MMN - 2024

10TH MISMATCH NEGATIVITY CONFERENCE

The Neuronal Basis of MMN and its Clinical Applications

PROGRAM BOOK

September 17th - 19th, 2024
Salamanca, Spain

VNIVERSIDAD D SALAMANCA

INSTITUTO DE NEUROCIENCIAS CASTILLA Y LEÓN

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The 10th Mismatch Negativity Conference

The Neuronal Basis of MMN and its Clinical Applications

(MMN-2024)

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Hospedería del Colegio Arzobispo Fonseca
Calle Fonseca 4, 37002, Salamanca, Spain

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WELCOME MESSAGE

Salamanca, 17th September 2024

Dear participants, dear friends:

Welcome to the 10th Mismatch Negativity Conference (MMN 2024) in the historic city of Salamanca! We are thrilled to host this prestigious event and we extend our heartfelt gratitude to all the contributors and supporters who have made this conference possible.

The 10th Mismatch Negativity meeting (MMN24) will be held at the Hospederia del Colegio Arzobispo Fonseca. Founded in the early 16th century (1519 anno domini), the colegio bears the name of its founder, Alonso de Fonseca, the Archbishop of Santiago de Compostela. The institution was established with the vision of providing a haven for intellectual and spiritual development, and we hope to continue this laudable goal for our MMN meeting.

Salamanca is a UNESCO city, with a preserved renaissance era centre, the most beautiful plaza mayor in all of Spain (and probably of the world), and it boasts not one, but two cathedrals. Our hosting institution, The University of Salamanca, was founded in 1218 and is the third oldest university in Europe, with a wide range of faculties and research institutes in both sciences and arts. In 2011, it was awarded the "Campus of International Excellence" status. The university offers a wide range of study every year to 26,000 undergraduate students and 2,600 post-graduates; it also contracts 3,200 researchers, who are distributed across 10 university schools and 12 institutes. The university is recognized as one of the most outstanding Spanish universities in both national and international rankings. During your visit, make sure to visit the historic façade, and see if you can find the hidden frog.

The University of Salamanca focuses its potential across research centres and institutes specifically devoted to certain topics of knowledge. One of these is the Institute of Neurosciences of Castilla y Leon, a centre created in 1998 and dedicated to scientific research across both the typical nervous system as well as its disorders. The INCYL was created with the philosophy of doing research, both basic and applied to the nervous system, linked to major social problems, and training the next generation to continue this world class research.

It is a great honour to host the MMN Conference, which is a platform dedicated to advancing the understanding of Mismatch Negativity and other neural responses associated with detecting regularity and change, prediction and prediction errors, and related phenomena across species and levels. Our conference mission is to foster collaboration and knowledge exchange among researchers, clinicians, and professionals in the field, with the ultimate goal of unravelling the mysteries of the brain's response to sensory mismatches. I am sure that MMN 2024, will foster sharing cutting-edge research across our field. Together, let's delve into the intricacies of the brain's response to mismatches, forging new paths in neuroscience, and contributing to the advancement of knowledge.

Our MMN conference offers a superb scientific program that includes 3 keynotes speaker, 13 symposia with 60 oral communications and 78 poster communications. Most importantly, we will come together with profound respect and admiration to celebrate and honour the enduring legacy of the late Professor Risto Näätänen, who was a true visionary in the realm of cognitive neuroscience, with a special symposium dedicated to him and his research. The conference and this special symposium will also provide a time to reflect on the transformative impact of Risto Näätänen's contributions to the discovery and subsequent understanding of mismatch negativity (MMN).

Throughout his illustrious career, Risto Näätänen received over 84,000 citations, achieving an impressive h-index of 143. His influence reverberated globally, establishing him as one of the most widely referenced Finnish scientists, and numerous prestigious awards adorned his career. His spirit will continue to inspire and guide our pursuit of knowledge in the fascinating realm of human cognition.

Finally, I wish to thank our sponsors, and the University of Salamanca for their support in making this MMN2024 meeting possible.

I am certain that MMN2024 will inspire vivid discussions and an exchange of ideas that will strengthen scientific cooperation and friendship across the globe, and I am looking forward to meeting many of you here in Salamanca.

Manuel S. Malmierca

Chair of the MMN 2024 meeting

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CONFERENCE ORGANISATION

Scientific contact

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GENERAL INFORMATION

Conference venue

Hospedería del Colegio Arzobispo Fonseca
Address: Calle Fonseca 4, 37002, Salamanca, Spain

Technical Secretary

For any inquires or assistance, please do not hesitate to contact us at:
Tel.: +34 923 29 45 00 Ext.: #4729 or #5301
E-mail: mmn24@usal.es
Website: https://mmn24conference.usal.es/
Or if you prefer to contact Dr. Manuel S. Malmierca, you can phone him directly at +34 670 613 116

On-site registration

17th September (Tuesday) 8:00-18:00.
18th September (Wednesday) 8:00-15:00.
19th September (Thursday) 8:00-15:00.

Registration fees include

For participants and students

- Attendance to scientific sessions and commercial exhibition
- Conference bag with Congress Program Book and pen
- Opening ceremony
- Coffee breaks
- Light lunches
- Welcoming reception at Palacio de Figueroa (17th September)
- Farewell banquet at Hacienda Zorita (19th September)

For accompanying persons

- Any accompanying person attending the MMN 2024 Conference is required to register through the International Courses page (https://ci.usal.es/MMN), under the designation of PhD Student.
- Since PhD delegates are required to upload a certificate of status, please attach the document available at: https://mmn24conference.usal.es/wp-content/uploads/sites/129/2024/06/guest.pdf

Accreditation

Participants will be given a Certificate of Attendance.

Posters

Poster exhibition will be available during the whole Conference in Posters Hall.
Posters should be set up the first day (17th September) from 08:00.
Please, dismantle your poster at the end of the Conference.
Due to the dimensions of the available boards, the maximum size for posters is 100 cm wide x 130 cm high (40 inches wide x 50 inches high).
Double-sided tape will be provided for attaching your poster to the display board. Each board will be marked with an abstract number.
IMPORTANT: Ensure that your poster is in portrait (vertical) orientation.

Slide check

All speakers should upload their slides to the computers in the Speaker Ready Room before the start of the Symposium. Slide preview and editing of presentations will be available at the MMN 2024 website.

Internet

Information on free internet access will be provided for participants at the Registration desk.

Lunch

During the three-day Conference, lunch will be provided for the participants at the Conference venue.

Social Program

Welcoming dinner
17th September, 2024
Venue: Palacio de Figueroa. Calle Zamora, 15, 37002, Salamanca, Spain.

How to reach: The restaurant is located in the city center. Please, check the map at the end of this Program Book.

Farewell Banquet
19th September, 2024
Venue: Hacienda Zorita. SA-300, km 10, 37115 Valverdón, Salamanca, Spain.

How to reach: Buses will be provided to get to the restaurant. For the outward journey, the bus will depart from outside Hospedería del Colegio Arzobispo Fonseca (conference venue). For the return journey the bus will depart from the restaurant, leaving us at the original pick-up point.

The 10th World Mismatch Negativity Conference

(MMN2024)

	Tuesday 17th	Wednesday 18th	Thursday 19th
8:45-9:00	**Opening ceremony** *Sala Mayor*		
9:00-10:00	**Keynote #1** ***V. Csépe*** *Sala Mayor*	**Keynote #2** ***J. P. Hamm*** *Sala Mayor*	**Keynote #3** ***E. Schröger*** *Sala Mayor*
10:00-11:30	**SYMP #1** ***B. Englitz & T. R. Barkat*** *Sala Mayor*	**SYMP #5** ***Y.A. Ayala & S. J. Eliades*** *Sala Mayor*	**SYMP #10** ***T. Jacobsen & S. Ylinen*** *Sala Mayor*
11:30-12:00	**Coffee break** *Refectory*	**Coffee break** *Refectory*	**Coffee break** *Refectory*
12:00-13:30	**SYMP #2** ***I. Winkler*** *Sala Mayor*	**SYMP #6** ***A. Calcus & K. Uhler*** *Sala Mayor* **SYMP #7** ***K. Kreegipuu*** *Sala Menor*	**SYMP #11** ***D. Salisbury*** *Sala Mayor* **SYMP #12** ***F. Blankenburg & W. von der Behrens*** *Sala Menor*
13:30-15:00	**Lunch/POSTERS** Refectory/Posters Hall	**Lunch/POSTERS** Refectory/Posters Hall	**Lunch/POSTERS** Refectory /Posters Hall
15:00-16:30	**SYMP #3** ***R. Zatorre & E. Coffey*** *Sala Mayor*	**SYMP #8** ***L. Faes & M. Enan*** *Sala Mayor*	**SYMP #13** ***H. Yabe*** *Sala Mayor*
16:30-16:45	**Coffee break** *Refectory*	**Coffee break** *Refectory*	***SPECIAL TRIBUTE SYMP TO RISTO NÄÄTÄNEN - CLOSING REMARKS*** *Sala Mayor*
16:45-18:15	**SYMP #4** ***C. Alain*** *Sala Mayor*	**SYMP #9** ***A. Bidet-Caulet & A. Caclin*** *Sala Mayor*	

20:00-22:30	**Welcoming dinner** *Palacio de Figueroa*	**Self organize**	**Farewell banquet** *Hacienda Zorita*

ORAL COMMUNICATIONS

SYMPOSIA

Tuesday 17th, September 2024

Keynote 1: *09:00 - 10:00*

"The many faces of MMN"

Lecturer: Valeria Csépe
HUN-REN RCNS, Brain Imaging Centre and
Hungarian Academy of Sciences. Hungary

Symposium 1: *10:00 - 11:30*

NEW INSIGHT INTO THE PHYSIOLOGICAL BASIS OF PREDICTIVE PROCESSING

Chairperson/s: Bernhard Englitz[1] and Tania Rinaldi Barkat[2]
[1]Department of Computational Neuroscience Laboratory. Department of Neurophysiology. Donders Centre of Neuroscience. Nijmegen, The Netherlands.
[2]Department of Biomedicine of the University of Basel. Switzerland

Talk 1: Cortical neuronal circuits for adaptation

Maria Geffen
University of Pennsylvania. USA

Talk 2: Sequential maturation of deviance detection in the mouse central auditory system

Tania Rinaldi Barkat
Department of Biomedicine of the University of Basel. Switzerland

Talk 3: The representation of mismatch responses across the auditory cortex of mice

Bernhard Englitz
Computational Neuroscience Laboratory. Department of Neurophysiology. Donders Centre of Neuroscience. Nijmegen, The Netherlands.

Talk 4: Temporal prediction as a sensory processing principle

Nicol Harper
Department of Physiology, Anatomy and Genetics. University of Oxford. UK

*Presenting authors are highlighted in blue

Talk 1: Cortical neuronal circuits for adaptation

Maria Geffen

University of Pennsylvania. USA

Hearing perception relies on our ability to adapt to the statistical structure of sounds, and to learn to use acoustical differences between sounds to distinguish behaviorally relevant sounds from noise. However, the neuronal circuits that underlie these modulations remain unknown. Our recent work suggests that inhibitory neurons in the auditory cortex mediate adaptation. I will discuss recent studies from my laboratory that elucidate the function of inhibition in the auditory cortex in temporal adaptation and in efficient coding. First, we found that distinct types of inhibitory neurons differentially regulate stimulus-specific and temporal adaptation (Natan et al., 2015, Natan et al., 2017, Briguglio et al., 2018). We have built a unifying model of the auditory cortex which provides for a candidate mechanism for differential control of multiple forms of adaptation in the cortex (Park and Geffen, 2021). Second, we tested whether and how the efficient coding of sounds of varying contrast in the auditory cortex informs auditory perception (Angeloni et al., 2023). We found that cortical contrast gain adaptation predicted behavioral performance, demonstrating that efficient neural codes in auditory cortex directly influence perceptual behavior. Our preliminary data suggest that specific cortical inhibitory neurons control contrast gain control in perception. These results demonstrate that adaptation mediated by inhibitory neurons is an important mechanism that controls multiple aspects of auditory perception.

Talk 2: Sequential maturation of deviance detection in the mouse central auditory system

Tania Rinaldi Barkat

Department of Biomedicine of the University of Basel. Switzerland

An essential task of our brain is to identify unexpected events and separate rare from common sensory inputs, a process known as surprise response or deviance detection. In the auditory system, the detection of surprising sounds has been well characterized in the mature brain of humans and animals. However, we know little about how this process develops.

In this presentation I will discuss how surprise response unfolds during life, and what circuit mechanisms are involved. We have explored this process during the adolescent period of mouse development, from postnatal day 20 (P20) to adulthood ((≥P50), in three hierarchically organized areas along the auditory pathway — the inferior colliculus (IC), the medial geniculate body (MGB), and the primary auditory cortex (A1). Using in vivo electrophysiological recordings and optogenetics, we observed deviance detection to be stable from P20 in the inferior colliculus, to develop until P30 in the MGB and even later in A1. We found this maturation process to be experience-dependent in A1 but not in MGB, and to be related to alterations in deep but not input layers of A1. We also identified corticothalamic projections to be implicated in MGB deviance detection development.

Together, our data put forward a possible prominent role for prediction errors in the maturation of surprise response, but more importantly, they show that the refinement of surprise response during adolescence is mainly a cortical effect, in the context of the cortex being a highly flexible and adaptive system. This work reveals how the response to surprising sounds is appropriately fitted to the environment in which a plastic, vulnerable adolescent brain matures. It also has the potential to suggest targeted intervention in case surprise is not processed normally such as in neurodevelopmental disorders like schizophrenia.

Talk 3: The representation of mismatch responses across the auditory cortex of mice

Bernhard Englitz

Computational Neuroscience Laboratory. Department of Neurophysiology. Donders Centre of Neuroscience. Nijmegen, The Netherlands.

Many organisms have been shown to actively utilize predictable information from the environment to optimize their behavior. Recently, we have shown that neurons in the auditory cortex of mice respond to the occurrence of an omitted stimulus inside a predictable sequence (Lao-Rodriguez, Przewrocki et al. 2023), however, the large-scale localization in auditory cortex remained unclear. We address this question using widefield (100Hz) and 2p (30Hz) imaging from the auditory cortex of GCaMP8m transfected mice. This recording configuration provides highly salient and fast responses, applicable to the study of rapid oddball sequences (2.5-10 sounds/second).

We find localized responses to omitted tones in the posterior boundary between A1 and VAF/DP in both widefield and 2p responses. These omission responses are not just stimulus-offset responses as identical, local stimulus conditions in control sequences without a predicted stimulus show no or much smaller responses. The omission response grows with the number of preceding standard stimuli, consistent with the build-up of regular predictions. We also relate these to the spatial structure of stimulus specific adaptation and frequency oddball responses. While the omission response was timed, its shape was more consistent with an integrated mismatch response, rather than a time-limited prediction.

Our results demonstrate that error signals are robust and anatomically separated from primary stimulus representations in the auditory cortex, but the responses are not consistent with a direct temporal prediction of the next stimulus, which leads us to propose a refinement of the predictive coding framework.

Talk 4: Temporal prediction as a sensory processing principle

Nicol Harper

Department of Physiology, Anatomy and Genetics. University of Oxford. UK

Sensory systems display a dizzying complexity of tuning properties and circuitry. Why do neurons in sensory pathways show the particular tuning properties and circuitry that we observe, instead of the many other possibilities? We investigate whether a simple principle can explain many features of this tuning and circuitry - temporal prediction. This principle posits that sensory systems are optimized to efficiently predict immediate future sensory input given recent past input for natural stimuli. This may be useful for guiding future action, uncovering underlying variables, and discarding irrelevant information (Bialek et al. 2001). Simple feedforward networks optimized for temporal prediction on spectrograms of natural sounds or retinal-filtered movies of natural scenes produce units with tuning properties resembling primary auditory cortical neurons or primary visual cortical simple cells respectively (Singer et al., 2018). When such networks are optimized for raw natural sound waveforms or unfiltered movies, they produce tuning properties resembling those in the auditory nerve (Trinh et al., 2023) or the retinothalamic pathway respectively (Singer et al., 2023; including for spiking networks, Taylor et al., 2024). Then, when temporal prediction is applied hierarchically to the activity of these retinothalamic-like units, units resembling visual cortical simple cells, complex cells and pattern-motion selective cells emerge as one moves up the hierarchy (Singer et al., 2023). Recurrency or hierarchical recurrency can be included to explain aspects of the connections between neurons in the visual and auditory cortex, as well as additional aspects of neural tuning. Furthermore, temporal prediction models can predict cortical responses to dynamic natural stimuli to a degree that rivals or exceeds many other models of sensory processing (Singer et al., 2023). Finally, I will present evidence of omission responses in auditory cortex that may enable temporal prediction learning (Auksztulewicz et al., 2023).

Tuesday 17th, September 2024

Symposium 2: *12:00 - 13:30*

PREDICTION PERMEATES SOUND PROCESSING IN THE HUMAN BRAIN

Chairperson/s: István Winkler
HUN-REN Institute of Cognitive Neuroscience and Psychology, Research Centre for Natural Sciences, Hungary

Talk 1: Auditory streams in perception – source and action representations in cognition
István Winkler[1] and Susan L. Denham[2]
[1]*HUN-REN Institute of Cognitive Neuroscience and Psychology, Research Centre for Natural Sciences, Hungary*
[2]*Faculty of Science and Technology, Bournemouth University, Poole, UK*

Talk 2: What does different temporal sensitivity teach us about the tracking of pattern repetitions and deviations?
Juanita Todd
Newcastle University. Australia

Talk 3: Is the auditory system a "smart" statistical learner?
Maria Chait
Ear Institute. Institute of Cognitive Neuroscience. University of London. UK

Talk 4: Hierarchical probabilistic inference for accurate prediction
Florent Meyniel
INSERM-CEA Cognitive Neuroimaging unit. CEA/SAC/DRF/I2BM/Neurospin center. France

Talk 1: Auditory streams in perception – source and action representations in cognition

István Winkler[1] and Susan L. Denham[2]

[1]*HUN-REN Institute of Cognitive Neuroscience and Psychology, Research Centre for Natural Sciences, Hungary*
[2]*Faculty of Science and Technology, Bournemouth University, Poole, UK*

Since Bregman's seminal work on Auditory Scene Analysis, the notion of the auditory stream, a coherent sound sequence likely originating from the same source has been viewed as the outcome of auditory processing. While auditory streams break down the proximal sound input into its likely constituents, humans perform cognitive operation on (e.g., recall) scenes (including sounds) in terms of "who did what"; for sounds, the sound source(s) and their sound-generating action(s). This is true whether either the source or the action can be identified or not (e.g., "something is beeping"). While it is possible that streams are further processed into sources and actions, we will argue that they are formed directly from the sound input, potentially in parallel with auditory stream segregation. To this end, we will show that in addition to their contents, auditory source and action representations can be distinguished by their stability, formation, and, perhaps most importantly, the role prediction plays in establishing them. Some event-related brain potentials can be associated with one or the other, while others may index processes related to both types of representations. We will then suggest a framework linking sound processing with how humans segment their experience into a hierarchy of events (the Event Segmentation theory). This allows us to seamlessly fit sound processing into multi-modal perception, as well as to specify how information from other modalities and previous knowledge shapes auditory perception.

Talk 2: What does different temporal sensitivity teach us about the tracking of pattern repetitions and deviations?

Juanita Todd

Newcastle University. Australia

Recording event-related brain potentials to patterned sound sequences is a popular way to study how repetition shapes information processing in task-independent sound exposure. It is well established that we learn patterns and become sensitive to pattern violations very rapidly, but the time course over which we continue to modify responsiveness to pattern repetition and violations is less well understood.

In this talk I will draw from several studies to illustrate circumstances in which auditory event-related response components exhibit sensitivities that are not easily explained by probability over timescales traditionally thought applicable to this form of perceptual inference. I will present data from different levels of sound sequence volatility to illustrate a different time course to the modification of responses for pattern repetitions and deviations. Under all levels of stability/volatility the data indicate localised (within-sequence) effects on the response to the repetitive elements in sound sequences that resets between sequence encounters. In contrast, the responsivity to pattern deviations displays a much longer timescale sensitivity that is dependent on volatility.

The results will be discussed with respect to how the information carried by sound might shape the response beyond what design probabilities would predict. Implications will be discussed for experimental design, and how we interpret results and group differences.

Talk 3: Is the auditory system a "smart" statistical learner?

Maria Chait

Ear Institute. Institute of Cognitive Neuroscience. University of London. UK

The human auditory system exhibits remarkable sensitivity to predictable information within rapidly unfolding sounds, even when such information may not directly impact behavior. However, the precise nature of the information being tracked by the listening brain, and how the ongoing volatility of the context influences this tracking, remains a subject of intense investigation.
One approach to unravelling this mystery is by comparing the dynamics of brain responses to predictions generated by ideal observed models operating under various heuristics. These models range from strictly Bayesian frameworks like D-REX to those tailored to assume sequential structures, such as the IDyoM model. By scrutinizing how brain responses align with model outputs across diverse contexts, we uncover a sophisticated statistical tracking mechanism. This mechanism involves evidence accumulation, which can be reset based on statistical beliefs (e.g., silences between stimuli or higher-order contextual cues). Moreover, we find that long-term context significantly shapes the brain's responses to auditory stimuli.
To illustrate, I will present examples from stimulus paradigms involving rapidly presented, specifically structured tone-pip patterns. These examples demonstrate how the brain dynamically adjusts its processing to the precision (inferred reliability) of sensory statistics, and how the representation of volatility within auditory stimuli can be systematically influenced by sudden context shifts.

Talk 4: Hierarchical probabilistic inference for accurate prediction

Florent Meyniel

INSERM-CEA Cognitive Neuroimaging unit. CEA/SAC/DRF/I2BM/Neurospin center. France

Accurate predictions are crucial for perception and decision making in dynamic and noisy environments. This talk makes the claim that the human brain spontaneously utilizes local statistical regularities to predict the next item in a sequence. The type of statistical regularities that the brain utilizes is currently debated, I propose that it reflects the sequential structure of the world and relies, at a minimum, on transition probabilities between consecutive items. Interestingly, the brain leverages local statistical regularities even when they emerge from stochastic fluctuations, leading in this case to erroneous predictions. Why does the brain sometimes rely more than it should on the recent past? One possibility is that the brain is adapted to a world that is changing, where the recent past is more informative about future observations than the distant past. I will explore the possibility that prediction in changing and noisy environment relies on an inference that is probabilistic and organized into several hierarchical levels. A key notable aspect of this probabilistic account is the association of predictions with confidence levels, indicating their precision and likelihood of accuracy. The talk demonstrates that humans can introspectively access this confidence, which also modulates neural responses triggered by unexpected sounds. Artificial neural networks trained to predict the next item in a sequence develop a representation of this confidence that regulates their inference process. These results highlight the importance of incorporating confidence representations for accurate predictions in dynamic and noisy environments. This requirement aligns with probabilistic inference, can be implemented in simple neural networks, and appears to be operative by the human brain.

