftah, 1996). Therefore, we expect more robust encoding of lexical stress in Arabic than in French learning infants. We suggest that this between-group difference should increase throughout development. Moreover, we suppose that bilingual infants' brain activity should respond to more variables than their monolingual peers and that this flexibility of responses should specialize through time, being more responsive only to features relevant to the targeted language in each condition.

The proposed poster will include results in adults and preliminary results of the infants' groups.

PS2_04 – Exploring the link between early rhythm ability and grammar development

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Studies consistently find associations between individuals' musical rhythm and linguistic grammar abilities as well as poor rhythm abilities in children with speech-language disorders. Building on these results, the Atypical Rhythm Risk Hypothesis posits that individuals with poor rhythm abilities are at a higher risk for speech-language disorders (Ladányi et al., 2020). The present study directly tested the hypothesis by measuring the longitudinal relationship between rhythm ability in infants and grammar ability at 4 years of age.

Data from 33 American-English-learning children were included in the analysis (18 female, mean age at T1: 10.06 months (SD: 1.94 months). An additional 12 participants were enrolled in the study but excluded from the analysis due to insufficient electroencephalography (EEG) data quality (n = 7) or a drop-out from the study before age 4 (n = 5). Rhythm ability was assessed with a passive listening beat-processing EEG paradigm adapted from Iversen et al. (2009) between 6 and 12 months. Infants were presented with 30-second-long blocks of a repeated tone-tone-rest patterns. In each block, either the first or the second tone was accented with increased intensity. Beat processing was examined by comparing the power of evoked time-frequency activity in the beta frequency range between the two types of blocks (accent on first vs. second tone). The Test for Reception of Grammar (TROG-2; Bishop, 2003) was used to measure grammar ability at age 4.

Results from a cluster-based permutation test of evoked time-frequency measures showed increased beta activity both at the first (Beat 1 effect) and the second tone (Beat 2 effect) when the tone was accented vs. not accented on fronto-central channels, providing evidence for beat processing in infants. We created a measure of rhythm ability at the individual level by using the mean power difference between the two conditions in the time range and channels of the significant clusters on the group level. Rhythm ability measured by the Beat 2 effect was correlated with grammar ability ($r = .39$, $p = .031$). This relationship remained significant ($p = .031$) even after controlling for the family's socio-economic status, home music environment and parental musicality.

The association of infant rhythm processing ability with grammar ability at 4 years is consistent with the hypothesis that domain-general beat processing abilities support early grammar acquisition presumably through the shared role of hierarchical processing in the two domains.

These results are also supporting the Atypical Rhythm Risk Hypothesis and motivate future research on the potential use of early rhythm skills in predicting later language abilities and the risk for a speech-language disorder.

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PS2_05 – Pupillary entrainment to natural speech reveals the development of bottom-up and top-down processes in speech perception

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To understand spoken language, listeners must parse continuous speech into words and discover how words combine into phrases, clauses, and sentences. Research suggests that adult listeners can achieve this remarkable feat by using two types of processes. On the one hand, they can rely on bottom-up processes that exploit the perceptual regularities in the prosody of spoken language that contains cues to word or phrase boundaries and that mimics the syntactic structure of sentences (Nespor & Vogel, 1986; Cutler et al., 1997). On the other hand, experienced listeners (i.e., adults, older children) can also rely on top-down processes that exploit the acquired knowledge of the syntactic structure of their native language. However, it remains largely unexplored how these processes interact when adult listeners parse natural speech and how they develop when language is acquired. Therefore, we investigated how adults, children, and young infants weigh prosodic cues and acquired grammatical knowledge to parse natural sentences. We did this by measuring how changes in participants' pupil size entrain to the auditory input, that is, how well the pupillary response correlated with the envelope of the auditory stimuli.

German-speaking adults, 3.5-year--old children, and 8-month-old infants listened to passages of German sentences with pauses inserted either within clauses or at clause boundaries. Because clause boundaries provide natural break points in speech (Pierrehumbert & Hirschberg, 1990), the pauses' occurrence should be more acceptable between, rather than within, syntactic clauses (Hirsh-Pasek et al., 1987; Nazzi et al., 2000). To investigate which prosodic cues participants use to parse the grammatical structure of sentences we replaced the words immediately preceding the pauses either with recordings of words containing prosodic cues to clause boundaries (e.g., higher pitch/intensity and longer duration), or with recordings of words that contained no prosodic cues to clause boundaries. This resulted in four experimental conditions (2-by-2 design): (1) prosodically well-formed boundaries at syntactically plausible positions (bottom-up +, top-down +); (2) prosodically well-formed boundaries at syntactically implausible positions (bottom-up +, top-down -); (3) prosodically ill-formed boundaries at syntactically plausible positions (bottom-up -, top-down +); and (4) prosodically ill-formed boundaries at syntactically implausible positions (bottom-up -, top-down -). We recorded participants' pupil size with an eye-tracker and measured how well their pupils entrained to the amplitude envelope of these sentences.