Tuesday 17th, September 2024

Symposium 3: *15:00 – 16:30*

CORTICAL AND SUBCORTICAL MECHANISMS IN AUDITORY PROCESSING AND PREDICTION

Chairperson/s: Robert Zatorre[1] and Emily Coffey[2]
[1]International Laboratory for Brain, Music and Sound Research (BRAMS), McGill University, Montreal, Quebec. Canada
[2]Concordia University

Talk 1: Cortical-subcortical interactions to violations of auditory predictions measured with 7T functional MRI
Alberto Ara
McGill University. Canada

Talk 2: The role of the Orbitofrontal cortex in building predictions and detecting violations
Alejandro Blenkmann
Department of Psychology, University of Oslo, Norway

Talk 3: Two prediction error systems in the nonlemniscal inferior colliculus: "spectral" and "non-spectral"
Guillermo V. Carbajal, Lorena Casado-Román and Manuel S. Malmierca
Cognitive and Auditory Neuroscience Laboratory (CANELab)
University of Salamanca. Spain

Talk 4: Cortico-subcortical interplay in auditory predictive coding
Carles Escera
University of Barcelona. Spain

Talk 5: Is there a tiny predictive coding mechanism hidden within frequency encoding?
Emily B. J. Coffey
Concordia University. Canada

Talk 1: Cortical-subcortical interactions to violations of auditory predictions measured with 7T functional MRI

Alberto Ara

McGill University. Canada

Perception integrates both sensory inputs and internal models of the environment. In the auditory domain prediction of future events plays a critical role because of the temporal nature of sounds. However, the precise contribution of cortical and subcortical structures in these predictive processes, as well as their interaction, remain unclear, especially in humans. It is also uncertain whether these subcortical signals are specific to abstract rules violations alone, or if they also respond to deviations in local features, such as periodicity. Here, we used high-field 7T fMRI to investigate interactions between cortex, medial geniculate and inferior colliculus during auditory predictive processing. Male and female volunteers listened to tone sequences in an pitch oddball paradigm, such that the deviant corresponded to different levels of expectancy on different trials. Perturbations in periodicity were also introduced orthogonally to test the specificity of the response. Results indicate that both cortical and subcortical auditory structures encode high order predictive dynamics, with the effect of predictability on error signals being strongest in the auditory cortex. These predictive dynamics were best explained by modelling a top-down flow of information, in contrast to unpredicted responses (to the first stimulus in the sequence), which followed a bottom-up information flow. No error signals were observed to deviations of periodicity, suggesting that these responses are specific to violations of abstract rules. Our results support the idea that predictive dynamics observed in subcortical areas represent predictions propagated from the auditory cortex, and that the associated error signals are specific to statistical contingencies between sounds.

Talk 2: The role of the Orbitofrontal cortex in building predictions and detecting violations

Alejandro Blenkmann

Department of Psychology, University of Oslo, Norway

The orbitofrontal cortex (OFC) is traditionally associated with inhibitory control, emotion regulation, and reward processing. However, recent perspectives propose that the OFC also generates predictions about perceptual events, actions, and their outcomes. To explore this idea, we investigated whether lesions to the OFC would impair the ability to build predictions of future auditory events and detect deviations from expected regularities. We used an auditory Global-Local task, in which the structural regularities of played tones were controlled at two hierarchical levels by rules defined at a local (i.e., between tones within sequences) and global (i.e., between sequences) level. In the first part of the talk, I will show that OFC lesions affect detecting prediction violations at two hierarchical levels of rule abstraction. Patients with OFC lesions had normal ERP responses to standard tones but altered MMN and P3a to local and simultaneous local + global prediction violations. In the second part, I will focus on the predictive aspect of the task. For this, we studied trial-by-trial modulations of the Contingent Negative Variation (CNV) – a marker of anticipatory activity. Healthy participants' CNV modulations tracked the expectancy of deviant tone sequences, but crucially, patients with OFC lesions lacked CNV sensitivity to the predictive context. These results were further supported by intracranial recordings in patients with epilepsy, who revealed expectancy modulations in the OFC. Altogether, I will argue that the complementary approach from behavioral, intracerebral EEG, scalp EEG, and causal lesion data provides compelling evidence for the role of the OFC in building up predictions of future events and the signaling of deviations from these expectations.

Talk 3: Two prediction error systems in the nonlemniscal inferior colliculus: "spectral" and "non-spectral"

Guillermo V. Carbajal, Lorena Casado-Román and Manuel S. Malmierca

Cognitive and Auditory Neuroscience Laboratory (CANELab)
University of Salamanca. Spain

According to the predictive processing framework, perception emerges from the reciprocal exchange of predictions and prediction errors (PE) between hierarchically organized neural circuits. The nonlemniscal division of the inferior colliculus (IC) is the earliest source of auditory PE signals, but their neuronal generators, properties and functional relevance have remained mostly undefined. We recorded single-unit mismatch responses to auditory oddball stimulation at different intensities, together with activity evoked by two sequences of alternating tones to control frequency-specific effects. Our results reveal a differential treatment of the unpredictable 'many-standards' control and the predictable 'cascade' control by lemniscal and nonlemniscal IC neurons that is not present in the auditory thalamus or cortex. Furthermore, we found that frequency response areas of nonlemniscal IC neurons reflect their role in subcortical predictive processing, distinguishing 3 hierarchical levels: (1) Nonlemniscal neurons with sharply tuned receptive fields exhibit mild repetition suppression without signaling PEs, thereby constituting the input level of the local predictive processing circuitry. (2) Neurons with broadly tuned receptive fields form the main, 'spectral' PE signaling system, which provides dynamic gain compensation to near-threshold unexpected sounds. This early enhancement of saliency reliant on spectral features was not observed in the auditory thalamus or cortex. (3) Untuned neurons form an accessory, 'non-spectral' PE signaling system, which reports all surprising auditory deviances in a robust and consistent manner, resembling nonlemniscal neurons in the auditory cortex. These nonlemniscal IC neurons show unstructured and unstable receptive fields that could result from inhibitory input controlled by corticofugal projections conveying top-down predictions.

Talk 4: Cortico-subcortical interplay in auditory predictive coding

Carles Escera

University of Barcelona. Spain

Current views of perception conceptualize the brain as predictive system actively inferring the causal dynamics of the sensory world, to build up generative models to predict future events. In this formulation, feedforward prediction errors and feedback predictions flow across hierarchically organized brain areas in distributed neuronal assemblies that support neuronal representations. Originally, predictive coding emerged as theory of cortical function, largely neglecting the intricate neuroanatomy of the subcortical auditory system, a kind of cortical "myopia". Yet animal and human studies have recently revealed subcortical correlates of predictions and prediction errors, so that the current debate is not whether the auditory subcortex is involved in predictive coding, but what is the precise interplay between cortical and subcortical structures in supporting auditory cognition. In this talk, I will present brain potential scalp recordings and neuroimaging data collected in human participants illustrating this interplay. These brain potentials encompass the mismatch negativity (MMN) and middle-latency (MLR) components of the auditory evoked potential. Of special interest will be the so-called frequency-following response (FFR) elicited complex auditory stimuli, of known generating sources in the inferior colliculus, for which we observed modulations by stimulus probability (i.e., prediction error) and by lexical experience, this latter resulting from corticofugal feedback.

Talk 5: Is there a tiny predictive coding mechanism hidden within frequency encoding?

Emily B. J. Coffey

Concordia University. Canada

In auditory cognitive neuroscience, deviance detection has mainly been studied using the slow evoked responses which make up the mismatch negativity (MMN) and middle-latency (MLR) components. Recent work has also started to investigate how a fast, high frequency evoked response known as the frequency-following response (FFR) is affected by predictable aspects of the auditory stream. The FFR encodes auditory stimulus frequency information and is often thought to come from the brainstem, though it has generators in the cochlear nucleus, inferior colliculus, thalamus and cortex. In this talk, I will present data relevant to the hypothesis that the FFR can not only be affected by predictive mechanisms, but is in fact a form of miniature predictive coding mechanism wherein each cycle of a periodic waveform is in some sense 'predicted'. Using data from human EEG and MEG recordings, intracranial and animal models, we will review evidence for an oscillatory entrainment mechanism, and explore where in the brain it might be found, and whether there is evidence that a violation of expectations specific to the moment-by-moment representation of periodicity leads to a neural event that might be thought of as the lowest-level equivalent of a MMN. Finally, we will discuss the possible functions of such a mechanism. These results will broaden the discussion of what is meant by a predictive brain mechanism, and suggest the necessary next steps to better understanding the role of low-level predictive mechanisms in perception (if any).

Tuesday 17th, September 2024

Symposium 4: *16:45 – 18:15*

NEUROSCIENCE OF MUSIC: FROM PERCEPTION TO COGNITION

Chairperson/s: Claude Alain
Rotman Research Institute, Baycrest Centre

Talk 1: Statistical Leaning of Novel Chord Transition Patterns in Adult Nonmusicians: An MMN Study
Kai Ishida
School of Human Sciences, Osaka University. Japan

Talk 2: Pattern Separation in Musicians and Non-Musicians: Is Sensory Discrimination Associated with Episodic Memory?
Jennifer A. Bugos
Center for Music Education Research, University of South Florida. USA

Talk 3: Alpha oscillation after correcting for aperiodic activity reveals the effect of music training on cognitive aging
Jing Lu
School of Life Science and Technology, University of Electronic Science and Technology of China. China

Talk 4: Music Training and the Deployment of Attention: Evidence from an Auditory Attentional Blink Paradigm
Claude Alain
Rotman Research Institute, Baycrest Centre. Canada

Talk 1: Statistical Leaning of Novel Chord Transition Patterns in Adult Nonmusicians: An MMN Study

Kai Ishida

School of Human Sciences, Osaka University. Japan

The human brain realizes the grouping and segmentation of events based on the learning of event probabilities. This function is called statistical learning and is considered domain-general processing. Regarding the auditory modality, statistical learning has been thought to underlie not only the acquisition of word segmentation and grammar in the language domain, but also the acquisition of music-syntactic regularities such as the schema of chord progression patterns in the music domain. The present study was designed to investigate the process of learning a novel chord progression pattern using the mismatch negativity (MMN) response. We hypothesized that infrequent chord progressions in a novel context would elicit a statistical MMN and that once the novel chord progression pattern is learned, a music-syntactic MMN would be elicited even when presented equiprobably.

Adult nonmusicians without hearing impairment participated in the study. Experiment 1 (N = 36) examined the MMN response during the acquisition phase, while Experiment 2 (N = 35) examined the MMN response after two days of learning. The same stimuli were used in both experiments. Six types of chords consisting of the 18-tone equal temperament scale were concatenated to create a learning sequence in which a particular progression pattern appeared with high ($p = .90$, standard) or low ($p = .10$, deviant) probability. To ensure that only the progression pattern was learned, each chord was presented with equal probability. In Experiment 1, ERPs were recorded while participants listened to the learning sequence and performed a timbre change detection task as a cover task. In Experiment 2, ERPs were recorded while participants passively listened to a sequence in which the standard and deviant progressions appeared at $p = .50$ each, after two days of online learning of the novel progression pattern. After the ERP recording, a behavioral familiarity test was administered in which participants selected the standard progression in each of the two chord progressions.

Results showed that the deviant progressions elicited a statistical MMN and a music-syntactic MMN, reflecting online irregularity detection and deviation from the acquired pattern representation, respectively. Participants were unable to choose the standard chord progression above chance in Experiment 1, but were able to choose it in Experiment 2, possibly reflecting the longer learning period. These results suggest that the schema of chord progression patterns can be acquired through statistical learning, even for adult nonmusicians without expert musical knowledge and skills.

Talk 2: Pattern Separation in Musicians and Non-Musicians: Is Sensory Discrimination Associated with Episodic Memory?

Jennifer A. Bugos

Center for Music Education Research, University of South Florida. USA

Performing a musical instrument is associated with enhanced performance on perceptual measures such as auditory processing, and speech-in-noise perception; however, little is known about the mechanisms that support underlying auditory perceptual differences and to what extent these relate to cognition in aging. Roll's theory (2016) of pattern separation, developed with visual material, underscores the importance of mnemonic discrimination mediated by the hippocampus. It posits that encoding highly similar details belonging to separate, yet overlapping, events are represented in discrete patterns, enhancing memory and retrieval processes. We hypothesized that music training enhances pattern separation which allows musicians to outperform non-musicians on a variety of cognitive measures. Musicians may negotiate interference between simultaneously performed tasks (i.e., sensorimotor integration) in which pattern separation may serve as the mechanism for disambiguating visual and sound objects.

We recruited 51 older adults (26 musicians, 25 non-musicians) and tested this hypothesis with a behavioral measure commonly associated with pattern separation (Mnemonic Similarity Task; MST) and an auditory discrimination measure (Auditory Similarity Task) while continuously recording electroencephalography. Event-related potentials were recorded using a 76-channel Biosemi Active Two acquisition system. Behavioral data on the MST suggest enhanced lure discrimination by musicians as compared to non-musicians. Similar latencies were found for both groups on the MST. Results of the mismatch negativity (MMN) support increased amplitude by musicians when compared to non-musicians. Our data lend support to the hypothesis that music engagement may strengthen sensory processing that leads to greater cognitive benefits in aging. Further analysis is currently underway to examine neural oscillatory activity related to these differences and how these relate to behavioral findings.

Talk 3: Alpha oscillation after correcting for aperiodic activity reveals the effect of music training on cognitive aging

Jing Lu

School of Life Science and Technology, University of Electronic Science and Technology of China. China

Studies indicate that neural oscillation in a resting state can represent cognitive aging. Top-down modulation of alpha oscillation contributes to working memory in older adults. It is affected by music training, which may be the potential mechanism of music intervention on cognitive aging. Some studies have found that aperiodic activity has biological meaning, and the correction of aperiodic activity can lead to changes in alpha oscillation differences. Thus, this work assessed aperiodic activity in young control, young musicians, older control, and older musicians and compared alpha oscillation activity after correcting the aperiodic component. We found that the aperiodic exponent and alpha power are smaller in older subjects than in young subjects. Meanwhile, we found a mitigating effect of music training on age-related alpha power reduction by comparing older control and musicians, which led to better performance in working memory tasks in older musicians. This work points out that aperiodic activity plays a vital role in cognitive aging, and correcting for it affects neural oscillations in cognitive aging regulation using music. Thus, it is necessary to investigate the possible changes caused by correcting for aperiodic activity in the mismatch negativity (MMN) studies, which could provide us with a perspective on the role of MMN in music intervention in cognitive aging.

Talk 4: Music Training and the Deployment of Attention: Evidence from an Auditory Attentional Blink Paradigm

Claude Alain

Rotman Research Institute, Baycrest Centre. Canada

The generalization of music training to unrelated non-musical domains is well established and may reflect musicians' superior ability to regulate attention. Combining scalp recording of neuroelectric brain activity with an attentional blink (AB) paradigm, we investigated the temporal deployment of attention in musicians and non-musicians. Participants listened to rapid sequences of stimuli and identified target and probe sounds. The AB was defined as a probe identification deficit when the probe closely follows the target. A neutral or informative cue about the probe position within the sequence preceded the sequence of stimuli. Musicians outperformed non-musicians in identifying the target and probe. In both groups, cueing improved target and probe identification and reduced the AB. We observed a processing deficit when the probe immediately followed the target, and this auditory AB was accompanied by reduced P3b amplitude. We also observed modulation of the N1/mismatch negativity elicited during the AB condition. Music training mitigated cue-related activity and brain responses elicited by the probe. Together, these results reveal musicians' superior ability to regulate attention, allowing them to prepare for incoming stimuli, thereby improving sound object identification. This capacity to manage attentional resources to optimize task performance may generalize to non-musical activities. The benefit of musical activities on attentional regulation is exciting because they open new avenues for developing innovative remediation programs and improving current rehabilitation protocols to enhance attention and executive control processes from children to late adulthood.

Wednesday 18th, September 2024

Keynote 2: *09:00 – 10:00*

"A cortical circuit for visual mismatch responses"

Lecturer: Jordan Paul Hamm

Neuroscience Institute Georgia State University. USA

Symposium 5: *10:00 – 11:30*

PREDICTION IN ACTION: PROBING ERROR AND PREDICTION SIGNALS IN SINGLE-NEURONS DURING ACTIVE SENSATION

Chairperson/s: Yaneri A. Ayala[1] and Steven J. Eliades[2]
[1]Department of Neurosurgery, University of Iowa, USA.
[2]Duke University School of Medicine, Durham, NC USA.

Talk 1: Vocal Sensory-Prediction and Error Mechanisms in Marmoset Auditory Cortex
Steven J. Eliades
Department of Head and Neck Surgery & Communication Sciences. Departments of Neurobiology, Biomedical Engineering. Duke University School of Medicine, Durham, NC USA.

Talk 2: A sensory-motor circuit links action to expected outcome
David M. Schneider
Center for Neural Science, New York University. USA

Talk 3: Multimodal mismatch responses in the mouse auditory cortex
Magdalena Solyga[1] and Georg B. Keller[1,2]
[1]Friedrich Miescher Insitute for Biomedical Research, Basel, Switzerland.
[2]Faculty of Science, University of Basel, Basel, Switzerland.

Talk 4: Single neuron activity in the human and non-human primate brain to unexpected events
Yaneri A. Ayala
Department of Neurosurgery, University of Iowa, USA. Laboratory of Comparative Neuropsychology, Newcastle University, UK.

Talk 1: Vocal Sensory-Prediction and Error Mechanisms in Marmoset Auditory Cortex

Steven J. Eliades

Department of Head and Neck Surgery & Communication Sciences. Departments of Neurobiology, Biomedical Engineering. Duke University School of Medicine, Durham, NC USA.

During both human speech and non-human primate vocalization, there is a well described suppression of activity in the auditory cortex. Despite this suppression, the auditory cortex exhibits increased sensitivity to perturbations in sensory feedback, a phenomenon that is important for vocal control, allowing us to rapidly compensate for changes in acoustic feedback during vocal production. However, many of the underlying neural mechanisms for this process remain uncertain. Here we summarize recent results from neural and behavioral recordings of vocalizing marmoset monkeys. These experiments suggest that vocal suppression and feedback sensitivity may represent an auditory error signal, a comparison between vocal feedback and top-down sensory predictions. We present evidence that these predictions likely originate in the frontal vocal motor system and are mediated through local circuits within the auditory cortex itself. These sensory-motor comparisons, and resulting feedback error signals, can be seen at both the individual unit and population levels. Importantly, this encoding of feedback error can predict subsequent feedback-dependent vocal control, and is causally involved in such control behaviors. Vocal sensory prediction and error calculation exhibits many features common to predictive coding and mismatch negativity, and we suggest may share similar underlying circuit mechanisms.

This work was supported by NIH/NIDCD Grant K08-DC014299, R01-DC018525

Talk 2: A sensory-motor circuit links action to expected outcome

David M. Schneider

Center for Neural Science, New York University. USA

The cortex integrates sound- and movement-related signals to predict the acoustic consequences of behavior and detect violations from expectations. Although expectation- and prediction-related activity has been observed in the auditory cortex of humans, monkeys, and mice during vocal and non-vocal acoustic behaviors, the specific cortical circuitry required for forming memories, recalling expectations, and making predictions remains unknown. By combining closed-loop behavior, electrophysiological recordings, longitudinal pharmacology, and targeted optogenetic circuit activation, we identify a cortical locus for the emergence of expectation and error signals. Movement-related expectation signals and sound-related error signals emerge in parallel in the auditory cortex and are concentrated in largely distinct neurons, consistent with a compartmentalization of different prediction-related computations. On a trial-by-trial basis, expectation and error signals are correlated in auditory cortex, consistent with a local circuit implementation of an internal model. Silencing the auditory cortex during motor-sensory learning prevents the emergence of expectation signals and error signals, revealing the auditory cortex as a necessary node for learning to make predictions. Prediction-like signals can be experimentally induced in the auditory cortex, even in the absence of behavioral experience, by pairing optogenetic motor cortical activation with sound playback, indicating that cortical circuits are sufficient for movement-like predictive processing. Finally, motor-sensory experience realigns the manifold dimensions in which auditory cortical populations encode movement and sound, consistent with predictive processing. These findings show that prediction-related signals reshape auditory cortex dynamics during behavior and reveal a cortical locus for the emergence of expectation and error.

Talk 3: Multimodal mismatch responses in the mouse auditory cortex

Magdalena Solyga[1] and Georg B. Keller[1,2]

[1]*Friedrich Miescher Insitute for Biomedical Research, Basel, Switzerland.*
[2]*Faculty of Science, University of Basel, Basel, Switzerland.*

Primary sensory areas of cortex have been shown to compute sensorimotor prediction errors in their respective modalities. However, for most coupling of movement with sensory feedback, this coupling is not limited to just one sensory stream. How sensory input in one modality influences the computation of sensorimotor prediction errors in a different modality is still unclear. Here we use coupling between running and both auditory and visual feedback generated in a virtual environment to the investigate multimodal integration of prediction errors. We used two photon recordings in L2/3 of primary auditory cortex to characterize responses to sounds, visual stimuli, and running onsets and found that those signals converge on the same cells suggesting that cross modal prediction errors could be calculated here. Probing responses evoked by audiomotor mismatches we found that they closely resemble visuomotor mismatches reported previously in visual cortex. Finally, coupling both sound amplitude and visual flow speed to the speed of running, we found that mismatch responses were amplified with increased number of available top-down information streams. Thus, we demonstrate that prediction errors can be potentiated by cross-modal interactions in cortical layer 2/3.

Talk 4: Single neuron activity in the human and non-human primate brain to unexpected events

Yaneri A. Ayala

Department of Neurosurgery, University of Iowa, USA. Laboratory of Comparative Neuropsychology, Newcastle University, UK.

Our ability to extract the temporal structure and the ordering relationships between auditory events in a sequence is fundamental for cognition. The granularity on how cortical circuits process expected and unexpected events when perceiving an acoustic stream or when using sensory information to guide our behaviors remains widely unexplored. To address this question, we study the activation dynamics of auditory cortical neurons recorded in behaving rhesus monkeys and awake epilepsy patients using massive and simultaneous extracellular recordings. First, we present how top-down motor-related and bottom-up sensory signals are encoded by a broad set of core and belt neurons while monkeys synchronize their movements to rhythmic acoustic metronomes. Importantly, subsets of auditory neurons maintain or increase their activation profiles to unexpected omissions of the sensory information during the execution of the synchronization task. Second, we report the first indication of human single-unit activity sensitive to sequence ordering relationships. Here, participants are exposed to an auditory statistical learning paradigm by listening to sequences of nonsense words with high- and low-probability transitions in their ordering relationships. We observe modulations in the neural activity that reflect sequencing prediction (high probability) and prediction error (low probability) signals. Results from both studies indicate that single neurons encode information on the expected timing and relationships of auditory events within a sequence and contribute to understand auditory processing in the primate brain during active and passive contexts.

Wednesday 18th, September 2024

Symposium 6: *12:00 – 13:30*

MISMATCH RESPONSES IN POPULATIONS WITH DEVELOPMENTAL DISORDERS

Chairperson/s: Axelle Calcus[1] and Kristin Uhler[2]
[1]*Center for Research in Cognition & Neurosciences. Université Libre de Bruxelles. Belgium*
[2]*Department of Physical Medicine and Rehabilitation. University of Colorado. USA*

Talk 1: Basic determinants of MMN elicitation in simple and complex listening environments during neurotypical development
Elyse Sussman
Albert Einstein College of Medicine. USA

Talk 2: Development among infants with hearing differences auditory access
Kristin Uhler[1,2], Philip M. Gilley[1,4] and Daniel J. Tollin[3]
[1]*Department of Physical Medicine and Rehabilitation. University of Colorado. USA.*
[2]*Institute of Cognitive Science, University of Colorado, Boulder.*
[3]*Department of Physiology & Biophysics, University of Colorado Anschutz Medical Campus. USA.*
[4]*Institute of Cognitive Science, University of Colorado, Boulder*

Talk 3: Comparing Mismatch Responses to Speech in Typical and Atypical Language Development versus Adult's MMNs using Inter-trial Phase Coherence
Ana Campos[1,2], Jyrki Tuomainen[3] and Outi Tuomainen[4]
[1]*UCL Ear Institute, University College London, London WC1E 6BT, UK*
[2]*Carrera de Fonoaudiología, Universidad San Sebastián, Lota 2465, Santiago 7510602, Chile*
[3]*Department of Speech, Hearing and Phonetic Sciences, University College London. UK*
[4]*Department of Linguistics, University of Potsdam. Germany*

Talk 4: Effect of childhood hearing loss on subcortical and cortical processing of speech
Axelle Calcus
Center for Research in Cognition & Neurosciences (CRCN). Université Libre de Bruxelles (ULB).

Talk 1: Basic determinants of MMN elicitation in simple and complex listening environments during neurotypical development

Elyse Sussman

Albert Einstein College of Medicine. USA

Auditory scene analysis makes it possible for infants and children to distinguish their mother's voice from other noises in the environment. From the moment we are born, we discern meaningful characteristics of the complex sound input. However, little is known about how these auditory processes change with maturation. The mismatch negativity (MMN) can provide a window into sound processing that does not require performance responses, making it an ideal tool to study how complex processes of perceptual sound organization develop during childhood. In this talk, I will provide an overview of how the MMN component can be used to index neurodevelopmental changes in sound perception in simple and complex listening situations. Studies will demonstrate, in children ages 7-17 years, that the acuity of scene perception continues to develop through adolescence. Results will also highlight the relationship between performance measures and MMN indices of scene perception and will be used to show how brain measures provide indicators of neurotypical development. The relevance for understanding disorders of auditory processing at different stages of life will be briefly discussed.

Talk 2: Development among infants with hearing differences auditory access

Kristin Uhler[1,2], Philip M. Gilley[1,4] and Daniel J. Tollin[3]

[1]*Department of Physical Medicine and Rehabilitation. University of Colorado. USA.*
[2]*Institute of Cognitive Science, University of Colorado, Boulder.*
[3]*Department of Physiology & Biophysics, University of Colorado Anschutz Medical Campus. USA.*
[4]*Institute of Cognitive Science, University of Colorado, Boulder*

Hard-of-hearing infants (IHH) are at risk for poor auditory development and speech perception, despite early detection and intervention. Developing a tool to identify at-risk children that can be used among IHH and infants with normal hearing (INH) is a focus of our lab. We have refined the mismatched response (MMR) paradigm which can be effectively used among IHH and INH. Specifically, we have examined the effects of hearing aid amplification on auditory detection and discrimination among IHH (n=41) where we recorded EEG while presenting auditory stimuli in a MMR paradigm. Responses were recorded during two listening conditions: aided and unaided. Temporal envelopes of MMR in the EEG alpha band were extracted from the latent, time-frequency transformed data. Aided alpha band responses were greater than unaided responses for deviant trials. Responses to deviant were greater than responses to standard trials for aided conditions but were not different for unaided conditions. Results suggest that alpha band MMR can be used to examine both detection and discrimination of speech and non-speech sounds in IHH. Currently, we are using our modified MMR paradigm to examine perceptual changes over the first year of life among IHH and INH. The first year is important for early perceptual development of spectral and temporal features, or cues, that favor discrimination of behaviorally relevant information. Past research suggests that early perceptual skill development is driven by an interaction of language experiences and concurrent maturation of auditory sensory pathways. Because refinement of speech discrimination abilities depends on exposure to speech, IHH are susceptible to atypical development during this period. What remains unknown is the impact of inconsistent auditory cue access and poor speech perception among IHH. We present data comparing neural encoding of native and nonnative speech sounds among IHH and INH at 3, 6, and 12 months of age.

Talk 3: Comparing Mismatch Responses to Speech in Typical and Atypical Language Development versus Adult's MMNs using Inter-trial Phase Coherence

Ana Campos[1,2], Jyrki Tuomainen[3] and Outi Tuomainen[4]

[1]*UCL Ear Institute, University College London, London WC1E 6BT, UK*
[2]*Carrera de Fonoaudiología, Universidad San Sebastián, Lota 2465, Santiago 7510602, Chile*
[3]*Department of Speech, Hearing and Phonetic Sciences, University College London. UK*
[4]*Department of Linguistics, University of Potsdam. Germany*

In infants and young children, the MMN is known as the Mismatch Response (MMR), which has a different morphology than the adult response. This variability results from typical neuromaturational processes and is often higher in clinical populations, making it hard to compare children and adults responses or establish MMR developmental trajectories.
Besides conventional time-domain measures as amplitude and latency, time-frequency (TF) analysis may be key to understand of how MMRs develops, as it informs about non-stimulus-locked neural activity. In particular, inter-trial phase coherence (ITPC) is an amplitude and polarity-free measure, useful for studying MMRs in neurotypical and clinical paediatric populations.
We compared MMR/MMN to phonemic changes in three groups of participants: preschoolers with typical language development (TLD), preschoolers with Developmental Language Disorder (DLD) and adults. We complemented conventional ERP measures with TF indices of oscillatory phase synchrony and spectral power. Because of previously identified links between phonological deficits and speech-processing difficulties in DLD, we also assessed children's phonological skills and examined their association with the MMR.
Time-domain measures revealed significant MMR/MMNs in all the participant groups for all stimulus types. However, the responses in children and adults varied greatly in terms of polarity, timing, and amplitude, complicating between-group statistical comparisons.
On the other hand, TF analyses allowed us to compare the effects of group and stimulus type regardless of the MMN/MMR patterns. Adults showed significantly higher ITPC than children in the theta and alpha bands, especially for stimuli involving meaning, although such effects were not observed for spectral power changes. Interestingly, we found no MMR differences between DLD and TLD children and no association between phonological skills and any MMR measures, even though the DLD group's phonological skills were significantly lower.
We will argue for the need to include inter-trial phase coherence measures when performing MMR developmental comparisons.

Talk 4: Effect of childhood hearing loss on subcortical and cortical processing of speech

Axelle Calcus

Center for Research in Cognition & Neurosciences (CRCN). Université Libre de Bruxelles (ULB).

Little is known about the effects of childhood mild-to-moderate sensorineural hearing loss HL on the function of the central auditory pathway. We aimed to examine the effect of childhood HL and the benefit of frequency-specific amplification on both subcortical and cortical auditory processing, and to relate it to speech-perceptual abilities. Cortical processing was indexed by the P1, N2 and MMN evoked by speech syllables (/ba/-/da/) in an oddball paradigm. Subcortical processing was indexed by the frequency-following response evoked by the standard syllables of the oddball paradigm. We recorded event-related responses in nineteen children with congenital mild-to-moderate HL (unamplified and amplified), and sixteen children with normal hearing (unamplified sounds only). Speech perception was measured behaviourally. Congenital HL led to smaller subcortical and cortical responses to unamplified speech sounds. There was a significant benefit of amplification on subcortical responses as well as early (P1), but not late (N2 and MMN), cortical responses, with some effects differing across age. No relationship was found between the neural and behavioural measures. Childhood mild-to-moderate HL affects both subcortical and cortical processing of speech. Amplification mostly benefits subcortical processing of speech in younger children. Childhood HL leads to functional changes in the processing of sounds, with amplification differentially affecting the function of subcortical and cortical levels of the auditory pathway.

Wednesday 18th, September 2024

Symposium 7: *12:00 – 13:30*

vMMN - The Poor Relative of MMN?

Chairperson/s: Kairi Kreegipuu
Institute of Psychology. University of Tartu. Estonia.
Estonian Center of Excellence of Well-Being Sciences

Talk 1: The more complex the better? – Visual change detection at different levels of complexity
Dagmar Müller
Wilhelm-Wundt-Institute of Psychology, Leipzig University. Germany.

Talk 2: Investigating the Contribution of Visual MMN to Posterior Negativity in Processing Geometrical Shape Deviants
Ann-Kathrin Beck[1], Thomas Lachmann[1] and Motohiro Kimura[2]
[1]*University of Kaiserslautern-Landau, Germany.*
[2]*National Institute of Advanced Industrial Science and Technology (AIST), Japan*

Talk 3: The roles of stimulus-specific adaptation and micro-sequences in visual mismatch negativity: Are there any?
Lili Kővári[1], Petia Kojouharova[2], Zsófia Anna Gaál[2] and István Czigler[2]
[1]*Doctoral School of Psychology, Eötvös Loránd University, Budapest, Hungary.*
[2]*Institute of Cognitive Neuroscience and Psychology, HUN-REN Research Centre for Natural Sciences, Budapest, Hungary.*

Talk 4: What are the relationships associated with a simple vMMN for letters?
Kairi Kreegipuu
Institute of Psychology, University of Tartu. Estonia; Estonian Center of Excellence of Well-Being Sciences

Talk 1: The more complex the better? – Visual change detection at different levels of complexity

Dagmar Müller

Wilhelm-Wundt-Institute of Psychology, Leipzig University. Germany.

It´s old news that our brain constantly checks incoming sensory information for the occurrence of regularities which form the basis of internal models predicting upcoming stimulation. For the auditory modality there are plenty of well-controlled studies showing that the auditory system is capable of extracting regularities in sound sequences. Such regularities can be defined by low-level features of the acoustic stimulation on the one hand but also on complex contingent relations between adjacent sounds on the other hand. Violations of both low-level and highly complex regularities are indicated by the auditory mismatch negativity (aMMN). In the past two decades various groups investigated the capability of the visual system to extract regularities within visual stimulus sequences, that is a visual analog of the MMN. In my talk I aim to discuss (seemingly?) contradictory results found when presenting the visual system with regularities defined by low-level (Male et al., 2020) versus complex regularities (Müller et al., 2013 & unpublished results): Violations of regularities defined by the fundamental visual dimensions orientation, spatial frequency or contrast did not elicit a genuine vMMN in a controlled paradigm whereas violations of more complex object-target-contingencies did. These results suggest that the visual system unlike the auditory one might use different mechanisms to process regularities of stimulus sequences defined by different levels of complexity.

Talk 2: Investigating the Contribution of Visual MMN to Posterior Negativity in Processing Geometrical Shape Deviants

Ann-Kathrin Beck[1], Thomas Lachmann[1] and Motohiro Kimura[2]

[1]*University of Kaiserslautern-Landau, Germany.*
[2]*National Institute of Advanced Industrial Science and Technology (AIST), Japan*

Automatic deviance detection in vision is reflected by the deviant-related posterior negativity, which is elicited in response to infrequent deviant stimuli that are embedded in a repetitive presentation of frequent standard stimuli (i.e., the oddball sequence). However, the deviant-related posterior negativity is considered to comprise two, temporally and spatially overlapping ERP effects: (1) refractoriness-related modulations of visual-evoked potentials and (2) a generation of visual mismatch negativity (MMN) reflecting a memory-based mismatch detection. To examine the contribution of a memory-based mismatch detection, previous studies have used the equiprobable sequence with control stimuli in addition to the oddball sequence and provided evidence for the contribution of a memory-based mismatch detection for several visual features (e.g., color, orientation, and motion-direction). Our study extends them to a visual feature, geometrical shape.
We utilized compounded figures featuring a larger (i.e., global) geometrical shape composed of smaller (i.e., local) geometrical shapes. Participants were required to view four types of stimulus sequences: (1) a local oddball sequence where the deviant (20%) differed from the standard (80%) only in local shape, (2) a global oddball sequence where the deviant (20%) differed from the standard (80%) only in globalshape, (3) a local equiprobable sequence where the five types of controls (20% each) differed from each other only in localshape, and (4) a global equiprobable sequence where the five types of controls (20% each) differed from each other only in global shape. To extract visual MMN in response to deviants for local and global shapes, the deviant-minus-control comparisons were made for local and global sequences, respectively.
The significant generation of visual MMN was observed via the deviant-minus-control comparisons. For the local deviant, the visual MMN had a parieto-occipital scalp distribution with right-hemispheric dominance and an onset at around 210-220 ms and a peak at around 310-320 ms. For the global deviant, the visual MMN had a parieto-occipital scalp distribution with right-hemispheric dominance and an onset at around 160-170ms and a peak at around 200-210 ms. These results provide evidence for the significant contribution of a memory-based mismatch detection for geometrical shape and highlight the significance of combining oddball and equiprobable sequences to unentangle ERP effects related to a memory-based mismatch detection and refractoriness-related modulations of visual-evoked potentials.

Talk 3: The roles of stimulus-specific adaptation and micro-sequences in visual mismatch negativity: Are there any?

Lili Kővári[1], Petia Kojouharova[2], Zsófia Anna Gaál[2] and István Czigler[2]

[1]*Doctoral School of Psychology, Eötvös Loránd University, Budapest, Hungary.*
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Visual mismatch negativity (vMMN), the difference between the event-related potentials (ERPs) to repeated events and changing events can be caused by the diminished activity to the repeated ones (stimulus-specific adaptation, SSA), the increased activity to the new ones, or by both effects. We investigated the effect of stimulus repetition on visual ERPs. We applied the OFF-ON stimulation, i.e., the alternation of whole and truncated objects. We analyzed ERPs to both kinds of stimulus changes (disappearance of a part of the whole: OFF, and reappearance of the whole: ON). We analyzed repetition effects within oddball and 50% sequences. There was no adaptation on the N1 component in the non-oddball sequences, but vMMN emerged to the OFF events in the oddball sequences. Therefore vMMN cannot be explained as a pure adaptation effect.

Talk 4: What are the relationships associated with a simple vMMN for letters?

Kairi Kreegipuu

Institute of Psychology, University of Tartu. Estonia; Estonian Center of Excellence of Well-Being Sciences

vMMN is often defined by analogy with auditory MMN: it is the ability to detect unexpected differences in usual visual input, and this ability is realized without active attention. Both auditory and visual MMN are typically disrupted (i.e., amplitude decreases and/or latency increases) when an individual's condition deteriorates. Therefore, if a simple measurement method can be found, both MMNs have the potential to be convenient predictors of a person's state. Between 2020 and 2024, we collected data on a very simple vMMN (using letters B and T, an oddball paradigm with the reversed design) from approximately 200 individuals (18-45 yrs), and in the talk, I'll share preliminary results regarding vMMN reliability and validity here. The experimental package related to the auditory and visual MMN conditions also included a variety of psychological tasks: a 2-back working memory task with consonant letters (concurrent with (v)MMN), a dichotic listening, a choice reaction time, Estonian matrices (an analogue to the Raven's matrices), a number-symbol substitution test, a stop-signal task, a numerosity estimation task, and working memory tasks for forward and backward spans. Additionally, participants were assessed using personality, mood, fatigue, and regular smartphone usage questionnaires. Investigating these associations is crucial for identifying potential causal relationships and refining the concept of vMMN.

Wednesday 18th, September 2024

Symposium 8: *15:00 – 16:30*

INSIGHTS INTO PREDICTIVE PERCEPTION: UNDERSTANDING THE ROLE OF CONTEXT

Chairperson/s: **Lonike Faes and Mahdi Enan**
Faculty of Psychology and Neuroscience
Maastricht University

Talk 1: Predictive processing in context
Ryszard Auksztulewicz and Hannah McDermott
Free University Berlin

Talk 2: Exploring Predictive Auditory Processing Using High-Field fMRI and MEG
Jorie van Haren[1], Lonike Faes[1], Mahdi Enan[1], Floris de Lange[1], Sonja Kotz[1] and Federico De Martino[1,3]
[1]*Faculty of Psychology and Neuroscience, Maastricht University, The Netherlands*
[2]*Donders Centre for Cognitive Neuroimaging, Nijmegen, The Netherlands*
[3]*Center for Magnetic Resonance Research, Minneapolis, USA*

Talk 3: Pre-stimulus alpha oscillations encode stimulus-specific visual predictions
Dorottya Hetenyi, Joost Haarsma and Peter Kok
Wellcome Centre for Human Neuroimaging, University College London. UK

Talk 4: Flexible and efficient representations through predictions in the macaque face-processing hierarchy
Tarana Nigam[1,2] and Caspar M. Schwiedrzik[1,2]
[1]*Neural Circuits and Cognition Lab, European Neuroscience Institute Göttingen - A Joint Initiative of the University Medical Center Göttingen and the Max Planck*
[2]*Institute for Multidisciplinary Sciences, 37077 Göttingen, Germany; Perception and Plasticity Group, German Primate Center, Leibniz Institute for Primate Research, 37077 Göttingen, Germany.*

Talk 1: Predictive processing in context

Ryszard Auksztulewicz and Hannah McDermott

Free University Berlin

The brain is thought to generate internal predictions, based on the memory of past stimulation, to optimise behaviour. Predictive processing has been repeatedly demonstrated in non-invasive studies on human volunteers and in animal models. However, it is unclear to what extent auditory predictions are modulated by other contextual factors such as attention and task demands. In this talk I will present results of several studies combining neural recordings in humans and rodents with computational modelling to identify the brain mechanisms of sensory predictions and their interactions with other cognitive factors. First, in a series of studies in humans, analysis of behavioural and neural data shows that the effects of predictions are not automatic but are modulated by their contextual relevance. Second, computational modelling of the data suggests that these modulations can be linked to specific candidate mechanisms, including gain control in sensory regions. Finally, in a recent electroencephalography study investigating the effects of predictions during associative learning, we show that the effects of stimulus predictability are dynamic at both short and long time scales. Specifically, the study shows that, within trials, valid predictions of visual stimulus category increase stimulus decoding at short latencies (consistent with representational sharpening) but decrease decoding at longer latencies (consistent with suppressive or dampening effects of predictions). Interestingly, across trials, valid predictions show opposite dynamics, such that putative dampening occurs at early stages of associative learning, and putative sharpening needs more time to build up. Taken together, these findings show that predictive processing is not mediated by a uniform neural process, but can rather be linked to context-specific mechanisms.

Talk 2: Exploring Predictive Auditory Processing Using High-Field fMRI and MEG

Jorie van Haren[1], Lonike Faes[1], Mahdi Enan[1], Floris de Lange[1], Sonja Kotz[1] and Federico De Martino[1,3]

[1]*Faculty of Psychology and Neuroscience, Maastricht University, The Netherlands*
[2]*Donders Centre for Cognitive Neuroimaging, Nijmegen, The Netherlands*
[3]*Center for Magnetic Resonance Research, Minneapolis, USA*

To make sense of the complex soundscape of our dynamic surroundings, human listeners continuously rely on contextual cues to form predictions about what is likely to occur next. Throughout the auditory processing hierarchy, acoustic content of sounds undergoes feedforward processing to extract complex information. This process is complemented by extensive feedback mechanisms, which are believed to add flexibility to auditory perception by predicting inputs and compensating for incomplete or noisy information. In this presentation, we build on this notion and delve into the neural dynamics underpinning sound processing in context. Employing ultra-high-field functional magnetic resonance imaging (7T fMRI) and magnetoencephalography (MEG), we examine both the spatial and temporal dynamics involved in the interplay between context and perception. First, we employed oddball paradigms to examine how deviations from the norm are processed within the mesoscopic circuitry of the auditory cortex, revealing the distinct roles of the cortical laminae in the processing of unpredictable and mispredictable sounds. Second, we investigated scenarios in which the auditory environment is ambiguous, lacking a consistent norm. In such cases, listeners must continuously adjust their model of the environment based on past acoustic statistics. Our findings show that the content of feedback can vary wildly depending on the strength of a listener's expectations and volatility of the environment. Third, we explored how predictive representations are formed within the framework of an audio-visual associative learning paradigm. The main focus of this study is on content-specific predictions and their link to stimulus-specific gain modulation. Results highlight the structural organization of the cortical laminae in facilitating content-specific auditory predictions. Together, these findings suggest a dynamic, contextually sensitive neural processing model, highlighting the brain's predictive capabilities throughout the hierarchy.

Talk 3: Pre-stimulus alpha oscillations encode stimulus-specific visual predictions

Dorottya Hetenyi, Joost Haarsma and Peter Kok

Wellcome Centre for Human Neuroimaging, University College London. UK

Our prior knowledge greatly influences how we perceive the world. However, it remains unclear how the brain keeps predictions online in anticipation of a stimulus. Here, using magnetoencephalography and decoding techniques, we investigated whether predicted visual shapes were encoded in pre-stimulus oscillations. Participants were engaged in a shape discrimination task while auditory cues predicted which specific shape would likely appear. We trained a shape decoder on a separate localiser run, and applied this decoder to the pre-stimulus time window to test for shape-specific representations of predicted stimuli. To test whether these representations oscillated, we conducted frequency analyses on the shape decoding traces. Our results revealed significant oscillatory fluctuations in the pre-stimulus decoded time series, predominantly in the alpha band within the 10 – 11Hz frequency range. Furthermore, we found that this stimulus-specific alpha power was linked to behaviour, such that higher alpha power resulted in stronger expectation effects on shape discrimination performance. Together, our findings demonstrate that sensory predictions are embedded in pre-stimulus alpha oscillations and modulate subsequent perceptual performance, providing a neural mechanism through which the brain deploys perceptual predictions.