Our results show that listeners' ability to rely on bottom-up and top-down processes to parse continuous speech develops during the first years of life. Eight-month-old infants' pupils entrained significantly more to (i.e., showed a higher correlation with) prosodically well-formed than ill-formed sentences, irrespectively whether the boundaries appeared at syntactically plausible or implausible positions. This suggests that during the first year of life, infants rely primarily on bottom-up prosodic cues to parse continuous speech. In contrast, 41-month-old children's pupils entrained significantly better to sentences in which the boundaries appeared at syntactically plausible positions, irrespectively of the prosodic cues. This suggests that young children weigh the syntactic structure of sentences more than the acoustic realization of speech prosody. Finally, only adult participants' pupils entrained best to sentences with prosodically well-formed boundaries at syntactically plausible positions, suggesting that they integrate top-down and bottom-up processes when parsing natural speech. Our results show that changes in pupil size can entrain to natural speech, and reveal how infants, children, and adults rely on bottom-up and top-down processes to parse structure from continuous speech.

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PS2_06 – How does my voice sound: The role of babbling in language acquisition

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Growing evidence shows that early speech processing relies on information extracted from speech production (Choi et al. 2023), with a boosting effect of developing production skills on perceptual processing. The representation of “own” speech sounds - sounds that have been practiced by the infant - would become stronger compared to the representation of “non-own” speech sounds, only experienced through the input (Lorenzini & Nazzi, 2022; Polka et al., 2021). Moreover, a recent study (Nallet et al., in prep) on newborns’ perception of cries showed a significantly greater brain activation for cries than for speech. Those heightened brain responses to cries may be linked to the fact that newborns are able to produce cries and use them for communication. So, what about older infants? To test that, we are exposing Italian infants between 6 and 12 months to blocks of babbling (produced by Italian infants), and adult Italian sentences, while their brain activity is recorded in the temporal and parietal regions using fNIRS. In this contribution, we will present the details of the study and some preliminary results.

PS2_07 – Infant cognitive and language development at the age of 12 months - Impacts of baseline gamma power and its relationship to maternal sensitivity

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Previous literature has indicated a positive association between baseline gamma power and later child development (Brito et al., 2016; Cantiani et al., 2019; Chirumamilla et al., 2022). Furthermore, research in attachment and relationship implicated, that the early parent-infant interaction is an important basis for both, the organisation of the infant's cognitive functions and the underlying neurological structures (Tarabulsy et al., 2016). Both, the mother's health and her behaviour in the early interaction influence the toddler's language skills and the faster increase in frequency bands (Bernier et al., 2016; Parfitt et al., 2014).
The aim of this master's thesis is to explore, whether the newborn's baseline gamma power (~24-48 Hz) serves as a positive predictor of infant's cognitive and language development at the age of 12 months and whether this association is moderated by maternal sensitivity.
Methods. This thesis is part of a long-term study carried out by the University of Salzburg, investigating the development from birth up to 12 months. Two weeks after birth (N = 40; M = 17.45 days; SD = 3.91), the infant's baseline brain activity was recorded using a 128-channel hdEEG. At six months (N = 32; M = 6.26 months; SD = 7.88 days), the mother-infant-interaction was video recorded and evaluated (Infant CARE-Index; Crittenden, 2006). The last testing point was conducted at 12 months of age (N = 40; M = 12.12 months; SD = 8.52 days) and assessed the infant's cognitive and language skills using the Bayley Scales III (Reuner & Rosenkranz, 2014).
Results. Against the hypothesis, the newborn's cognitive skills at 12 months were negatively correlated with baseline gamma power (24-45 Hz) at the parietal area ($r = -.36$, $p = .046$). The other associations between baseline gamma power and both cognitive (N = 32; frontal: $r = -.23$, $p = .209$; central: $r = -.28$, $p = .121$) and language (N = 32; frontal: $\rho = -.04$, $p = .827$; central: $\rho = -.15$, $p = .416$; parietal: $\rho = -.07$, $p = .705$) development at 12 months did not reach statistical significance.
The Infant CARE-Index evaluates the mother's behaviour as sensitive, controlling and non-responsive.

None of these subscales indicated a statistically significant correlation. Maternal sensitivity –the mother's ability to recognise and respond appropriately to the infant's signals- was not related to infant development (N = 32; cognitive skills: $\rho = .09$, $p = .607$; linguistic skills: $\rho = -.06$, $p = .750$).
Furthermore, maternal sensitivity neither moderated the effect between parietal baseline gamma power and cognitive skills ($\Delta R^2 = 0\%$, $F(1, 26) = 0.04$, $p = .839$, 95% CI [-0.4, 0.33]) nor central baseline gamma power and language abilities ($\Delta R^2 = 0\%$, $F(1, 26) = 0.07$, $p = .797$, 95% CI [-7.77, 6.03]). Maternal control and non-responsiveness did not moderate this association either.
Conclusion. We found a negative correlation between the newborns' gamma power in the parietal area and their cognitive abilities at 12 months of age, which is not consistent with the findings of previous literature. Generally, the field of research on early markers in brain activity in relation to infant development is still in progress, and further research is needed to obtain a more comprehensive understanding. Whether and in which way maternal sensitivity plays a role, should be investigated in a broader sample.