Talk 4: Flexible and efficient representations through predictions in the macaque face-processing hierarchy

Tarana Nigam[1,2] and Caspar M. Schwiedrzik[1,2]

[1]*Neural Circuits and Cognition Lab, European Neuroscience Institute Göttingen - A Joint Initiative of the University Medical Center Göttingen and the Max Planck*
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Computing predictions and prediction errors is thought of as an efficient neural mechanism – but often only in terms of metabolic costs – i.e. decrease in firing rate amplitudes or reduction of spikes in single neurons. But how predictions benefit perception, likely comes about through a context-dependent restructuring of neural representations responsible for perception or recognition. Here, we ask how predictions and prediction errors give rise to efficient and flexible neural representations for perception, specifically in the paradigmatic case of face recognition. We investigate this in the macaque monkey's face-processing system, a 3-level processing hierarchy in ventral visual cortex. Distinguishing faces constitutes a significant computational challenge that relies on well separable neural representations which are also invariant to changes like pose. These representations are usually inherent to the top of the face-processing hierarchy. We hypothesize that top-down predictions endow early areas with already highly separable and invariant representations. To this end, we conduct both functional neuroimaging and in-vivo electrophysiology in macaque monkeys after predictions are learnt through statistical learning. We find that in the presence of predictions, early stages of the macaque face-processing hierarchy exhibit well separable and high-dimensional neural geometries otherwise characteristic only of the top of the hierarchy. This is accompanied by a systematic shift of representations from higher to lower areas, endowing lower areas with higher-order, invariant representations instead of their feedforward tuning properties. Thus, top-down signals don't just refine the existing representation, but rather radically transform neural representations of faces towards higher-order, separable and high-dimensional neural geometries in a highly dynamic and flexible manner. Our results provide evidence how predictive context transforms flexible representational spaces to optimally use the computational resources provided by cortical processing hierarchies for better and faster distinction of facial identities. Therefore, flexibility of neural representations that predictions enable offers a fresh perspective on how predictions lead to efficient processing for perception.

Wednesday 18th, September 2024

Symposium 9: *16:45 – 18:15*

PROCESSING OF PREDICTABLE AND NON-PREDICTABLE MELODIC AND RHYTHMIC SEQUENCES

Chairperson/s: Aurélie Bidet-Caulet and Anne Caclin
Lyon Neuroscience Research Center

Talk 1: What are the neural mechanisms of temporal prediction in probabilistic sensory contexts?
Pierre Bonnet, Mathilde Bonnefond and Anne Kösem
Lyon Neuroscience Research Center (CRNL), Computation, Cognition and Neurophysiology team (Cophy), Lyon, France

Talk 2: The influence of tempo on neural encoding of rhythmic hierarchy in premature newborns
Mohammadreza Edalati[1], Fabrice Wallois[1], Ghida Ghostine[1], Guy Kongolo[1], Laurel J. Trainor[2], and Sahar Moghimi[1]
[1]Institut National de la Santé et de la Recherche Médicale, Unité Mixte de Recherche 1105, Groupe de Recherches sur l'Analyse Multimodale de la Fonction Cérébrale (GRAMFC), Université de Picardie, 80054 Amiens, France.
[2]Department of Psychology, Neuroscience, and Behaviour, McMaster University, Hamilton, Ontario L8S 3L8, Canada

Talk 3: Musical expectations and neural error responses in natural music listening
Paul Robert[1,2], Mathieu Pham Van Cang[3], Manuel Mercier[1], Agnès Trébuchon[1,4], Luc Arnal[3], Keith Doelling[3] and Benjamin Morillon[3]
[1]Institut de Neurosciences des Systèmes, Aix-Marseille Université, Inserm UMR 1106, Marseille, F France
[2]Institute for Language, Communication, and the Brain, Aix-Marseille Université, Marseille, France
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[4]APHM, Hôpital de la Timone, Service de Neurophysiologie Clinique, Marseille, France

Talk 4: Musical expectations in human and non-human primates
Roberta Bianco[1], Nathaniel J. Zuk[2], Felix Bigand[1], Eros Quarta[3], Stefano Grasso[3], Flavia Arnese[1], Andrea Ravignani [3,4,5], Alexandra Battaglia-Mayer[3] and Giacomo Novembre[1]
[1]Italian Institute of Technology, Rome, Italy
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[5]Aarhus University & The Royal Academy of Music, Aarhus, Denmark

*Presenting authors are highlighted in blue

Talk 1: What are the neural mechanisms of temporal prediction in probabilistic sensory contexts?

Pierre Bonnet, Mathilde Bonnefond and Anne Kösem

Lyon Neuroscience Research Center (CRNL), Computation, Cognition and Neurophysiology team (Cophy), Lyon, France

Current theories link observed neural oscillatory dynamics to temporal predictions mechanisms. These theories propose that neural oscillations indicate cyclic fluctuations in excitability that align with the onset of expected events in time. Such alignment occurs in the presence of periodic auditory streams and when the temporal intervals between sounds are fully predictable, and is associated with enhanced sound discrimination when the targets are presented at the expected timing. However, in more naturalistic environments as speech or music, while being temporarily regular, sensory events may also occur with a certain amount of temporal variability. Thus, if neural oscillations are relevant for temporal predictions mechanisms in more naturalistic contexts, we should expect that both auditory perception and neural oscillatory activity are influenced by the temporal variability of the temporal context in the presence of probabilistic auditory streams. To test this, we ran an EEG experiment where participants were asked to discriminate between standard and deviant sounds that were embedded in 3 min-long sound sequences. The Stimuli Onset Asynchrony (SOA) of the sequences were drawn from distributions with the same mean (500 ms) but distinct distribution profiles: periodic, Gaussian distributions with 25 ms and 150 ms SD, uniform. First results support previous findings (Bonnet et al., 2024) and indicate that temporal context affects perception. The more regular temporal sequences show better behavioral performances in both auditory discrimination and response times. Notably, evoked responses to the target sound were also influenced by the temporal context alone: targets that were presented in more regular sound sequence showed increased P300 response. Time frequencies fluctuations are still being analyzed but are also expected to variate with the level of temporal predictability of the sound sequences.

Bonnet, P., Bonnefond, M., & Kösem, A. (2024). What is a rhythm for the brain?
The impact of contextual temporal variability on auditory perception. Journal of Cognition, 7(1).

Talk 2: The influence of tempo on neural encoding of rhythmic hierarchy in premature newborns

Mohammadreza Edalati[1], Fabrice Wallois[1], Ghida Ghostine[1], Guy Kongolo[1], Laurel J. Trainor[2], and Sahar Moghimi[1]

[1]Institut National de la Santé et de la Recherche Médicale, Unité Mixte de Recherche 1105, Groupe de Recherches sur l'Analyse Multimodale de la Fonction Cérébrale (GRAMFC), Université de Picardie, 80054 Amiens, France.
[2]Department of Psychology, Neuroscience, and Behaviour, McMaster University, Hamilton, Ontario L8S 3L8, Canada

Perceiving time intervals and structure of rhythmic patterns are of fundamental importance during early development, for instance for language, music, and social skills. Our previous studies in premature infants at 30-34 weeks gestational age (wGA) revealed selective enhancement of the neural response (in terms of frequency tagging) to two-beat grouping (duple meter) compared to single beats, in a 6-beat ambiguous rhythm, contrasting with an absence of enhancement for three- beat grouping (triple meter). Subsequently, in premature infants at 28-36 wGA, we demonstrated that while the neural response to the beat is present even at the beginning of the third trimester of gestation, the neural response to beat groupings develops gradually with significant neural responses to groupings of beats only near-term. Beat groups are at slower tempi than the beat, so these findings raised the question about whether the lack of early response to beat groups stemmed from very young infants' difficulty processing long periodic cycles.
To address this question, we recorded electroencephalography in early premature newborns (27-32 wGA), while exposed to the same 6-beat ambiguous rhythmic pattern at two tempi: the beat frequency was 3.33 Hz and 6.66 Hz for slow and fast tempi, respectively. We observed significant neural synchronization to the periodicity related to the beat and duple meter frequencies at both tempi, whereas neural synchronization to the periodicity related to the triple meter was only significant for the fast tempo. We conclude that tempo (cycle duration) plays an important role in the neural coding of the rhythmic hierarchy at this stage of neurodevelopment and that neural synchronization to slower periodicity arrives at later a gestational age. These results shed light on early neural capacities for coding temporal regularities and together with our previous studies highlight the fast evolution of rhythm processing during this phase of neurodevelopment.

Talk 3: Musical expectations and neural error responses in natural music listening

Paul Robert[1,2], Mathieu Pham Van Cang[3], Manuel Mercier[1], Agnès Trébuchon[1,4], Luc Arnal[3], Keith Doelling[3] and Benjamin Morillon[3]

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[4]*APHM, Hôpital de la Timone, Service de Neurophysiologie Clinique, Marseille, France*

When listening to music, we continuously form expectations based on our musical background and on the present musical context. These expectations lead to behavioral and neural effects in line with the predictive coding theory, and play an important role in our ability to enjoy music. However, previous research investigating the neural bases of music listening relied either on heavily controlled experiments with artificial stimuli, or on modeling approaches restricted to monophonic music (i.e. melody only). These paradigms suffer important limitations in terms of generalizability to ecological settings, and do not allow to relate neural error responses to the cognitive and affective processes occurring in real life music listening. To bypass these limitations, we designed and trained a recurrent neural network (RNN) that yields time-resolved predictions about upcoming notes in pieces of western polyphonic music. We then acquired MEG (n=27) and intracranial EEG (n=10) data in human participants passively listening to real recordings of polyphonic piano music. We extracted the surprise (prediction error), uncertainty and timing predictions from the RNN model, and used these features to predict the neural broadband response at the piano notes level. In both MEG and intracranial EEG datasets, musical expectations are encoded in auditory regions with a peak at 150-200ms after notes onset. This effect is mainly driven by the surprise predictor, and can be interpreted as an auditory mismatch response. This modeling framework enables us to track the neural correlates of error responses during natural music listening, and opens new avenues for understanding their interplay with cognitive and affective aspects of music perception.

Talk 4: Musical expectations in human and non-human primates

Roberta Bianco[1], Nathaniel J. Zuk[2], Felix Bigand[1], Eros Quarta[3], Stefano Grasso[3], Flavia Arnese[1], Andrea Ravignani [3,4,5], Alexandra Battaglia-Mayer[3] and Giacomo Novembre[1]

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The appreciation of music is a universal trait of humankind. Evidence supporting this notion includes the ubiquity of music across cultures and the natural predisposition toward music that humans display early in development. Are we musical animals because of species-specific predispositions? This question cannot be answered by relying on cross-cultural or developmental studies alone, as these cannot rule out enculturation. Instead, it calls for cross-species experiments testing whether homologous neural mechanisms underlying music perception are present in non- human primates. We present music to two rhesus monkeys, reared without musical exposure, while recording electroencephalography (EEG) and pupillometry. Monkeys exhibit higher engagement and neural encoding of expectations based on the previously seeded musical context when passively listening to real music as opposed to shuffled controls. We then compare human and monkey neural responses to the same stimuli and find a species-dependent contribution of two fundamental musical features—pitch and timing—in generating expectations: while timing- and pitch-based expectations are similarly weighted in humans, monkeys rely on timing rather than pitch. Together, these results shed light on the phylogeny of music perception. They highlight monkeys' capacity for processing temporal structures beyond plain acoustic processing, and they identify a species-dependent contribution of time- and pitch-related features to the neural encoding of musical expectations.

Thursday 19th, September 2024

Keynote 3: *09:00 – 10:00*

"A framework for MMN theory and a taxonomy for MMN paradigms"

Lecturer: Erich Schröger

Wilhelm Wundt Institut für Psychologie. Universität Leipzig. Germany.

Symposium 10: *10:00 – 11:30*

LANGUAGE

Chairperson/s: Thomas Jacobsen[1] and Sari Ylinen[2]
[1]Experimental Psychology Unit, Helmut Schmidt University. Germany
[2]Faculty of Social Sciences. Tampere University. Tampere. Finland

Talk 1: Incorporating more phonetic contrasts into bilingualism and language learning research: Can MMN be made more efficient?
Begoña Pericas Herrero and Paul Iverson
Dept. of Speech, Hearing and Phonetic Sciences, University College London. UK

Talk 2: Sensitivity to statistical stimulus properties in within-category MMN.
Chao Han[1], Arild Hestvik[2] and William Idsardi[3]
[1]University of Toronto
[2]University of Delaware
[3]University of Maryland

Talk 3: Effects of language environment on auditory neurocognition
Mari Tervaniemi
Brain Research Unit, Centre of Excellence in Music, Mind, Body and Brain, Faculty of Educational Sciences, University of Helsinki

Talk 4: Establishing neural representation for new word forms in 12-month-old infants
Sari Ylinen[1], Emma Suppanen[2], István Winkler[3] and Teija Kujala[2]
[1]Faculty of Social Sciences, Tampere University, Finland. Tampere University
[2]University of Helsinki
[3]HUN-REN Institute of Cognitive Neuroscience and Psychology

Talk 1: Incorporating more phonetic contrasts into bilingualism and language learning research: Can MMN be made more efficient?

Begoña Pericas Herrero and Paul Iverson

Dept. of Speech, Hearing and Phonetic Sciences, University College London. UK

Early phonetic learning has been extensively studied in monolingual infants, but the complexities of bilingual language acquisition are less well-understood. As multilingualism becomes increasingly common, it is important to uncover the factors that contribute to successful bilingual language learning. Insights from this research can also shed light on the mechanisms that facilitate language acquisition in adults later in life.
Mismatch Negativity (MMN), is a well-established method for studying phonetic and phonological perception. However, existing MMN paradigms often present challenges when exploring multiple phonetic contrasts within a single study. Our approach aims to simplify MMN testing by developing a time-efficient framework that accommodates various phonetic contrasts. We utilize a vowel-pair oddball paradigm combined with machine learning techniques to analyze MMN data. This approach allows us to obtain reliable MMN measurements while minimizing the number of deviant instances needed, per deviant type in our oddball paradigm. As a result, we can conduct shorter MMN tests, even with larger phoneme subsets.
Our primary objective is to apply these findings to bilingual populations across different age groups, providing insights into phonetic learning across the lifespan. Through this research, we seek to enhance our understanding of language acquisition and contribute to the development of effective language education strategies.

Talk 2: Sensitivity to statistical stimulus properties in within-category MMN.

Chao Han[1], Arild Hestvik[2] and William Idsardi[3]

[1]*University of Toronto*
[2]*University of Delaware*
[3]*University of Maryland*

The "varying standards hypothesis" (Phillips et al., 2000) says that if standards are varied acoustically within its category, then the MMN memory trace must be the abstract phoneme itself (a distinctive feature matrix), rather than a memory representation of the phonetic standard tokens presented in the experiment. A hitherto untested prediction is that the varying standards paradigm should eliminate within-category MMN. In Experiment 1 we show that this prediction is not borne out: An MMN was elicited by a [t] with 119ms VOT deviants embedded in varying standard [t] with a mean VOT of 48ms. This result is inconsistent with a discrete phoneme memory trace, but consistent with an auditory scene analysis of the proximal stimuli, which identifies the 119ms VOT as a statistical outlier (Garrido et al., 2013, 2016). In Experiment 2 we tested this hypothesis by conceptually replicating Garrido's experiment with speech stimuli. We used two conditions of varying standards both with a mean of 65ms VOT but differing in the standard deviation of the VOT, tested against a 128ms VOT oddball. This revealed only a main effect of mismatch and no sensitivity to the difference in standard deviations. This suggests another interpretation of Experiment 1, namely that varying standards activate a phoneme with statistical information about its phonetic realizations (Smolensky et al., 2014). Experiment 3 probed this idea by presenting "atypical" varying standards centered around 128ms VOT and a deviant with a "prototypical" VOT of 64ms. If the MMN in Experiment 2 was generated by a "Smolensky-phoneme", this should eliminate MMN for a prototypical [t] stimulus as deviant. However, this condition also elicited MMN, suggesting a role for both statistical analysis of the proximal stimuli as well as a statistical prototypicality effect.

Talk 3: Effects of language environment on auditory neurocognition

Mari Tervaniemi

Brain Research Unit, Centre of Excellence in Music, Mind, Body and Brain, Faculty of Educational Sciences, University of Helsinki

We live in an auditory world - we perceive and memorize sounds even before our birth (Partanen et al. 2013). Many studies have investigated the impact of explicit training (such as music instrument lessons) on auditory neurocognition. Here, I review findings about the impact of implicit training (such as language environment) on auditory neurocognition.
MMN studies indicate that the features of one's native language modulates the neural encoding of sounds: First evidence of the effects of the native language environment on auditory neurocognition was obtained when the MMN elicitation was compared between the speakers of quantity and non-quantity languages (in quantity languages the duration of a phoneme carries semantic meaning). It was shown that quantity language speakers have enhanced and/or earlier duration MMN, implying more accurate encoding of sound duration (Tervaniemi et al. 2006, Ylinen et al. 2006, Kirmse et al. 2008). Later, quantity language speakers' duration MMN was enhanced when compared with musicians who have non-quantity language as their native language (Marie et al. 2010). Recently, native speakers of a tonal language (in which pitch information carries semantic meaning) displayed enhanced pitch-MMN after exposure to foreign language and music training (Tervaniemi et al. 2022). Taken together, current evidence suggests that implicit training in a given native language environment can modulate our auditory neurocognition and learning as indicated by the MMN. In my talk I will also discuss how the interplay between native language environment and music training is reflected in auditory working memory performance (Nie et al. forthcoming).

Talk 4: Establishing neural representation for new word forms in 12-month-old infants

Sari Ylinen[1], Emma Suppanen[2], István Winkler[3] and Teija Kujala[2]

[1]*Faculty of Social Sciences, Tampere University, Finland. Tampere University*
[2]*University of Helsinki*
[3]*HUN-REN Institute of Cognitive Neuroscience and Psychology*

The mismatch negativity (MMN) and infants' mismatch response (MMR) may be used to measure plastic changes in the brain as a result of learning. Here we familiarized 12-month-old infants (N = 52) with two pseudowords and studied their neural signatures. Specifically, we determined whether a newly learned word form elicits the MMR similar to that observed when a known word is recognized (i.e., when a well-established word representation is activated), or whether the processing of a newly learned word form shows the suppression of the neural response along with the principles of predictive coding of a learned rule (i.e., the order of the syllables of the new word form). The pattern of results obtained in the current study suggests that recognized word forms elicit MMR of negative polarity similarly for newly learned and previously known words with an established representation in infants' long-term memory. In contrast, prediction errors caused by acoustic novelty or deviation from the expected order in a sequence consisting of (pseudo)words elicit MMRs of positive polarity. Although previous studies have shown that predictive processing is involved in word recognition and learning words in infants, our pattern of results suggests that electric brain activity reflecting newly established word representations is not fully explained by the predictive coding framework.

Thursday 19th, September 2024

Symposium 11: *12:00 – 13:30*

NEW APPROACHES TO MMN MEASURES IN PSYCHOSIS

Chairperson/s: Dean F. Salisbury
Clinical Neurophysiology Research Laboratory, Western Psychiatric Hospital, University of Pittsburgh School of Medicine, Pittsburgh, PA, USA

Talk 1: Selective Dysfunction of NMDA Receptor in First Episode Psychosis as Revealed by Computational Synaptic Modeling of Mismatch Negativity
Fran López-Caballero
Clinical Neurophysiology Research Laboratory, Pittsburgh, USA

Talk 2: Children at familial high risk of schizophrenia and bipolar disorder exhibit altered connectivity patterns during pre-attentive processing of an auditory prediction error
Kit Melissa Larsen
Copenhagen University Hospital. Denmark

Talk 3: Abnormal inter-hemispheric effective connectivity from left to right auditory regions during Mismatch Negativity (MMN) tasks in psychosis
Christian Valt
University of Bari Aldo, Italy

Talk 4: Volatility effects on group differences in MMN in schizophrenia
Matthew Godfrey
University of Newcastle, Australia

Talk 5: Stream segregation and temporal integration in psychosis
Ken Suzutani
Fukushima Medical University, Fukushima, Japan

*Presenting authors are highlighted in blue

Talk 1: Selective Dysfunction of NMDA Receptor in First Episode Psychosis as Revealed by Computational Synaptic Modeling of Mismatch Negativity

Fran López-Caballero

Clinical Neurophysiology Research Laboratory, Pittsburgh, USA

The attenuation of Mismatch Negativity (MMN) responses to pitch (pMMN) and duration (dMMN) deviant stimuli is significantly more pronounced in individuals with long-term psychotic illness compared to those experiencing their first episode of psychosis (FEP). Recent studies have demonstrated that employing source modeling techniques on magnetically-recorded MMN can enhance the detection of deficits specifically in the left auditory cortex among individuals with FEP. Additionally, computational circuit modeling of electrically-recorded MMN has revealed abnormalities in the left hemisphere auditory cortex. Computational modeling using Dynamic Causal Modeling (DCM) can also be used to infer synaptic activity from EEG-based scalp recordings. We used Electroencephalography (EEG) to measure pMMN and dMMN in 26 individuals with FEP and 26 matched healthy controls (HC), employing a DCM conductance-based neural mass model incorporating AMPA, NMDA, and GABA receptors to examine changes in effective connectivity and receptor rate constants in FEP. Our model included MMN sources in bilateral A1, superior temporal gyrus (STG), and inferior frontal gyrus (IFG), using a boundary element model in MNI space as a standardized brain template. Our findings revealed no significant differences in model parameters between groups for pMMN. However, for dMMN, we observed reduced NMDA receptor activity specifically in the right IFG among individuals with FEP. This aligns with existing literature on prefrontal NMDA receptor hypofunction in chronic schizophrenia (SZ), suggesting that impaired NMDA-induced synaptic plasticity may be present at the onset of psychosis, where scalp dMMN responses are only moderately reduced. DCM presents a promising approach for investigating, non-invasively, cortical circuit activity and interactions, offering insights into subtle functional auditory processing deficits in early psychosis, even in cases where sensor MMN responses are generally within normal limits.

Keywords: dynamic causal modeling, EEG, schizophrenia, MMN, inferior frontal gyrus, deviance detection

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Talk 2: Children at familial high risk of schizophrenia and bipolar disorder exhibit altered connectivity patterns during pre-attentive processing of an auditory prediction error

Kit Melissa Larsen

Copenhagen University Hospital. Denmark

Background: Individuals with schizophrenia or bipolar disorder have attenuated auditory mismatch negativity (MMN) responses, indicating reduced abilities to adapt to environmental changes. Computational models of effective connectivity between brain areas underlying MMN responses show reduced connectivity between fronto-temporal areas in individuals with schizophrenia. Here we ask whether children at familial high risk (FHR) of developing a serious mental disorder show similar alterations.
Methods: In this study we recruited 67 children at FHR for schizophrenia, 47 children at FHR for bipolar disorder as well as 59 matched population-based controls from the Danish High Risk and Resilience study - VIA-11. The 11– 12-year-old participants engaged in a classical auditory MMN paradigm with deviations in frequency, duration, or frequency and duration, while we recorded their EEG. We used dynamic causal modelling (DCM) to infer on the effective connectivity between brain areas underlying MMN.
Results: DCM yielded strong evidence for differences in effective connectivity among groups in connections
from right inferior frontal gyrus (IFG) to right superior temporal gyrus (STG), along with differences in intrinsic connectivity within primary auditory cortex (A1). Critically, the two high-risk groups differed in intrinsic connectivity in left STG and IFG as well as effective connectivity from right A1 to right STG. Results persisted even when controlling for past or present psychiatric diagnosis.
Conclusions: We provide novel evidence that connectivity underlying MMN responses in children at FHR for schizophrenia and bipolar disorder is altered at an age of 11-12, echoing findings that have been found in individuals with manifest schizophrenia. We are now following up this cohort with the same assessments at age 15-16 to study age specific changes in connectivity underlying MMN responses.

Talk 3: Abnormal inter-hemispheric effective connectivity from left to right auditory regions during Mismatch Negativity (MMN) tasks in psychosis

Christian Valt

University of Bari Aldo, Italy

Blunted auditory Mismatch Negativity (MMN) is a reliable observation in schizophrenia spectrum disorders. Friston's dysconnection hypothesis posits that schizophrenia results from disrupted functional connectivity of neural circuits, hindering effective communication between brain regions. Accordingly, anomalous MMN in psychosis could be a consequence of disturbed neural oscillatory activity already at sensory/perceptual stages of stimulus processing. This study investigated effective connectivity within and between the auditory regions during an auditory oddball task. The analyses were performed on two different magnetoencephalography (MEG) datasets: one (Exp1) on duration MMN in a cohort with various diagnoses within the psychosis spectrum (N = 82) and neurotypical controls (N = 153), and one (Exp2) on duration and pitch MMN in first-episode psychosis patients (N = 36) and matched neurotypical controls (N = 38). Spectral Granger causality to MEG source-reconstructed signals was used to compute effective connectivity within and between the left and the right auditory regions. Both experiments showed that deviance detection was associated with early increases of effective connectivity in the beta band followed by increases in the theta band, with the beta connectivity strength linked to the laterality of the MMN peak (Exp1: $R2 = .17$, $p < .001$; Exp2: $R2 = .14$, $p < .001$). Compared to controls, people with psychosis had overall smaller effective connectivity (Exp1: $F(1,232) = 8.31$, $p = .004$; Exp2: $F(1,70) = 5.54$, $p = .021$), particularly for theta frequencies from left to right auditory regions (Exp1: $p = .005$; Exp2: $p = .040$), in the pathway where bilateral information converges toward lateralized processing, often rightward. Blunted MMN in psychosis might reflect a deficit in inter-hemispheric communication between auditory regions, highlighting a "dysconnection" already at perceptual stages.

Talk 4: Volatility effects on group differences in MMN in schizophrenia

Matthew Godfrey

University of Newcastle, Australia

Most of what we know about mismatch negativity (MMN) in schizophrenia is based on data obtained from "traditional oddball" sound sequences, in which we measure responses to rare physical property changes in a regularly repeating sound. These sequences represent a comparatively stable learning environment in which the repetition does not change, the occurrence rate of the deviant does not change, and the nature of the deviant does not change either. Under such conditions, there is a highly replicable reduced MMN in response to deviations, which is almost entirely attributable to a smaller response to the deviations. This talk explores what happens to MMN when the learning environment is more volatile; that is, where the nature of the repetition and deviation change over time, which, in turn, changes the occurrence rate of deviations. Our results show that MMN recorded in this more volatile setting does not exhibit the same group differences as those established using traditional oddball paradigms and shifts the dominant group difference to aberrant responses to the repetition rather than deviation. Results will be discussed in relation to what different protocols reveal about the underlying group differences and how these relate to the prevailing accounts put forward to explain smaller MMN in schizophrenia in traditional oddball sequences.

Talk 5: Stream segregation and temporal integration in psychosis

Ken Suzutani

Fukushima Medical University, Fukushima, Japan

Both stream segregation and temporal integration are considered important for auditory scene analysis in the brain. Several previous studies have indicated that stream segregation may precede temporal integration when both processes are required. In the present study, we utilized mismatch negativity (MMN), which reflects automatic change detection, to systematically estimate the threshold of the frequency difference at which stream segregation occurs prior to temporal integration when these functions occur together during a state of inattention. We have done several studies of stream segregation and temporal integration. Hikita reported that stream segregation should cancel temporal integration of close sounds, as indicated by omission-MMN elicitation, when the frequency difference is 1000 Hz or larger. But this study was done by using only one base tone (3000Hz). In a follow-up experiment, we used two base tones (3000Hz and 2000Hz). In this study, stream segregation did not cancel temporal integration even with the minimal frequency difference (1000Hz) when we used 2000Hz as the base tone. Mori examined stream segregation and temporal integration in schizophrenia, and observed a frequency difference between schizophrenia and healthy control participants for when stream segregation canceled temporal integration. The results of these stream segregation and temporal integration paradigms will be discussed with respect to sensory/perceptual processes in schizophrenia.

Thursday 19th, September 2024

Symposium 12: *12:00 – 13:30*

SOMATOSENSORY MMN, PREDICTION ERROR AND SURPRISE

Chairperson/s: Felix Blankenburg[1] and Wolfger von der Behrens[2]
[1]*Freie Universität Berlin*
[2]*University of Zurich and ETH Zurich*

Talk 1: Somatosensory Errors and Surprise shape Cortical Circuit Activity and Perception
Gwendolyn English, Newsha Ghasemi Nejad, Mehmet Fatih Yanik and Wolfger von der Behrens
Institute of Neuroinformatics.University of Zurich and ETH Zurich. Switzerland

Talk 2: Modeling mismatch responses across the somatosensory, visual, and auditory domain
Miro Grundei, Pia Schröder, Sam Gijsen, Timo Torsten Schmidt and Felix Blankenburg
Neurocomputation and Neuroimaging Unit. Department of Education and Psychology. Freie Universität. Berlin, Germany

Talk 3: Dynamics of the Somatosensory Mismatch Response Across Ages: Insights from EEG and MEG Studies
Piia Astikainen, Elina Kangas, Heidi Pesonen, Qianru Xu and Juho Strömmer
University of Jyväskylä. Finland

Talk 4: Action-related omission responses in the somatosensory modality
Nicole Wetzel, Andreas Widmann and Tjerk T. Dercksen
Leibniz-Institute for Neurobiology. Magdeburg, Germany

Talk 1: Somatosensory Errors and Surprise shape Cortical Circuit Activity and Perception

Gwendolyn English, Newsha Ghasemi Nejad, Mehmet Fatih Yanik and Wolfger von der Behrens

Institute of Neuroinformatics.University of Zurich and ETH Zurich. Switzerland

Surprising error stimuli influence perception and signal detection and trigger attentional reallocation. Here, we investigated first the relationship between cortical somatosensory error stimulus representation and stimulus detection and second the neural circuitry underlying the Bayesian inference that governs sensory decision making.

In the first study, we used a somatosensory-visual behavior paradigm in mice, combined with extracellular recordings from the primary somatosensory whisker cortex (barrel cortex). We found a distraction effect of deviating stimuli on the animals' performance: Faster reaction times but worsened target detection was observed in the presence of an error stimulus. Multiunit activity and local field potentials exhibited enhanced neuronal responses to error compared with standard whisker stimuli across all cortical layers, as a result of stimulus-specific adaptation. The deviant-triggered behavioral distraction correlated with these enhanced neuronal deviant responses only in the deeper cortical layers. However, the layer-specific effect of stimulus-specific adaptation on perception is reduced with increasing task experience as a result of statistical distractor learning. These results demonstrate a layer-specific involvement of stimulus-specific adaptation on perception that is susceptible to modulation over time.

In the second study, we recorded extracellular neural activity along the somatosensory pathway of mice while delivering sensory stimulation paradigms designed to isolate the response to the surprise generated by Bayesian inference. Our results demonstrate that laminar cortical circuits in early sensory areas encode Bayesian surprise. Extracellular spiking activity and evoked potentials in layer VI of these regions exhibited the highest sensitivity to surprise. Gamma power in the field potentials in layer II/III of the barrel cortex exhibited an NMDAR-dependent scaling with surprise, as does alpha power in layers II/III and VI of the secondary somatosensory cortex. These results show a precise spatiotemporal neural representation of Bayesian surprise and suggest that Bayesian inference is a fundamental component of cortical processing.

Talk 2: Modeling mismatch responses across the somatosensory, visual, and auditory domain

Miro Grundei, Pia Schröder, Sam Gijsen, Timo Torsten Schmidt and Felix Blankenburg

Neurocomputation and Neuroimaging Unit. Department of Education and Psychology. Freie Universität. Berlin, Germany

The human brain is constantly subjected to a multimodal stream of sensory inputs governed by statistical regularities. Brain signatures in response to regularity violations in sensory inputs can give valuable insight into the computational principles underlying sequence perception and inference. Although previously reported for different senses, mismatch responses (MMRs) have largely been studied in isolation with a focus on the auditory system. Thus, many of the uni- and cross-modal aspects of mismatch processing remain unknown. We have inspected MMRs across the senses using a novel tri-modal roving stimulus paradigm in both EEG (study 1) and fMRI (study 2). The probabilistic sequences in the auditory, somatosensory and visual modality were defined by uni-modal transition probabilities and cross-modal conditional dependencies. We combined average-based approaches with single-trial computational modeling (study 1) and PPI-connectivity (study 2) to shed light on mismatch processing in the multi-sensory brain. Across sensory modalities we identified highly comparable response profiles of modality specific early signatures (MMN) as well as modality general late responses (P3). In addition to parametric dependence of MMRs on the number of stimulus repetitions, strikingly, we found sensitivity to cross-modal probabilistic dependencies, particularly at later latencies (P3) and within modality general hubs of the extended mismatch network (IPS). Model comparison indicated that the observed EEG dynamics were best captured by Bayesian learning models tracking uni-modal stimulus transitions as well as cross-modal conditional dependencies. While earlier MMRs tended to reflect confidence-weighted surprise, later MMRs rather reflected model updating.

Talk 3: Dynamics of the Somatosensory Mismatch Response Across Ages: Insights from EEG and MEG Studies

Piia Astikainen, Elina Kangas, Heidi Pesonen, Qianru Xu and Juho Strömmer

University of Jyväskylä. Finland

Deviance in somatosensory stimulation induces a mismatch response (MMR) in electrophysiological recordings of brain activity. I will present our results from studies in which MMR has been measured in response to finger stimulation in young and older adults. In a magnetoencephalography (MEG) study, we used a novel oddball stimulus condition in young adults to investigate brain responses to unpredictable and predictable rare somatosensory events. We found two main components, M55 and M150, which were located in the contralateral somatosensory cortex relative to the stimulation. However, only M55, was higher in amplitude for the unpredictable than for the predictable rare stimulus, suggesting that it can signal prediction error. In an electroencephalography (EEG) study in healthy adults between 18-60 y, we investigated whether somatosensory MMR is elicited for both intensity deviance and location deviance. We found a sMMR at 150-190 ms latency to location changes but not to intensity changes in finger stimulation. sMMR to location deviance did not correlate with auditory intensity MMN. Aging effects were investigated in two studies. In an EEG study, participants were young and older women. The somatosensory MMR was elicited as a shift toward positive polarity at 153–193 ms latency. It was attenuated in older adults and associated with executive functions.. In an MEG study, responses to the location changes in finger stimulation were measured in young, middle-aged, and older adults. We found a group difference between younger and older adults in M100 and M250, reflecting sensory gating and attention shift toward changes, respectively. In sum, we have demonstrated somatosensory MMR to changes in somatosensory location changes in both MEG and EEG, and attenuation of it in older adults in EEG. The association of somatosensory MMR with physical fitness and cognitive abilities in older adults makes it an interesting target for research on ageing-related biomarkers.

Talk 4: Action-related omission responses in the somatosensory modality

Nicole Wetzel, Andreas Widmann and Tjerk T. Dercksen

Leibniz-Institute for Neurobiology. Magdeburg, Germany

Prediction has been proposed as a fundamental principle of perception. Recent concepts postulate that sensory and motor information are integrated in a common prediction system. When a motor action, that has been reliably coupled to a sensory event, results in an unexpected event, a prediction error is generated. The omission of an expected sensory event, instead of the presentation of an unexpected event, minimizes confounding influences on neural activity associated with mismatch responses and prediction error. The unexpected omission of an expected sensory event allows the analysis of brain responses that can only be explained by prediction and prediction error.

Omission responses have been studied mostly in the auditory modality. We present two omission studies in the somatosensory modality. Based on auditory omission studies, a self-paced key press was reliably coupled to a somatosensory stimulus. A first EEG study showed that the omission of the expected somatosensory stimulus evoked a cascade of omission brain responses. While early omission responses showed a typical somatosensory scalp distribution, later omission responses most likely reflect modality-unspecific higher-order processes. Results are discussed in the framework of MMN and attention-related brain responses.

A second pupillometry omission study focused on surprise and attentional orienting as a consequence of prediction violation in two modalities. A self-paced key press was paired with a somatosensory or auditory stimulus. Similar omission responses were observed in both modalities, suggesting a modality-unspecific activation of the surprise and attention-related brain circuits. The pupillometry approach could facilitate studies of sensory prediction in developmental or clinical samples.

The specification of mismatch responses and especially omission responses across different modalities contributes to a better understanding of sensory prediction and subsequent higher order processes.

Thursday 19th, September 2024

Symposium 13: *15:00 – 16:30*

SIGNIFICANCE AND USEFULNESS OF OMISSION MMN RESEARCH

Chairperson/s: Hirooki Yabe
Department of Mind & Brain medicine. Fukushima Medical University (FMU). Japan.

Talk 1: Conditions for omission MMN generation and its research significance
Hirooki Yabe
Fukushima Medical University. Japan

Talk 2: Prediction-Related Frontal-Temporal Network for Omission Mismatch Activity in the Macaque Monkey
Takanori Uka
Juntendo University, Tokio. Japan

Talk 3: Neuronal Responses to Omitted Tones in the Auditory Brain: A Neuronal Correlate for Predictive Coding
Ana Belén Lao-Rodríguez[1], David Pérez-González[1], Bernhard Englitz[2] and Manuel S. Malmierca[1]
[1] CANELAB. University of Salamanca. Spain
[2] Department of Computational Neuroscience Laboratory. Department of Neurophysiology. Donders Centre of Neuroscience. Nijmegen, The Netherlands.

Talk 4: Negative Prediction-Error Neurons in Rat Auditory Cortex: Response Properties and Implications for Predictive Coding Circuits
Amit Yaron[1], Tomoyo Shiramatsu-Isoguchi[2], Felix Kern[1], Hirokazu Takahashi[2], Zenas C. Chao[1]
[1]International Research Center for Neurointelligence (WPI-IRCN), The University of Tokyo Institutes for Advanced Study.
[2]Graduate School of Information Science and Technology, The University of Tokyo

Talk 1: Conditions for omission MMN generation and its research significance

Hirooki Yabe

Fukushima Medical University. Japan

Sound omission can never elicit MMN when the commonly used SOAs such as 500 msec are employed in a series of repeated sounds, but only under special conditions of very short SOAs. This feature is significantly different from P300, where the definite omission P300 appears even for 1 second that is commonly used. This is because omission MMN is fundamentally different from omission P300 in its generation mechanism and significance. In other words, although it may seem contradictory, omission MMN essentially does not exist. When identifying omission MMN, one must pay close attention to the apparent fake MMN-like waveform caused by the stimulus immediately before the omitted stimulus.

Sound omission can elicit MMN only with SOA of less than around 200msec in which the brain mechanism termed Temporal Window of Integration (TWI) can work. The generation mechanism of omission MMN is thought to be the same as those of the partial omission MMN when part of the deviant sound is missing and the duration MMN when the duration of deviant sound is shorter than that of the standard one. This is because the omission (silence)-containing sound units formed by TWI of 160-170 msec become synonymous with the partial omission or the shortened duration. Finally, the effects of the omission MMN study are as follows. First, the emergence of “omission MMN” itself provides strong evidence for a memory-based mechanism. Second, it can detect abnormalities in TWI, which corresponds to sensory memory. Third, it helps clarify the prioritization of TWI and stream separation features. Forth, it allows a detailed examination of MMN abnormalities in psychiatric disorders revealed by duration MMN.

Talk 2: Prediction-Related Frontal-Temporal Network for Omission Mismatch Activity in the Macaque Monkey

Takanori Uka

Juntendo University, Tokio. Japan

Sensory prediction is considered an important element of mismatch negativity (MMN) whose reduction is well known in patients with schizophrenia. Omission MMN is a variant of the MMN which is elicited by the absence of a tone previously sequentially presented. Omission MMN can eliminate the effects of sound differences in typical oddball paradigms and affords the opportunity to identify prediction-related signals in the brain. Auditory predictions are thought to reflect bottom-up and top-down processing within hierarchically organized auditory areas. However, the communications between the various subregions of the auditory cortex and the prefrontal cortex that generate and communicate sensory prediction-related signals remain poorly understood. To explore how the frontal and temporal cortices communicate for the generation and propagation of such signals, we investigated the response in the omission paradigm using electrocorticogram (ECoG) electrodes implanted in the temporal, lateral prefrontal, and orbitofrontal cortices of macaque monkeys. We recorded ECoG data during the omission paradigm and examined the functional connectivity between the temporal and frontal cortices by calculating phase-locking values (PLVs). This revealed that theta- (4–8Hz), alpha- (8–12Hz), and low-beta- (12–25Hz) band synchronization increased at tone onset between the higher auditory cortex and the frontal pole where an early omission response was observed in the event-related potential (ERP). These synchronizations were absent when the tone was omitted. Conversely, low-beta-band oscillation then became stronger for tone omission than for tone presentation approximately 200ms after tone onset. The results suggest that auditory input is propagated to the frontal pole via the higher auditory cortex and that a reciprocal network may be involved in the generation of auditory prediction and prediction error.

Talk 3: Neuronal Responses to Omitted Tones in the Auditory Brain: A Neuronal Correlate for Predictive Coding

Ana Belén Lao-Rodríguez[1], David Pérez-González[1], Bernhard Englitz[2] and Manuel S. Malmierca[1]

[1] *CANELAB. University of Salamanca. Spain*
[2] *Department of Computational Neuroscience Laboratory. Department of Neurophysiology. Donders Centre of Neuroscience. Nijmegen, The Netherlands.*

The human brain detects perceptual mismatches between expected and actual sensory inputs. These responses have been widely recorded in all sensory systems and have been interpreted in terms of predictive processing. Predictive processing is a leading and unifying theory of how the brain performs probabilistic inference. According to this framework, the brain extracts the regularities from the environment and uses them to actively predict what should happen next. When the prediction and input do not match, a prediction error signal is generated. It has been argued that the omission response provides conclusive, empirical evidence of the predictive process, as it occurs in the absence of sensory input (Wacongne et al., 2011, 2012). Nevertheless, to date, empirical evidence of omission responses at the neuronal level remains elusive. We investigated whether auditory neurons were signaling the omission deviant in an oddball paradigm context by measuring the evoked neuronal activity. The recordings were conducted in the inferior colliculus and the auditory cortex of anesthetized and awake rodents. Our results reveal a subset of neurons that robustly increases their activity during the omission of an expected tone. These responses are evident, although weak, at anesthetized preparations and become stronger and distinct at the cortical level. Omission responses also show a higher probability of occurrence with shorter SOAs which aligns with the highest probability of omission responses at short latencies in humans (Raij et al. 1997; Hughes et al. 2001; SanMiguel et al., 2013a, 2013b). A deeper analysis based on individual stimulation sequences unveiled the so-called omission-selective responses (Fiser et al., 2016) and its distribution across the auditory cortex fields. Our findings suggest that neurons in the auditory system detect a deviation from expectations without the need for an external stimulus (Bendixen, et al 2012) and gives a decisive empirical support to the theory of predictive processing.

Talk 4: Negative Prediction-Error Neurons in Rat Auditory Cortex: Response Properties and Implications for Predictive Coding Circuits

Amit Yaron[1], Tomoyo Shiramatsu-Isoguchi[2], Felix Kern[1], Hirokazu Takahashi[2], Zenas C. Chao[1]

[1]*International Research Center for Neurointelligence (WPI-IRCN), The University of Tokyo Institutes for Advanced Study.*
[2]*Graduate School of Information Science and Technology, The University of Tokyo*

Predictive coding theory posits that the brain predicts sensory inputs and signals prediction errors. While positive prediction-error neurons have been studied, negative ones that respond when inputs are less than expected lack research. We record single-unit activity in the rat auditory cortex during a novel omission paradigm where tone predictability is manipulated. We identify neurons that respond robustly to omissions and display two distinctive characteristics indicative of their role as negative prediction-error neurons mirroring prediction signals. The first characteristic is the ramping-up responses over trials, which suggests a learning process, and the second is a direct correlation between their responses to omissions and the probability of the expected tones. Interestingly, these neurons showed selective omission responses but broad tone responses, revealing an asymmetry in error signaling. We propose a circuit model featuring laterally interconnected prediction-error neurons which captures this asymmetry and demonstrates that lateral connections enhance the precision of prediction. Our findings reveal how negative prediction-error neurons in the auditory cortex enable precise and efficient predictive coding across receptive fields through their unique response properties and lateral connectivity.