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PS2_08 – Rhythm in numbers: An explorative study on numeric processing in toddlers

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Research suggests that humans possess innate constraints for processing numerical information (Wang et al., 2021; Gennari et al., 2023). Consistently, infants can visually discriminate between large numerosities differing by a 1:2 ratio (e.g., 8 vs. 16 dots). However, they struggle with more challenging ratios like 2:3 (e.g., 8 vs. 12 dots; Libertus & Brannon, 2009), but for small numerosities, infants can discriminate a 2:3 ratio (Cordes & Brannon, 2009). Auditory studies reveal similar limited discrimination abilities. Infants discriminate 1:2 but not 2:3 quantitative ratios for tone (vanMarle & Wynn, 2009) and speech sounds (Benavides-Varela & Reoyo-Serrano, 2021). However, it remains unclear whether basic numerical abilities can be equated across different sensory modalities or what mechanisms facilitate auditory numerical processing. Research on auditory representations in young children, particularly in language and music, emphasizes rhythm's role in language acquisition and general cognitive abilities (Woodruff Carr et al., 2014; Ladanyi et al., 2020). Several studies report effects of prenatal exposure to rhythm in early discrimination abilities (Ullal-Gupta et al., 2013; Granier-Deferre et al., 2011). For instance, infants are found to discriminate and prefer binary overand ternary meters (Bergeson & Trehub, 2006), with early rhythmic abilities encompassing music as well as non-musical stimuli including speech and tones (Fiveash et al., 2021). In summary, rhythm serves as a bridge between language, cognition, and musical learning, showcasing its significant impact on infant development (Russo et al., 2023; Miendlarzewska & Trost, 2014). However, we haven't found any evidence of rhythm eliciting numeric processings. Therefore, in this pilot study, we investigate the influence of auditory rhythm on a visual numerical match-to-sample task. First, we ask whether infants can abstract a mental numerical representation from a rhythmic auditory sequence (encoding) and recognise it in the form of a visual image (test). Secondly, we ask which ratio (1:2 vs. 2:3) is easier to recognise. This poster presents preliminary results on 10 subjects participating in the ongoing data collection. All subjects are monolingual learners of Italian (5 females; from 18 to 37 months; M = 809 days; SD = 185). Nine additional toddlers were excluded from the analysis because of their oldest age (N = 4) or incomplete trials (N = 5). Testing is conducted online, with infants at home sitting in a high chair or on a parent's lap. Parents signed the informed consent before the experiment and after they had understood the procedure and all their questions had been answered. They are instructed to perform the task before starting. The Ethics Committee of the University of Padova approved the study. The task is presented as a serious game with a ladybug singing the rhythms (auditory stimuli) with different numbers of black dots in her body (visual stimuli).

On each trial, an auditory, rhythmic sequence displaying from between 1 to 12 tones is played (i.e., song by the ladybug). This is followed by two pictures displaying a congruent and an incongruent set of dots (i.e., two ladybugs with different numbers of black dots on their bodies). Participants hear a recorded voice instructing them to select one of the two pictures (e.g., "Who played this sound?"). Infants complet 8 trials for each of the 2 conditions (16 total trials): 8 trials for the 1:2 ratio (1:2 small; 6:12 large) and 8 trials for the 2:3 ratio (2:3 small; 4:6 large). The auditory stimuli were synthesized using the piano timbre from the MuseScore4 app and equalized via Audacity. Using CUSTOM (De Marco & Cutini, 2020), we created visual stimuli controlling for all relevant parameters and physical variables such as total area, total perimeter and convex hull. We matched the two arrays for total area, total perimeter and convex hull. Preliminary results (i.e., descriptive statistics) on 10 subjects show a general accuracy (percentage of correct over total performed trials) of 0.55 (sd = 0.11) and a relative accuracy of 0.61 (sd=0.28) for 1:2 ratio and 0.52 (sd=0.13) for 2:3 ratio. Therefore, toddlers show modest abilities to recognize auditorily presented rhythmic sequences into visually stimuli, with 1:2 ratio simplifying the task with respect to 2:3 ratio.

These results confirm that there is a limited ability to discriminate numerical information in a 2:3 ratio. The potential correlation between infants' inclination towards ternary meters in musical rhythm and their capacity to differentiate numerical information in a 2:3 ratio is still uncertain. When finished (planned sample size N=60), this Study will potentially inform the scientific literature on numeric and rhythm processing about cross-sensory transfers of numeric mental representations and the possibility to benefit from rhythmic structures to aid number discrimination abilities in early childhood.