Thursday 19th, September 2024

SPECIAL TRIBUTE SYMPOSIUM TO RISTO NÄÄTÄNEN: *16:30-18:15*

Talk 1: ***Teija Kujala***
Preattentive language processing and its deficits in developmental language dysfunctions
Professor. Cognitive Brain Research Unit
Centre of Excellence in Music, Mind, Body and Brain
Department of Psychology and Logopedics
Medicum, Faculty of Medicine
University of Helsinki. Finland

Talk 2: ***Leon Y. Deouell***
What can we learn from the variety of mismatch responses across the brain?
"Jack H. Skirball Professor" Brain Research Department of Psychology Edmond and Lily Safra Center for brain sciences (ELSC)
The Hebrew University of Jerusalem. Israel

Talk 3: ***Elvira Brattico***
MMN for studying musical predictions in the brain
Center for Music in the Brain, Department of Clinical Medicine, Aarhus University, Denmark Department of Education, Psychology, Communication, University of Bari, Italy

Talk 4: ***Paula Virtala***
Mismatch responses from infancy to childhood and their relationship with language abilities
PhD. Academy of Finland Centre of Excellence for Music, Mind, Body, and the Brain
Cognitive Brain Research Unit
Department of Psychology and Logopedics
Faculty of Medicine
University of Helsinki. Finland

Talk 5: ***Israel Nelken***
From single neurons to mismatch negativity – analogies, homologies, and gaps
Professor. Edmond and Lily Safra Center for Brain Sciences
Goodman Building,
Edmond J. Safra Campus, Givat Ram
Jerusalem 9190401, Israel

Talk 6: ***Gregory Light***
MMN as a Biomarker: Developing Innovative Treatments for Schizophrenia in Global Clinical Trials
Professor. UCSD Department of Psychiatry.
Director of the Mental Illness, Research, Education and Clinical Center (MIRECC) at the VA San Diego Healthcare System. USA

POSTER COMMUNICATIONS

Abstract #1

Speech-elicited Obligatory and Mismatch Responses in Children at Dyslexia Risk: An Early Predictor for Atypical Reading Development

Sergio Navarrete-Arroyo[1,2], Paula Virtala[1,2], Peixin Nie[1,2], Satu Salonen[1], Linda Kailaheimo-Lönnqvist[1] and Teija Kujala[1,2]

[1]Cognitive Brain Research Unit, Department of Psychology and Logopedics, Faculty of Medicine, University of Helsinki, Finland
[2]Finnish Centre of Excellence in Music, Mind, Body and Brain, Department of Psychology and Logopedics, Faculty of Medicine, University of Helsinki, Finland

Introduction: Foundations for neural speech-processing and reading skills are formed during early development, although difficulties in learning to read become evident only at school age. Therefore, finding early precursors of deficient reading development may be crucial for the detection of those at highest risk and for designing preventive and rehabilitation strategies. In this context, both obligatory-elicited (P1 and N2) and mismatch responses (positive mismatch response, P-MMR; mismatch negativity, MMN; late discriminative negativity, LDN) recorded in infancy and early childhood have shown associations with reading skills. However, there is a lack of longitudinal studies assessing their potential as early predictors of reading development, particularly in the preschool stage, when children already possess basic pre-reading skills that support subsequent literacy. Such pre-reading skills are phonological awareness, letter recognition, verbal short-term memory and serial naming.
Objective: To investigate in longitudinal settings the associations between newborn and early childhood speech-elicited ERPs and MMRs and the development of pre-reading skills in a large sample of children in the DyslexiaBaby project.
Methods: We recorded ERPs (P1, N2) to repeating pseudo-words and MMRs (MMN, P-MMR, LDN) to vowel, duration, and frequency deviants elicited by pseudo-words at birth (N=190) and 28 months (N=146) in a sample over-represented by children at familial dyslexia risk. Using multiple linear regression models, we tested the associations between ERPs' and MMRs' amplitudes, latencies, and hemispheric lateralization and test results for phonological awareness, verbal short-term memory, letter knowledge and serial naming at 28 months and 4.5 years, controlling for dyslexia risk.
Results: Larger P-MMRs amplitudes and earlier P1 latencies recorded already at birth were associated with faster serial naming at 28 months. Larger and left-lateralized P1, MMN and LDN recorded at 28 months were associated with better serial naming and verbal short-term memory in both neurocognitive testing sessions. Moreover, children at risk for dyslexia exhibited worse linguistic short-term memory, serial naming and letter recognition than control children.
Conclusions: Infant and early childhood auditory ERPs, providing information about neural speech processing abilities, may serve as early neural markers of typical/atypical linguistic development already during the pre-reading stage. Speech processing deficits may contribute to deficits in language and reading acquisition observed in dyslexia. These results may help in planning preventive and rehabilitation interventions in children at risk of learning difficulties.

Abstract #2

Effects of the overall paradigm context on intensity deviant responses in healthy subjects

Ekaterina A. Yukhnovich[1], Kai Alter[1,2] and William Sedley[1]

[1]*Newcastle University*
[2]*Cambridge University*

Previously, three experiments were carried out to explore Mismatch Negativity responses to intensity deviants in a roving intensity deviant paradigm in control and tinnitus groups. The first experiment used interspersed blocks of two (high) tinnitus-like frequencies set by each participant with tinnitus, which were usually around 1/3 of an octave apart. On the other hand, two later studies used interspersed blocks tones at tinnitus-like frequencies and at 1 kHz. Inclusion of blocks of a lower frequency was the crucial and only difference in the paradigms used, however, there were differences in the patterns of results during the higher frequency blocks displayed by the control group in the first study compared to the other two.

Consequently, in the current experiment, three hearing-matched groups of healthy controls were recruited to measure responses to intensity deviants when different frequencies were used for the alternating blocks. For one group, the whole experiment was set at a single frequency; for the next, blocks were played at 6 kHz and at a frequency 1/3 octave below 6 kHz; the last group was presented with blocks that had tones at 6 kHz and 1 kHz frequencies.

Overall, the wider context of the different frequency ranges in the experimental paradigms dramatically influenced the Mismatch Negativity response patterns. Unchanging or widely separated frequencies resulted in upward intensity deviant responses being larger than for downward, and narrowly separated frequencies produced the opposite pattern. This effect applied even when the frequency changes were remote (e.g. tens of seconds to minutes away) from the intensity responses they influence.

In the future, it would be useful to see whether these results generalise to other experiment designs such as attended and ignored stimulus conditions, different stimulus durations, non-isochronous, or paradigms with frequency deviants.

Abstract #3

How the human brainstem processes auditory deviants

Johannes Wetekam[1], Nell Gotta[1], Julio Hechavarria[1,2] and Manfred Kössl[1]

[1]*Goethe University Frankfurt*
[2]*Ernst Strüngmann Institute (ESI) for Neuroscience*

The ability of the brain to identify unexpected acoustic stimuli (i.e. deviance detection) has been extensively examined in both animals and humans. Significant advancements have been achieved in both fields over the past decade, with each benefiting from the other due to a large number of complementary findings. However, while human research so far mostly focussed on studying cortical deviance detection in the forms of MMN and MLR, studies with animals could demonstrate effects of deviance detection in lower brain areas, like the thalamus and the inferior colliculus. In this study, we conducted auditory brainstem response (ABR) recordings on human subjects, uncovering evidence of subcortical deviance detection in the human brain. The observed effects were stimulus-specific and not only ABR amplitude but also the peak latency was sensitive to stimulus probability. This enhances our overall understanding of auditory deviance detection and also narrows the gap between animal and human deviance detection research. Essentially, our findings may facilitate the integration of future findings from animal studies into our understanding of the human brain, and vice versa.

Abstract #4

Exploring cortical and subcortical brain responses to CV syllables in newborns and adults

Giulia Danielou[1,2], Estelle Hervé[1,2], Anne-Sophie Dubarry[1,2], Lucie Delefosse[1,3], Thierry Legou[1,2], Béatrice Desnous[3,4] and Clément François[1,2]

[1]*Laboratoire Parole et Langage, CNRS, France*
[2]*ILCB, Aix-Marseille University, France*
[3]*APHM, Reference Center for Rare Epilepsies, Timone Children Hospital, France*
[4]*INS, INSERM, France*

Event-related brain potentials and the Frequency Following Response can be used to decipher how speech sounds are encoded along the auditory pathway at the cortical and subcortical levels. The aim of this experiment was to explore the cortical and subcortical brain responses to syllables in healthy full-term newborns (N=30, mean age = 3 days) and adults (N=30, mean age= 22.7). Both groups performed a passive listening task with several blocks of high and low stimulation rates while we recorded EEG. Specifically, 30 short blocks with the synthetic /oa/ syllable (Arenillas-Alcón et al., 2021), alternated with 30 "oddball" blocks with three semi-natural syllables (one standard /da/ and two deviants /ba/ and /ga/). This interleaved paradigm allowed us to collect subcortical and cortical EEG responses from the same individual (Bidelman, 2015). Even though data are currently being collected and analyzed for newborns, we expect to observe significant between-group differences in the subcortical encoding of the fine temporal structure of syllables. Besides, we expect to observe a larger Mismatch Negativity for both deviant types in adults compared to newborns. These preliminary results may suggest that experience-dependent developmental factors differentially shape the subcortical and cortical processing of speech sound features. Furthermore, these data may demonstrate the feasibility of assessing cortical and subcortical encoding of speech sounds within a short time and in challenging situations.

Abstract #5

Error Signal Coding in the Auditory Cortex during Vocal Production

Steven J. Eliades[1] and Joji Tsunada[2]

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Vocalization is a sensory-motor process requiring auditory self-monitoring to detect and correct errors in vocal production. This process is thought to be mediated through an error signal encoding the difference between vocal motor predictions and sensory feedback, but direct evidence for the existence of such an error signal is lacking, and the underlying coding mechanisms remain uncertain. One potential mechanism for this error coding is a well-described suppression of the auditory cortex, seen for both human speech and animal vocalization, however past studies have been limited in their experimental manipulations of feedback, and therefore have been unable to fully test the error signal hypothesis. In this study, we investigated vocal responses in the auditory cortex marmoset monkeys, testing frequency-shifted feedback of varying magnitudes and directions. Consistent with an error signal, we found population-level activity that scaled with the magnitude of feedback shifts. Feedback sensitivity was greatest in vocally suppressed units, and in units whose spectral preferences overlapping vocal acoustic frequencies. Individual units often exhibited preferences for either positive or negative frequency changes, with many responding to shifts in both directions. These results suggest that vocal responses and feedback sensitivity in the auditory cortex are consistent with an error calculation during vocal production, seen at both the individual unit and population level, and suggest coding using both rate and place mechanisms. This vocal error coding shares many common features with mismatch negativity and stimulus specific adaptation, and may have similar underlying circuit mechanisms.

Abstract #6

N1 suppression for self-generated sounds is unaffected by predictability of sound identity and occurrence

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Recent theories describe perception as an inferential process based on internal predictive models that are adjusted following prediction violations (prediction error). Two modulations related to the auditory N1 event-related brain potential component have been interpreted in the context of prediction error: The sound-related N1 component is attenuated for self-generated sounds compared to the N1 elicited by externally generated sounds (N1 suppression). An omission-related component in the N1 time-range is elicited when the self-generated sounds are occasionally omitted (omission N1). Both phenomena were explained by action-related forward modeling, which takes place when the sensory input is predictable: Prediction error signals are reduced when predicted sensory input is presented (N1 suppression) and elicited when predicted sensory input is omitted (omission N1). Our studies were designed to test the hypothesis that both phenomena may share a common underlying mechanism. In a first study we manipulated the predictability of a sound in a self-generation paradigm in which, in two conditions, either 80% or 50% of the button presses did generate a sound, inducing a strong or a weak expectation for the occurrence of the sound. Consistent with the forward modelling account, an omission N1 was observed in the 80% but not in the 50% condition. However, N1 suppression was highly similar in both conditions. Thus, our results demonstrated a clear effect of predictability for the omission N1, but not for the N1 suppression. In a second study, we wanted to replicate the findings that both N1 suppression and omission N1 are sensitive to the predictability of sound identity, as reported previously. We manipulated the predictability of sound identity in a self-generation paradigm in which button presses in one condition always produced the same sound, and in another condition, they produced a sound randomly selected from a large set of sounds, thereby inducing a strong or a weak expectation for a specific sound. Again, omission N1 was modulated by manipulating the predictability of sound identity but N1 suppression was not. The results of these experiments partly contradict previous reports and further challenge prediction-related interpretations of N1 suppression, supporting alternative explanations such as action-related unspecific suppression of sensory processing. We show that omission N1 and N1 suppression do not share a common underlying mechanism.

Abstract #7

Temporal dynamics of feature segregation and integration revealed by MMN in a multi-level oddball paradigm

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Segregation and integration are two fundamental yet competing computations in cognition. For example, in serial speech processing, stable perception necessitates the sequential establishment of perceptual representations to remove irrelevant features for achieving invariance. Whereas, multiple features need to combine to create a coherent percept. How to simultaneously achieve seemingly contradicted computations of segregation and integration in a serial process is unclear. To investigate their neural mechanisms, we used loudness and lexical tones as two representative auditory features and employed a novel multi-level oddball paradigm with EEG recordings to explore the dynamics of mismatch negativity (MMN) responses to their deviants. When two types of deviants were presented separately, distinct topographies of MMNs to loudness and tones were observed at different latencies (loudness earlier than tones), supporting the sequential dynamics of independent representations for two features. When the two deviants changed simultaneously, the latency of responses to tones became shorter and aligned with that to loudness, while the topographies remained independent, yielding the combined MMN as a linearly additive of single MMNs of loudness and tones. These results suggest that neural dynamics rapidly adapt and temporally synchronize neural processes to distinct sensory features. The temporal facilitation of independent neural representations balances the computational demands of segregation and integration and serves as a foundation for achieving invariance and feature-binding in serial processing.

Abstract #8

Negative Prediction-Error Neurons in Rat Auditory Cortex: Response Properties and Implications for Predictive Coding Circuits

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Predictive coding theory posits that the brain predicts sensory inputs and signals prediction errors. While positive prediction-error neurons have been studied, negative ones that respond when inputs are less than expected lack research. We record single-unit activity in the rat auditory cortex during a novel omission paradigm where tone predictability is manipulated. We identify neurons that respond robustly to omissions and display two distinctive characteristics indicative of their role as negative prediction-error neurons mirroring prediction signals. The first characteristic is the ramping-up responses over trials, which suggests a learning process, and the second is a direct correlation between their responses to omissions and the probability of the expected tones. Interestingly, these neurons showed selective omission responses but broad tone responses, revealing an asymmetry in error signaling. We propose a circuit model featuring laterally interconnected prediction-error neurons which captures this asymmetry and demonstrates that lateral connections enhance the precision of prediction. Our findings reveal how negative prediction-error neurons in the auditory cortex enable precise and efficient predictive coding across receptive fields through their unique response properties and lateral connectivity.

Abstract #9

Dynamic effects of expectation on stimulus decoding during statistical learning

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The brain is thought to generate internal predictions, based on the memory of past stimulation, to optimise behaviour. Predictive processing has been repeatedly demonstrated in non-invasive studies on human volunteers and in animal models and seemingly explains Expectation Suppression (ES) or the suppression of neural activity in response to expected stimuli. However, the mechanisms behind ES are unclear and many early studies failed to acknowledge ES as a standalone phenomenon independent of Repetition Suppression. Various models of the mechanisms supporting ES have been suggested with conflicting evidence. Among the various models of these mechanisms, sharpening models propose that expectations suppress neurons that are not tuned to the expected stimulus. In contrast, dampening models posit that expectations suppress neurons that are tuned to the expected stimuli. A Dual Process model has suggested that both processes may occur at different time points, namely that initial processing relies on prior knowledge to sharpen sensory representation, and a later processing stage follows, dampening the neural representations of the expected stimulus. In this study we aim to shed light on the sharpening/dampening processes behind ES and how it relates to prediction formation and deployment. Thirty-one participants completed a statistical learning task consisting of paired scene categories whereby a "leading" image from one category is quickly followed by a "trailing" image from a different category. Multivariate EEG analyses focussed on decoding stimulus information related to the trailing image category. Within-trial, decoding analyses showed early sharpening followed by later dampening in line with the Dual-Process Model. However, across trials an early dampening was followed by a later sharpening. These results suggest that higher-order regions may quickly detect stimulus statistics and show evidence of predictive dampening to expected inputs, and then gradually delegate those predictions to lower-order regions, which start showing evidence of predictive sharpening.

Abstract #10

Rare tone suppression in inferior colliculus that depends on the relative predictability of sounds

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To make sense of the acoustic environment, the auditory system must segregate, based on their history, streams of sounds arriving at the ear simultaneously. This requires sensitivity to both the probability and the predictability of the different sounds in the stream. That the auditory system is sensitive to the probability of appearance of a sound is well established. Here we presented complex sound protocols with varying predictability to anesthetized mice. Neuronal responses in the mouse inferior colliculus (IC) were recorded using with Cambridge NeuroTech and Neuropixels probes. Neurons exhibited suppression that was specific to unpredictable sounds and could not be explained through tuning, probability of appearance, or adaptation triggered by the immediately preceding sounds. Notably, the magnitude of the suppression was dependent on the tuning of the neurons relative to the predictable sounds. Furthermore, the effect was insensitive to temporal expansions in the sound sequence resulting from increasing the inter-tone interval up to 4 times. Therefore, in complex auditory environments, neurons reflect unsupervised learning of the relative predictability of various sounds, in a process that might be relevant for stream segregation.

Abstract #11

The susceptible brain: How short interruptions affect long term auditory scene representations – evidence from EEG

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The auditory system predicts future events by constantly tracking the statistics (‘context’) of the environment. Previous work has demonstrated a neural signature for this process in the sustained EEG response. It has been shown that listeners’ brains represent the predictability (or volatility) of the ongoing stimulus and use this inferred model to process incoming information. Here we investigated how these context representations are affected by brief interruptions (e.g., phone notifications). Two hypotheses were considered: (a) interruptions and the ongoing context are separately represented in the brain, (b) interruptions are integrated into the representation of the context. Understanding these processes is crucial for unravelling the heuristics utilised by the brain for environment tracking and may also provide simple models for more complex phenomena like post-traumatic stress disorder (PTSD).
We used EEG measurements in 28 naïve participants passively listening to regularly repeating tone-pip sequences (50 ms tones; cycles of 10 tones) while performing a “decoy” visual task. Some scenes included unexpected tone-pip interruptions violating the established patterns (1, 3, or 5 random tones introduced partway). The results revealed that the learning trajectory of the sound context was reflected in the EEG sustained response, characterised by an increase and plateau of sustained power with exposure to the sound context, followed by a drop upon interruption onset and subsequent recovery as the original context re-emerged. Notably, we observed that brief interruptions affected ongoing scene representations: the post-interruption sustained power never reverted to the pre-interruption level even though the presented regular pattern was physically the same before/after the interruption. These dynamics are consistent with predictions from an ideal observer model (perfect memory), which quantifies the entropy (uncertainty) of each tone-pip in the sequence based on the previously experienced patterns. The alignment of results suggests that (1) the sustained neural power reflects the brain’s representation of the entropy of the unfolding sound and (2) the pattern interruption results in the increased inferred volatility of the environment and the reduced predictability of the regular pattern. These findings provide new insight into how dynamic environments are represented in the brain and highlight the influence of transient surprises on long-term processing, even when they are behaviourally irrelevant. This could be crucial for understanding conditions like PTSD, where unexpected events can have lasting effects on the context representation in the brain.

Abstract #12

Rare sounds and rare pitch changes elicit involuntary motor responses

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Unpredictable deviations from a regular auditory sequence, as well as rare sounds following longer periods of silence are detected automatically. Recent studies show that the latter also lead to involuntary modulations of ongoing motor activity emerging as early as 100 ms after sound onset, which was attributed to supramodal processing reflected in the vertex potential. In the present study we explored whether such force modulations were also elicited by deviant sounds. Participants (N=29) pinched a force sensitive device and maintained a constant (1-2 N) force for one-minute periods, while task-irrelevant tones were presented. In the Rare condition, 4000 Hz tones were presented every 8-to-16 s. In the Roving condition, 4000 Hz and 2996 Hz tones were presented with onset-to-onset intervals of 1 s, with infrequent (p=1/12) frequency changes. Confirming previous reports, in the Rare condition, transient force modulations were observed with a significant increase at 234 ms and a decrease at around 350 ms. In the Roving condition, tone changes to the low frequency elicited a force increase at around 277 ms followed by a decrease at 413 ms. Interestingly, no significant modulations were elicited by changes to the high frequency. These results suggest that both rare silence-breaking sounds and low-pitched deviants evoke automatic fluctuations of motor responses, which suggests that these force modulations are triggered by stimulus-specific change-detection processes.

Abstract #13

Exploring the interplay: early-life exposome, hearing, gating, and cognitive development in children

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Objectives. While the detrimental effects of prolonged exposure to loud recreational noise are widely recognized, the impacts of moderate levels of everyday noise on school-aged children remain underexplored. This study investigates the intricate relationship between early-life environmental noise exposure, hearing, gating and cognitive development during the transition period from kindergarten to primary school.
Design.
Environmental exposure at home was assessed using a parent questionnaire and objective sound level measurements in a cohort of 42 normal-hearing children aged 5-6 years. Cognitive parameters (IDS-2 test battery), hearing parameters (Auditory Brainstem Response, Envelope Following Response, Sound detection in Noise), and gating-related EEG markers (MisMatch Negativity) were evaluated at the end of kindergarten and after the first year of primary school. Results.
Direct impacts on cognitive performance were not observed based on measured exposure levels alone. However, significant cognitive differences emerged in groups categorized by their level of traffic noise annoyance, which also corresponded to statistically different exposure levels. Higher noise exposure was significantly associated with improved sound detection abilities in noisy environments. While no direct link between sound detection and cognitive performance was found, outlier analysis revealed that better sound detection was associated with superior cognitive performance. Visual exploration indicated no significant differences between children exhibiting a clear adult-like MMN, and those with an absence/presence of a positive mismatch response. Conclusions.
Improved sound detection in noise suggests that moderate noise exposure can enhance auditory processing skills. Although high noise levels are detrimental, moderate exposure may benefit attention and inhibitory control mechanisms. Comprehensive analyses of the MMN will be discussed in detail at the conference.

Abstract #14

Layer dependent fMRI and biophysical modeling reveal the distinct roles of cortical laminae in processing unpredictable and mispredicted sounds

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Predictive coding postulates that our brains build an internal representation of the sensory world through the comparison of predictions casted by an internal model and the sensory input. Such a process takes place throughout the (sub-) cortical hierarchy. A specific role is attributed to the different cortical layers in the information flow between top-down predictions and bottom-up sensory evidence [1, 2]. In this study, we have collected high-resolution data from 10 healthy participants while they listen to tones that either respect or deviate from contextual cues using BOLD fMRI. With this paradigm, we aimed to disentangle responses to mispredicted and unpredicted sounds (compared to predictable tones). However, while ultra-high field fMRI (7 Tesla) can be used to observe cortical depth dependent brain activity non-invasively in humans, the effect of draining veins renders laminar gradient-echo BOLD activity tainted, making it difficult to disentangle neuronal from vascular dynamics [3]. Therefore, we use a biophysical model [4, 5] that combines neuronal dynamics and laminar vascular physiology within a dynamic causal modeling (DCM) framework. Using this approach we account for draining effects and reveal the laminar distribution of responses to unpredictable and mispredicted tones across the bilateral auditory cortex. In accordance with the predictive coding hypothesis [1, 2, 6] our results indicate a distinct role of deep and superficial cortical layers in the contextual processing of auditory stimuli.

[1] Bastos et al., 2021
[2] De Lange et al., 2018
[3] Turner, 2002
[4] Havlicek & Uludag, 2020
[5] Uludag & Havlicek, 2021
[6] Heilbron & Chait, 2017

Abstract #15

Rock around the clock: The size of prediction error determines the amplitude of the mismatch negativity (MMN)

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A key assumption of the Predictive Processing framework is that each level of the nervous system generates a model of its inputs, and then assesses new input against this model. If the new input matches the model no changes to the model are necessary, but if it does not match, a so-called prediction error occurred, further processing is needed to refine or adjust the model.

Mismatch negativity (MMN) has been treated as empirical evidence of processing of prediction errors.

We tested the precision of predictive processing in the auditory system by using Shepard tones—a series of notes, each comprising sine tones of different amplitudes and one octave apart, arranged into a discrete Shepard scale and separated from each other by one semitone. This yields a scale that apparently ascends or descends forever. We unpredictably and occasionally replaced an expected note in the scale by one that was two thirds of a semitone less, one third of a semitone less, one third of a semitone more, or two thirds of a semitone more. We found larger MMNs to deviants more different from the predicted tone and to deviants that were less than the expected note. We conclude that the predictive model for the kind of regularity in a discrete Shepard scale has a precision of less than one third of a semitone and is more sensitive to undershoots than to overshoots.

Abstract #16

The laminar patterns of predicting content in learned audio-visual associations

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To make sense of the external world, our brains use contextual information to predict upcoming stimuli. Previous studies have shown that content ("what") and temporal ("when") predictions are supported by different mechanisms. In particular, "what" predictions are linked to stimulus-specific gain modulation. Here, we aimed to understand how these mechanisms are grounded within the laminar cortical architecture using laminar fMRI. Using an audio-visual associative learning paradigm, we examined responses to predictable and unpredictable stimuli (i.e., when no associations were present). Within the predictable context, we distinguish responses to valid and invalid predictions, as well as responses associated with the omission of the content. We use both univariate and multivariate analysis techniques (decoding and representational similarity analysis). Our preliminary results suggest that it is possible to discriminate predictable from unpredictable content, as well as valid from invalid predictions, using cortical activity. Future analyses will focus on investigating the laminar patterns related to these responses. Within the predictive coding framework, we hypothesize that prediction errors are linked to stronger responses in superficial layers of the superior temporal gyrus (STG) and within the inferior temporal gyrus, while the contrast between predictable and unpredictable content should be highlighted in deep layer activity in STG.

Abstract #17

Audiovisual pitch perception training in congenital amusia: behavioral and neurophysiological benefits

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Congenital amusia is a neurodevelopmental disorder characterized by an impairment in pitch perception and memory. Individuals with amusia have difficulties with detecting pitch changes, processing pitch contours, and memorizing pitches. Our present study builds on previously reported benefits of multisensory integration of audiovisual (AV) cues on pitch processing and tested whether AV training could result in an enhancement of pitch processing in amusic (n=17) and control participants (n=19).
The training consisted of three pitch-related tasks, performed twice per week over 15 weeks: a pitch change detection task (PCD), a pitch direction of change identification task (DCI), and a pitch short-term memory task (STM). Each session lasted about 15-20 min. Half of the training trials were auditory only, and the other half audiovisual. Participants underwent testing sessions without visual cues before and after the training, as well as before and after an unrelated visuo-spatial training. During the testing sessions, participants performed the same three tasks as during the pitch (and visuo-spatial) training and additional untrained tasks. In addition, we used magnetoencephalography (MEG) measures to assess the effect of the AV pitch training on brain plasticity. We recorded brain responses during an active short-term memory task for pitch and a passive oddball paradigm with small and large pitch deviants and with short SOA and long SOA (the latter was tested only for large pitch changes).
Our results revealed a benefit of AV pitch training (compared to control visuo-spatial training) on amusics' behavioral performance, with higher accuracy for the PCD and DCI tasks. The investigation of the training effect on auditory networks revealed a decrease of N100 component during active sound sequence encoding in amusics and an increase of MMN during passive sound sequence encoding after the AV training in amusics and controls. In amusic participants we observed an increase of the MMN amplitude for small pitch deviants (0.25 semitone, short SOA of 500ms) while controls exhibit increased MMN amplitude for pitch deviants presented in sequences with long SOA (1500ms, 2 semitone pitch deviants). These results suggest that pitch perception can be improved -in active and passive listening- thanks to pitch AV training and this improvement can be observed both at a behavioral and neurophysiological level. It provides new perspectives to alleviate pitch perception deficits in various conditions and pathologies, including in cochlear implant users.

Abstract #18

Neuronal Responses to Omitted Tones in the Auditory Brain: A Neuronal Correlate for Predictive Coding

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Predictive processing is a leading and unifying theory of how the brain performs probabilistic inference. This mechanism let the brain to detect perceptual differences between expected and actual sensory inputs. According to this framework, the brain extracts the regularities from the environment and uses them to actively predict what should happen next. When the prediction and input do not match, a prediction error signal is generated. These responses have been widely recorded in all sensory systems.
It has been argued that the omission response provides conclusive, empirical evidence of the predictive process, as it occurs in the absence of sensory input (Wacongne et al., 2011, 2012). Nevertheless, to date, empirical evidence of omission responses at the neuronal level remains elusive. We investigated whether auditory neurons were detecting the omission deviant in an oddball paradigm context. The recordings were performed in the inferior colliculus and the auditory cortex of anesthetized and awake rodents. Our results reveal a subset of neurons that robustly increases their activity during the omission of an expected tone. These responses are evident, although weak, at anesthetized preparations and become stronger and distinct at the cortical level. Omission responses also show a higher probability of occurrence with shorter SOAs which aligns with the highest probability of omission responses at short latencies in humans (Raij et al. 1997; Hughes et al. 2001; SanMiguel et al., 2013a, 2013b). A deeper analysis based on individual stimulation sequences unveiled the so-called omission-selective responses (Fiser et al., 2016) and its distribution across the auditory cortex fields.
Our findings suggest that neurons in the auditory system detect a deviation from expectations without the need for an external stimulus (Bendixen, et al 2012) and gives a decisive empirical support to the theory of predictive processing.

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Abstract #19

Involuntary attentional capture induced by the unexpected omission of sounds

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Salient unexpected and task-irrelevant sounds can act as distractors by capturing attention away from a task. Consequently, a performance impairment (e.g., prolonged response times, RTs) is typically observed along with a pupil dilation response (PDR) and the P3a event-related potential (ERP) component. Previous results showed prolonged RTs in response to task-relevant visual stimuli also following unexpected sound omissions. However, it was unclear whether this was due to the absence of the sound's warning effect or to distraction caused by the violation of a sensory prediction. In our paradigm, participants initiated a trial through a button press that elicited either a regular sound (80%), a deviant sound (10%) or no sound (10%). Thereafter, a digit was presented visually, and the participant had to classify it as even or odd. To dissociate warning and distraction effects, we additionally included a control condition in which a button press never generated a sound, and therefore no sound was expected. Results show that, compared to expected events, unexpected deviants and omissions lead to prolonged RTs (distraction effect), enlarged PDR and a P3a. Moreover, sound events, compared to no sound events, yielded faster RTs (warning effect), larger PDR and increased P3a. Overall, we observed a co-occurrence of warning and distraction effects. This suggests that not only unexpected sounds, but also unexpected sound omissions can act as salient distractors. This finding supports theories claiming that involuntary attention is based on prediction violation.

Abstract #20

Modeling Hierarchical Multi-scale Classification Characteristics for Detection of Passive Auditory ERPs

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Behavioural diagnosis of patients with disorders of consciousness (DOC) is challenging and prone to inaccuracies. Consequently, passive auditory event-related potentials (ERPs) requiring low cognitive capacity are used to assess the residual auditory functions. However, these components can be difficult to detect using conventional averaging approaches at the individual level, which leads to false negatives.

We propose a novel hierarchical multi-scale classification approach to detect N1-P2 and mismatch negativity (MMN) components in a passive auditory oddball paradigm. This approach involves two classification tasks: (1) classifying standard stimuli against baseline to detect N1-P2, which is suitable for evaluating obligatory sensory responses, and (2) classifying standard stimuli against deviant stimuli to detect MMN, which is appropriate for assessing the representation in auditory sensory memory. We hypothesize that if the components are present, the classification performance should gradually improve as the number of averaged trials increases. Conversely, if the components are absent, the classification performance should vary around the chance level as the number of sub-averaged trials increases.

The proposed method was validated on 20 healthy participants. Results demonstrate that all participants exhibit a significant linear increase in classification accuracy, indicating the effectiveness of the approach in detecting N1-P2 and MMN components at the individual level.

The hierarchical multi-scale classification approach leverages the multi-scale characteristics of ERP components, enabling effective detection of N1-P2 and MMN in healthy participants at the individual level. These promising results lay the foundation for future applications in detecting ERPs in patients with DOC, potentially improving the accuracy of diagnosis and prognosis.

Abstract #21

Response characteristics of the nucleus accumbens dopamine to salient stimuli in rats

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Rapid discrimination of salient sensory input is considered to be one of the fundamental functions of sensory information processing. In auditory perception, the intensity of sound stimuli and the deviation, i.e., the low probability of occurrence, are examples of physical characteristics that determine the salience of the sound. Mismatch negativity (MMN) is a well-known neural component elicited by deviant stimuli, appearing not only in the human electroencephalogram but also in the rat auditory cortex, as we previously reported. In the present study, we focused on how sound saliency is represented outside the auditory cortex. It is known that stimulus saliency activates the salience network in the brain, which is mainly mediated by dopamine (DA). Therefore, we aimed to investigate whether and how the concentration of DA in the nucleus accumbens (NAc) of rats represents stimulus salience, i.e., the intensity of the salience and deviation in the oddball paradigm.
We employed fiber photometry to record DA concentrations in freely moving rats exposed to auditory stimuli. The DA response to the auditory stimulus exhibited several phases: an initial transient increase at 100 ms after stimulus onset, a sustained decrease during the stimulus, and another transient increase at 400 ms after stimulus offset. Remarkably, when the sound intensity decreased unpredictably during stimulus presentation, the DA level fluctuated and its amplitude corresponded to the decrease in sound intensity. Moreover, by analyzing the intensity of the onset response relative to the offset, we found that NAc-Shell showed a larger onset response ratio than NAc-Core, suggesting that these subregions may process saliency-related information differently.
We then conducted operant conditioning to determine whether rats could detect changes in saliency represented by DA levels in the NAc. Rats were rewarded for nose poking after the offset of the sound. In subsequent test session trials, the sound was attenuated instead of being stopped and rats were able to detect the change in saliency, i.e., sound attenuation; however, their behavior remained consistent across all levels of attenuation. Given that the DA levels differed across sound attenuation levels, these observations indicate that DA in the NAc is not directly involved in the perception of saliency determined by sound intensity. In upcoming studies, we plan to investigate DA dynamics in response to the auditory oddball paradigm to examine whether DA in the NAc is involved in the perception of saliency based on the unpredictability of the sound stimuli.

Abstract #22

A developmental perspective on the influence of arousal on auditory attention

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Distraction by unexpected auditory events is common in the daily lives of both children and adults. Although previous research has shown that unexpected salient sounds impair task performance, an increasing number of studies have demonstrated that unexpected stimuli can be beneficial for performance and result in faster responses. Current theories attribute this beneficial effect to a transient increase in arousal levels, under the control of the Locus Coeruleus – Norepinephrine (LC-NE) system. While the interplay between attention and arousal has been central to physiological research in animals and theoretical works, empirical evidence in humans is limited, particularly during childhood. However, understanding the dynamic interplay between arousal and attention is crucial for elucidating cognitive processes and attention-related developmental disorders, such as Attention deficit hyperactivity disorder (ADHD). Interestingly, a previous work in adults suggests that increasing arousal levels using music improves voluntary attention during a behavioral auditory task.

The objective of the present study was to investigate the impact of arousal on attention in 44 children (6 to 8 years old) and 46 adults (18 to 35 years old) using a 3-tone oddball paradigm. We modulated tonic arousal by presenting calm and exciting music extracts, as well as exciting videos, preceding each block of the oddball task (induction period). We recorded behavioral responses (reaction times, response rates) and physiological parameters (skin conductance, pupil dilation, heart rate).

Results indicate that exciting videos result in the strongest level of tonic arousal in both children and adults, during the induction period and the following oddball task, as shown by peripheral measure of tonic arousal. However, the behavioral measures (reaction time and reaction time variability) during the oddball task appear to be unaffected by the tonic arousal level in both age groups. Additionally, children display both larger tonic and phasic responses as compared to adults. Therefore, the present study provides new knowledge about the effect of arousal on attention during childhood and adulthood.

Abstract #23

Is the oddball just an odd-one-out? A new perspective on the predictive potential of deviations from structured auditory regularities

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The oddball paradigm underlies many empirical studies demonstrating the impressive ability of the auditory system to rapidly encode auditory regularities. Here, we examine the widely neglected characteristics of the rare deviants being bearers of predictive information themselves, in addition to them violating the global rule defined by the standards. Naive participants listened to sound sequences constructed according to a new, modified version of the oddball paradigm including two types of deviants that followed diametrically opposed rules: one deviant sound occurred mostly in pairs (repetition rule), the other deviant sound occurred mostly in isolation (non-repetition rule). Due to this manipulation, the sound following a first deviant was either predictable or unpredictable based on its conditional probability associated with the preceding deviant sound. Importantly, because this sound was either the same deviant or a standard sound, each conditional contrast is controlled for effects related to the global rule. The response times and false alarm rates in an active deviant detection task show that deviant repetition rules (based on conditional probability) can be extracted when behaviourally relevant, both when the sound in question confirms and violates the global rule, respectively. The electrophysiological findings obtained in a passive listening setting indicate that conditional probability also translates into differential processing at the P3a level. However, MMN was confined to global deviants and was not sensitive to conditional probability. This suggests that higher-level processing (reflected in P3a and behaviour) but not lower-level sensory processing (reflected in MMN) is affected by rarely encountered rules.

Abstract #24

Five-year old preschoolers' MMN responses for speech-sound changes predict their pre-reading skills and non-verbal intelligence

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Background
Fluent reading is suggested to be based on auditory processes: when reading, there is a need of matching auditory image of a phoneme with its visual image. One commonly used index for pre-reading skills is a behavioral test called rapid serial naming. In such a task, the children are asked to identify e.g., objects and colors as fast as possible. Performance in this task has been linked to children's mismatch responses (MMR). Also, non-verbal intelligence has been suggested to be associated with maturation of the auditory event-related potentials (ERPs). Here, we wished to determine, in a longitudinal paradigm, whether auditory mismatch negativity responses (MMN) predict the development of preschool-aged children's pre-reading and cognitive skills.

Methods
Five-year-old children (N = 74) participated in a longitudinal study for two school years. We measured children's auditory ERPs with a multifeature MMN paradigm consisting of speech sound changes. We also tested their language abilities and non-verbal intelligence. The tests and measurements were conducted four times during the longitudinal study.

Results
Our preliminary results show that the magnitude of the MMN response in the first recording predicted children's behavioral test scores a year later in rapid serial naming and in non-verbal intelligence. The association was found specifically with responses for vowel changes. Unlike expected, no such association was found for phoneme processing abilities.

Conclusions
On a group-level, five-year old children's MMN responses predict their pre-reading skills and non-verbal intelligence a year later. The result supports the views associating auditory and (pre-) reading skills and highlights the promises of sound-based training programs to support fluent reading acquisition.

Abstract #25

Are eyes a potential objective measure of auditory scene analysis?

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The auditory system plays a crucial role as the brain's early warning system. Previous work has shown that the brain automatically monitors unfolding auditory scenes and rapidly detects new events. Here, we focus on understanding how automatic change detection interfaces with the networks that regulate arousal and attention, measuring pupil diameter (PD) and pupil dilation events (PDE) as an indicator of listener arousal and microsaccades (MS) index of attentional sampling. Naive participants (N=30) were exposed to artificial 'scenes' comprised of multiple concurrent streams of pure tones while their ocular activity was monitored. The scenes were categorized as REG or RND, featuring isochronous (regular) or random temporal structures in the tone streams, respectively. Previous work showed that listeners are sensitive to predictable scene structure and use this information to facilitate change processing. To model changes, a single component was added (change appearance) or removed (change disappearance) from the scenes. Results show that non-attended scene changes elicit pupil dilation and inhibit MS responses, providing evidence for automatic attentional capture and increased arousal. Importantly, change-evoked MS inhibition (MSI) responses were modulated by scene regularity, exhibiting increased MSI in REG scenes, consistent with heightened attentional capture by changes in predictable contexts. Overall, findings shed light on how automatic auditory scene analysis interfaces with attentional/arousal networks.

Abstract #26

Initiation of cortical up states by auditory deviants: a mismatch negativity generation mechanism in unconscious states

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Cortical slow oscillations are the reliable changes between "Up" and "Down" states in the cortex, corresponding to high- and low activity levels. These synchronised state changes occur at a rate of 0.2-0.5 Hz and are a global event throughout the thalamus and cortex during slow-wave sleep and deep anaesthesia. Slow cortical oscillations are present in the deafferented cortex (e.g., in vitro or lesion studies), demonstrating that thalamocortical input is not required for generation, however intact preparations show that thalamocortical input increases slow oscillation frequency. Furthermore, thalamocortical activity precedes Up states, suggesting that thalamocortical activity is the initiator of Up states, and therefore controls Up state frequency. External somatosensory and visual stimuli have been shown to initiate cortical Up states, with the travelling wave of activity initiated from the relevant sensory cortex. Here we test initiation of cortical up states during the oddball paradigm in the urethane-anaesthetised rat.
Long Evans female rats were implanted with ECoG arrays consisting of 6 silver-ball electrodes placed bilaterally over auditory cortex and medial prefrontal cortex. We recorded local field potentials and oscillatory activity from rats at 4 hours post-induction of anaesthesia with urethane. Auditory stimuli consisted of an oddball paradigm using a frequency pair of 10 and 14.142 kHz at a stimulus onset asynchrony of 250 ms.
Here, we demonstrate that the urethane-anaesthetised rat exhibits strong spontaneous cortical slow oscillations, consisting of "Up" and "Down" states. Deviant stimuli of the oddball paradigm trigger cortical Up states, resulting in mismatch negativity signals across the cortex. With optimised inter-deviant timings this initiation is highly reliable, occurring after most auditory deviant. Such data provide evidence for thalamocortical initiation of cortical Up states, while suggesting a mechanism for MMN generation in unconscious states. It is tempting to speculate that these data may share some of the neural mechanisms that initiate cortical slow oscillations and mismatch negativity and/or P300.

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Abstract #27

Medial prefrontal cortex outputs contribute to prediction error generation in the auditory cortex

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Under the Bayesian brain hypothesis, the brain continuously generates a model of the environment based on predictions gained from previous experiences. Incoming sensory information is compared to this model and either confirms the prediction, or if significantly different enough, prediction errors update the generative model. Using the auditory "oddball" paradigm, neural correlates of prediction errors are observed as early as the auditory midbrain, with the strength of error increasing up the auditory hierarchy to the auditory cortex (AC). The medial prefrontal cortex (mPFC), which is involved in planning complex behaviour and decision making, exhibits strong and long-lasting responses solely to auditory deviants, consistent with coding of prediction error. This raises the hypothesis that mPFC exerts a top-down control of deviance detection in sensory cortices, by transmitting prediction signals. To test this, we injected Female Long-Evans rats with 1 µl AAV5-hSyn-eNpHR3.0-EYFP to the mPFC to allow optogenetic suppression of mPFC neurons. After 7-11 days of recovery, 64-channel neural recordings were conducted in the AC under urethane anesthesia. An auditory "oddball" paradigm composed of standard (STD) repeating stimuli, deviants (DEV) and no-repetition controls (CTR) were presented monaurally. This allowed decomposition of the neural mismatch effect into two components: repetition suppression and prediction error, which were measured during suppression of mPFC neurons.
Rats showed expression of EYFP throughout the mPFC, demonstrating successful optogenetic virus transfection. Further, neural recordings using an optrode in the mPFC showed that local LED illumination reduced activity of mPFC neurons during spontaneous and auditory-evoked activity. LFP and single-unit recordings in the AC during the auditory "oddball" paradigm showed robust neural mismatch, with responses to DEV stimuli greater than CTR stimuli, and limited responses to STD stimuli. Inhibition of the mPFC had no effect on neural responses during STD or CTR stimuli, but reduced LFP amplitudes and single-unit responses to DEV stimuli, providing evidence for top-down predictive transmission from mPFC which enhances AC responses to unpredicted stimuli. The reduced deviant response during mPFC inhibition was accompanied by reduced neural synchrony in the auditory cortex, suggesting weakening of the previously described cortical deviant-detector ensembles.

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Abstract #28

The ABR, MLR, and late AEP with high temporal resolution during dichotic selective attention

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The traditional view of attention research provides a negative judgement against attentional modulation of auditory evoked potentials (AEPs) preceding to N1 wave (Näätänen, 1990). Ikeda (2018) suggested that auditory brainstem response (ABR) modification due to selective attention might be available in a limited dichotic condition where lower frequency tones to the left ear and higher frequency tones to the right ear were delivered. The present study kept the same dichotic listening procedure and further examined attentional influence on sequential AEPs of ABR, middle latency response (MLR), and late AEP by using a common high sampling frequency (10 kHz).
Eighteen right-handed persons participated through writing their informed consents in this study that was approved by the ethical committee of Tokyo Gakugei University. They performed dichotic listening tasks in which the standard (0.5 kHz) and target (0.6 kHz) tones to the left ear, while those stimuli (1 and 1.2 kHz) to the right ear, were presented at 35-dB SL intensity with SOA 180-320 ms. Participants received two probability combinations, i.e., one combination had target probability at 0.01 (left ear) and 0.10 (right ear), whereas the other had the probability at 0.10 (left ear) and 0.01 (the right ear). For each probability combination, participants implemented three tasks (auditory left-side detection, auditory right-side detection, and visual detection). Scalp potentials (band-pass frequency 0.16-2110 Hz) were recorded with a sampling frequency at 10 kHz from Fz and Cz-electrodes referenced to the earlobes or mastoids. In off-line analyses, band-passed (20-2000 Hz) EEGs were averaged for standard tones over 3000 epochs in ABR/MLR and low-passed (100 Hz) EEGs over 1500 epochs in late AEP. Three difference waveforms were calculated from subtraction between (1) auditory relevant and irrelevant detections, (2) auditory relevant and visual detections, and (3) auditory irrelevant and visual detections. A repeated-measures ANOVA (2 sound frequencies x 2 probabilities x 3 subtractions x 2 scalp electrodes x 2 reference types) was applied to an amplitude among the next nine wave ranges: pre-wave IV/V, wave IV/V, No/Po, Na, Pa, Nb for ABR/MLR, and pre-Nd, early Nd, late Nd for late AEP.
Focused to a main effect of subtraction types, significant F values were identified for the eight wave ranges ($ps < 0.03$) except for the pre-wave IV/V. Partial eta squared was maximum at late Nd (0.80) followed by Pa (0.44) and Na (0.41) ranges. The present outcomes favor with non-traditional view stressing attentional AEP modulation before N1 wave.

Abstract #29

Absence of visual mismatch negativity in a classical lightness oddball task

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The visual mismatch negativity (vMMN) is argued to have provided some of the strongest evidence in favour of models that posit high-level, categorical effects on early processing of colour: Thierry et al. (2009, PNAS) reported higher vMMN elicited by stimulus deviants and standards in light/dark blue series compared to light/dark green series in Greek speakers, who have two basic terms for 'blue' (ghalazio/ble). However, recent behavioural evidence in the field of colour cognition has leaned away from such direct influences positing a more indirect (i.e., attention mediated) effect of colour cognition on colour perception (e.g., Witzel, 2019, Rev Philos Psychol). In our re-evaluation of the vMMN evidence for early colour category effects, we used the same classical oddball paradigm as in Thierry et al.: light or dark blue standards were repeated 3–5 times followed by deviants that differed in either lightness, or shape, or both. The vMMN was calculated by subtracting the activity elicited by the standards from that elicited by task-irrelevant (i.e., standard shape) lightness deviants. We conducted two experiments: (1) a direct replication of Thierry et al.'s design with Russian speakers, who, too, have two basic terms for 'blue' (goluboj/sinij). Predicted was a greater vMMN for blue relative to green stimuli, in line with Thierry et al. (2009). (2) An indirect replication with English-speaking participants, with standards and deviants in four areas of colours space: in the 'cool' region, light/dark green and light/dark blue, and in the 'warm' region, pink/red and yellow/brown. We expected an enhanced vMMN solely for the two 'warm' colour series, which both in English involve basic categorical distinction. We failed, however, to identify a robust vMMN component in either of the experiments. Notably, we did observe a later modulation of the amplitude, in the P300 window, indicating that attention was directed to lightness non-target deviants, likely by virtue of them sharing the same lightness with the lightness-shape deviant targets. This aspect of our design was inherited from the original study and complicates the pre-attentive interpretation further. In conclusion, the vMMN evidence of categorical effects on colour processing appears to be less robust than previously thought. Our findings rather support more recent explanatory schemes – models of attention-facilitated categorical influences on colour perception, as well as the adaptation-driven account of the vMMN to a change in basic visual features (Male et al., 2020, Psychophysiol).

Abstract #30

Mismatch negativity changes throughout urethane anesthesia in the rat

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The mismatch negativity (MMN) is an auditory response elicited when a regular pattern in stimuli is disrupted by an event that breaks the regularity of that pattern. Is thought to emerge from two cortical sources: the auditory cortex (AC) and the prefrontal cortex (PFC). The generation of the MMN is consistent with the predictive coding hypothesis in which the AC sends afferent signals to the PFC, which generates a predictive model that it sends by efferent projections to the AC. This causes anticipated stimuli to be inhibited, and unpredictable stimuli create a prediction error to be transmitted bottom-up to update the model in the PFC. MMN has become a useful biomarker for several diseases because it has the advantages of being a reliable neurological signal that does not require attention or consciousness, it can be recorded by electroencephalography, electrocorticography (ECoG) or by invasive recording of individual neurons (neuronal mismatch). We studied how MMN changes under anesthesia and under different stimuli paradigms. Long Evans female rats were implanted with ECoG arrays consisting of silver-ball electrodes placed over left and right rostral and caudal AC, and two more electrodes over right and left PFC. We recorded local field potentials (LFPs) from anesthetized animals at different times points after induction of anesthesia with urethane (4, 6, 8, 10, 12 & 16 hours). Stimuli consisted of oddball, with a frequency pair of 10 kHz and 10 kHz + _ octave, and cascade control paradigms, using different stimulus onset asynchrony (SOA; 125, 250, 500 & 1000 ms). We observe that longer SOAs (500 & 1000 ms) produce greater amplitude deviant responses, and over 16 hours there is a progressive decrease in the amplitude of the deviant response, producing a decreased prediction error and consequently in the MMN. In contrast, at shorter SOAs (125 & 250 ms), showed a smaller amplitude of the deviant response without changes observed over the 16 hours. These results show that, larger SOAs (500 & 1000 ms) are preferable for observing the MMN by ECoG in anesthetized rat. This method of MMN recording offers a global study of the different areas of the cerebral cortex and can be more transferable to human studies.

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Abstract #31

Predictive encoding of deviant tone sequences in the human prefrontal cortex

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The ability to use predictive information to guide perception and action relies heavily on the prefrontal cortex (PFC), yet the involvement of its subregions in predictive processes remains unclear. Recent perspectives propose that the orbitofrontal cortex (OFC) generates predictions about perceptual events, actions, and their outcomes while the lateral prefrontal cortex (LPFC) is involved in prospective functions, which support predictive processes, such as selective attention, working memory, response preparation or inhibition. To further delineate the roles of these PFC areas in predictive processing, we investigated whether lesions would impair the ability to build predictions of future events and detect deviations from expected regularities. We used an auditory deviance detection task, in which the structural regularities of played tones were controlled at two hierarchical levels by rules defined at a local (i.e., between tones within sequences) and global (i.e., between sequences) level.

We have recently shown that OFC lesions affect detecting prediction violations at two hierarchical levels of rule abstraction, i.e., altered MMN and P3a to local and simultaneous local + global prediction violations (https://doi.org/10.7554/eLife.86386). Now, we focus on the task's predictive aspect and present the latest results showing the involvement of PFC subregions in anticipation of deviances informed by implicit predictive information.

Behavioral data shows that deviance expectancy induced faster deviance detection in healthy adults (n=22), suggesting that participants track a state space representation of the task and anticipate upcoming deviant sequences.

The analysis of EEG data from patients with focal lesions to the OFC (n = 12) or LPFC (n = 10), and SEEG from the same areas in patients with epilepsy (n = 7), revealed interesting differences. Healthy adults (n = 16) showed modulations of the Contingent Negative Variation (CNV) – a marker of anticipatory activity - tracking the expectancy of deviant tone sequences. However, patients with OFC lesions lacked CNV sensitivity to the predictive context, while patients with LPFC lesions showed moderate sensitivity compared to healthy adults. These results were further supported by intracranial recordings, which revealed expectancy modulation of the high-frequency broadband signal from electrodes in OFC and LPFC, with an earlier latency of activity modulation for the OFC and a later one for the LPFC.

Altogether, the complementary approach from behavioral, intracerebral EEG, scalp EEG, and causal lesion data provides compelling evidence for the distinct engagement of the two prefrontal areas in predicting future events and signaling deviations.

Abstract #32

Atypical predictive processing in the inferior colliculus of the valproic acid-induced model of Autism

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Autism Spectrum Disorder (ASD) is a neurodevelopmental condition characterized by restricted, repetitive interests, and atypical sensory perception. Unusual auditory processing would compromise environmental experience, compromising the acquisition of progressively more elaborate cognitive abilities throughout postnatal development. Particularly, when stimuli (e.g. sounds) and contexts (e.g. social) become dynamic and unpredictable. The predictive coding theory frames these symptoms. It postulates that the brain constantly compares prior predictions with upcoming sensory information. In case of mismatch, a prediction error arises, updating the predictions to the new environmental information, facilitating adaptive behavior. The predictive coding theory of ASD suggests an atypical predictive processing of sensory stimuli, compromising adaptability to non-routine events. To study atypical predictability in ASD, autistic traits were induced to pups born of pregnant rats that received an i.p injection of valproic acid solution (400 mg/kg) at the gestational day 12. Female and male prepubertal (PD30-45) and adult (PD65-120) animals were included, addressing developmental and sex biases. We studied the predictive processing of auditory stimuli at the subcortical level, recording single neurons in the lemniscal and nonlemniscal inferior colliculus. Five auditory conditions were presented: A classical oddball paradigm was used to study mismatch negativity; the brain response to the disruption of the regularity, and control sequences were used to further analyse predictive indexes. Results support the notion of unusual predictive processing in ASD, which could explain limited adaptive behaviour in unexpected situation.

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Abstract #33

The relationship between reading difficulties and the speech MMN in Japanese native speakers

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Background: Recent studies show that the Mismatch Negativity (MMN) of the speech sounds oddball paradigm is lower in dyslexia than in healthy children, and the MMN is related to reading skills. Lower MMN indicates atypical auditory processing in dyslexia. In Japan, reading performance is related to rapid automatized naming (RAN), and the RAN performance predicts the risk of reading difficulty, called Learning Disorder (LD). However, the relationship between reading skills and the auditory process is unclear because of the heterogeneity in reading difficulty in Japanese. One reason for heterogeneity is that there are three types of characters in the Japanese language: Hiragana, Katakana, and Kanji. Hiragana and Katakana's letters almost correspond to one sound, but Kanji's letter has many sounds, including visual complexity, impoverished phonological information, and changes in their sounds and meanings depending on the context. Thus, in the case of Japanese, reading difficulties due to the complexity of the characters are related to visual processing, attention, and working memory issues in addition to auditory processing. This study investigated the relationship between reading skills and speech MMN in Japanese native speakers.
Methods: In this study, 18 Japanese-speaking adults with typical development (M = 21.8 years old) and a child with LD (12 years old) participated in behavioral assessments for reading skills and a speech-syllable MMN paradigm (Norton et al., 2021). All participants completed the behavioral assessments: letter naming, real words naming, pseudowords naming, RAN, and Kanji writing tasks. The MMN paradigm contained the standard stimulus in 90% of trials (1620 trials) and the deviant stimulus in 10% (180 trials). The EEG data was recorded using a 18-channels at a sampling rate of 500Hz. We investigated how MMN mean amplitude and laterality were related to the behavioral assessments.
Results: In correlation analysis, MMN mean amplitude at Fz was significantly correlated with letter naming ($r = -.55$), real words naming ($r = -.47$), pseudowords naming ($r = -.64$), and RAN($r = -.60$). These results showed that the larger the MMN amplitude, the slower the reading speed.
Discussion: This study's results showed a correlation between reading skills and MMN among Japanese speakers. However, unlike previous studies in Western countries, MMN increased with reading difficulty. This finding suggests that the relationship between reading skills and the auditory process may vary across different languages and reading systems, and further research is needed to understand these differences.

Abstract #34

Can a Multi-Deviant Gap Detection Paradigm be effective in eliciting Mismatch Negativity in Children: A Pilot Study

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Objective: This pilot study aimed to assess the efficiency of a multi-deviant gap detection paradigm and compare the amplitudes and latencies of Mismatch Negativity (MMN) elicited by the multi-deviant and single-deviant oddball paradigms in children.
Background: Mismatch negativity is a negative event-related potential that can be triggered by introducing a silent gap in a frequently presented standard stimulus. The single-deviant oddball paradigm is commonly used for this purpose. However, evaluating the effects of different gap durations using this paradigm can be time-consuming. Recently, a time-efficient multi-deviant paradigm was proposed by Duda et al. (2019), involving six different gap sizes as deviants, which demonstrated satisfactory results in adults.
Methods: Nine children aged between 8 and 12 years participated in this study. The multi-deviant oddball sequence consisted of six deviants with gap sizes ranging from 2 to 40 ms, inserted in a 200 ms white noise burst serving as the standard stimulus. The deviants and standard stimuli were presented alternately in each run. Multiple runs of the single-deviant oddball paradigm were also presented with gap sizes of 5, 20, or 40 ms, with each deviant presented in a separate sequence.
Results: Although MMN was observed in response to all gap sizes in children, there was no consistent increase in amplitudes as the gap duration lengthened at both Cz and Fz locations. Furthermore, the amplitudes of MMN recorded by the same gap duration differed between the multi-deviant and single-deviant oddball sequences.
Conclusions: The multi-deviant gap detection paradigm in children may not be as efficient as in adults, as the amplitudes of MMN did not consistently improve with increasing gap durations. Modifications to the current paradigm, such as increasing the stimulus onset asynchrony or altering the gap size, may be necessary to achieve better results.

Abstract #35

Functional connectivity between temporal and frontal cortices during deviance detection processing in awake monkey

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MMN is a well-established biomarker for psychiatric disorders, particularly schizophrenia. To elucidate the biological mechanisms reflected in altered MMN in patients, we investigated the neural basis of MMN in awake macaque monkeys. The complex cortical structures of non-human primates, which closely resemble humans, is suitable for translational research. The mechanisms generating MMN can be divided into two components, adaptation and deviance detection. We previously reported that the deviance detection component is reduced in patients with schizophrenia. In the present study, we recorded both components of MMN in two macaque monkeys performing a fixation task using high-density electrocorticography (ECoG) examinations, and explored the localization and functional connectivity between the temporal and frontal lobe of MMN and each component. We applied the frequency oddball paradigm and a many-standard paradigm to dissociated adaptation and deviance detection. In the temporal cortex, both MMN and deviance detection was localized anteriorly, whereas in the frontal cortex, only deviance detection was apparent in the frontal pole and orbitofrontal cortex (OFC). The generation of the adaptation component was more broadly distributed than that of deviance detection and MMN. We analyzed the functional connectivity between the frontal pole, OFC and the anterior temporal cortex using phase locking value (PLV). The functional connectivity between the OFC and the anterior temporal cortex was enhanced during MMN and deviance detection. These results suggest that the deviance detection components of the MMN may underlie communication between the OFC and the anterior temporal cortex.

Abstract #36

Audiovisual Rabbit Illusion and multimodal Mismatch Negativity: A Dual Approach to Investigate Multisensory Integration

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Multisensory integration is a prevailing phenomenon in our daily information processing. The mechanism of multisensory integration has been investigated in two aspects. One is the multisensory illusion, in which the multisensory integration mechanism produces a falsely integrated perception of multisensory inputs that are not actually integrated. The other is deviance detection, where an error signal, i.e., multimodal mismatch negativity (MMN), is elicited by the deviations in one or both modalities of multisensory stimuli. To better understand multisensory information processing, we aimed to examine whether the strength of multisensory information processing quantified by these two methods is similar, by comparing the individual differences in the strength of multisensory integration.

First, we refined a recently developed auditory-dominant illusion called the Audiovisual (AV) rabbit illusion. In this illusion, the number of presented auditory stimuli and visual stimuli contradict each other, leading to the suppression of a superfluous stimulus or the elicitation of an illusory stimulus. We proved that the dominant sensory modality could be changed by modulating the intensity of auditory stimuli. Moreover, individual differences were observed in the psychophysical experiment. Regardless of the intensity change of auditory stimuli, most participants appeared to have a certain sensory modality that dominated over the other, while a minority showed a weak illusion in both audio and visual modalities.

Second, as an electrophysiological approach, we recorded audiovisual MMN from the same participants and investigate whether similar individual difference is found between the dominant modality to elicit MMN. The electroencephalography (EEG) study uses auditory, visual, and audiovisual oddball paradigms, and the resulting mismatch negativities are compared among groups of participants with different dominant sensory modalities. The EEG study aims to find connections between behavioral results from the psychophysical experiment and brain wave features from the EEG experiment. It also holds promise in exploring the field of neural and cognition science if the possibility of using MMN as an indicator of multimodal integration is proven.

Abstract #37

Differential auditory mismatch responses depending on awareness and task relevance

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Presenting rare among frequent auditory stimuli results in a mismatch response, where, on a neural level, the rare deviants elicit a stronger response than the frequent standards. While mismatch responses in event-related potentials (ERPs), like mismatch negativity and P3 have been studied extensively in the auditory modality, the separated effects of awareness and task relevance on different components of the ERP to deviant and standard stimuli remain to be investigated. In the current EEG study, we used a roving oddball design, in which speech stimuli (the German words oben [ˈoːbn] and unten [ˈʊntn], meaning above and below, respectively) were presented in sequences of varying length, leading to a classification of the first stimulus presentation as deviant, which– after several repetitions – turns into a standard. Four different task conditions using the same physical stimuli were implemented, so that the roving oddball stimuli were (1) unaware, (2) aware but task-irrelevant, (3) task-relevant but target-irrelevant and (4) target-relevant. The order of the conditions was pseudo-randomized, with the exception of the unaware condition being the first condition for every participant. Behavioral data showed that participants were able to easily differentiate presented words from not presented words in all aware conditions, but not in the unaware condition. We compared ERPs in response to deviant versus standard speech stimuli in all four conditions and found early fronto-central negativities and late positivities that varied with awareness and task relevance. Results have important implications concerning theories of unconscious and conscious deviance processing.

Abstract #38

Underlying mechanisms of visual mismatch responses – an EEG-fMRI study

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Seeing unexpected changes in regular visual input is important for perception and action. Unexpected visual events compared to expected events are usually accompanied by a stronger neural response that can be measured by blood oxygenation level-dependent (BOLD) response as well as electroencephalography (EEG). These deviance responses have been proposed to rely on different mechanisms, including prediction error-related activity and fatigue-based mechanisms. Whether these mechanisms vary systematically between early and late responses or different cortical areas is yet unknown. One way to delineate the contribution of these two mechanisms to deviance effects is to compare the responses of deviant and standard stimuli to a control stimulus. In the current study, we recorded EEG-fMRI while participants (N = 54) viewed a visual oddball sequence as well as a suited control condition. Comparing activation to deviants and standards, we found a visual mismatch negativity as well as a P3 in the EEG, while we observed activations in occipital cortex (OC) and superior parietal lobe (SPL) in the fMRI. Mismatch responses in the EEG and posterior OC were predominantly driven by fatigue-based mechanisms. However, responses in anterior OC and SPL could be best explained by predictive processing. This suggests that the relative contribution of these mechanisms in deviance processing varies systematically and fMRI and EEG can differ in the processes they potentially uncover.

Abstract #39

Tracking the Statistical Structure of Rapidly Unfolding Sound Sequences - Evidence from EEG in Humans

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Human listeners have an inherent capacity to automatically track the structure of rapidly evolving sound sequences. An enduring question pertains to understanding which statistics are being tracked monitored by the brain under automatic (passive listening) conditions.

Here, we combined computational modelling and EEG (n=30) to examine how the brain processes dynamic changes in sequence structure. Naïve listeners were exposed to two stimulus conditions (StimA and StimB, below) that contained complex statistical changes. Predictions were guided by two commonly used computational models, PPM (Pearce, 2005) and D-REX (Skerritt-Davis & Elhilali, 2018), representing different hypotheses concerning the brain's statistical tracking heuristics (Markov chain-based vs Bayesian ideal observer based). We focused on analyzing the sustained response, which recent evidence from our lab and others has linked to the dynamic representation of 'precision' (inferred reliability) of unfolding auditory signals.

Auditory signals consisted of 50ms tone pips, drawn from a pool of 20 log-spaced values between 222-2000 Hz. StimA contained a transition from a random pattern of 5 tones, to a regular pattern consisting of the original 5 tones and 5 new tones. The sequence, therefore, contains a shift between 3 different levels of predictability (discovery of initial random structure; increase in unpredictability associated with the transition to a larger alphabet; discovery of regularity).

The EEG findings demonstrated that naïve listeners automatically track the statistics of StimA, and that the PPM model provided a more robust fit to the data, consistent with many previous demonstrations that brain tracking of the emergence of structural dependence is well captured by Markov chain-based statistics.

StimB consisted of a sequence of 6 randomly chosen tone pips characterized by a probabilistic structure marked by a transition from a more predictable pattern (3 of the tones presented at a probability of 29.6%, 3 at a probability of 3.7%) to a less predictable pattern (all tones equiprobably at 16.6%). Such statistics are commonly used, e.g. in the decision-making literature (but using slower presentation rates). However, despite both models being sensitive to the transition in the stimulus, EEG data revealed no difference between StimB, and it's no change control. We discuss several interpretations for these effects.

Overall, the findings shed light on the intricate processes underlying the brain's ability to track statistical changes in rapidly evolving sound sequences.

Abstract #40

Neural discrimination of phonemes and rule violations in school-aged children with dyslexia risk

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Intro

Developmental dyslexia (DD) is the most common and highly heritable learning disorder, affecting about 5-17 % of children. Although DD is a reading deficit, it is understood to stem from dysfunction of auditory processing that negatively impacts early language learning.

The underlying core deficit in DD has been suggested to be a phonological processing deficit (PPD) or a more general implicit learning deficit (ILD). In PPD, the ability to phonetically differentiate speech sounds from one another and to learn the correct mapping between graphemes and phonemes are impaired. In ILD, the ability to acquire knowledge on patterns, such as regularities of sequential stimuli, is compromised. There are some MMN results supporting these theories, but the evidence is so far very scarce.

This study of the DyslexiaBaby/DyslexiaKid project investigated whether 7 to 8 year old children at dyslexia risk, who have finished the 1st grade of school, have PDD and/or ILD by recording deviance-related ERPs in these children and in children without such risk.

Methods

Mismatch responses (MMN and early and late LDN) were recorded with EEG in response to phoneme changes (vowel deviant, probing PPD) and violations of an implicit sound-order rule (rule violation, probing ILD) in a multi-feature paradigm consisting of speech sounds with continuous acoustic variation. Reading skills were assessed by using standardized age-level matched reading and writing tests.

Results and conclusions

There was a group difference in the reading test performance, the risk group performing worse than the control group, suggesting that our risk group included children who might become reading impaired. We found a diminished LDN to the vowel deviant in the left hemisphere of the risk group. As speech processing is often lateralized in the left hemisphere, the more right lateralized responses in the risk group may indicate abnormal neural organization of speech processing which is typical in dyslexia. In addition, the risk group had a longer LDN latency to the vowel deviant compared to the control group which indicates that they processed the stimuli more slowly than the control group which is common in dyslexia. We also found that MMN to the rule violation was insignificant in the risk group but significant in the control group. This suggests that the risk group was not able to detect the violation of an implicit rule. In conclusion, our results support for the PPD and ILD theories of dyslexia.

Abstract #41

Investigating Specific and Nonspecific Prediction-
Do predictions represent a summary statistic or multiple discrete outcomes?

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The brain's ability to use previous knowledge to anticipate inputs and enhance information processing has been extensively studied. In everyday life, cues rarely predict a single outcome (e.g. the sound of steps signals one of several expected visitors). Yet, most existing research primarily focuses on measuring prediction errors in scenarios with singular expected inputs. This leaves a gap in understanding how the brain predicts inputs when there are multiple potential outcomes. Does it rely on a condensed summary of possibilities for prediction (e.g., a central measure of the distribution), or does it hold discrete potential options?
To address this question, we designed experiments pairing visual cues with auditory stimuli. In one condition, the cue did not predict the tone identity (no prediction condition); in another, it signaled a single expected tone (single prediction condition); and in a third condition, it signaled three equally probable tones (multiple prediction condition). Five percent of trials were incongruent trials, where the sound violated the prediction.
Previous studies show that event-related responses to predicted tones should be different from unpredicted tones. We hypothesized that if the brain produces a summary prediction (e.g. the mean) in the multiple prediction condition, the response to the predicted tones should vary depending on their similarity to the single prediction. Conversely, if the brain maintains all the predictions, all responses should be similarly affected.
By applying cluster permutation analysis to EEG data recorded from 34 participants, we identified spatio-temporal clusters with significant differences between predictable and unpredictable conditions. We also found clusters with significant differences between conditions involving single and multiple predictions. These clusters were used as Regions of Interest (ROIs) to compare the ERPs elicited by the 3 tones of the multiple prediction condition. No differences were found between the different tones (confirmed by Bayesian analysis). We thus tentatively conclude that the brain generates multiple predictions simultaneously.

Abstract #42

The effect of harmonicity on mismatch negativity responses to different auditory features

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Predictive processing theories of perception suggest that perception relies on the process of updating the generative model through prediction errors. An important aspect of this process is precision weighting, where some prediction errors lead to a higher chance of model update than others. Precision weighting depends on the information content (or information entropy) of the stimulus - the more information in the stimulus, the less precise the prediction. The mismatch negativity (MMN) component of the event-related potential (measured with electroencephalography) can be seen as a neural marker of prediction error, or generative model update. In this study, we explore the mechanisms of precision weighting in the auditory domain by experimentally manipulating harmonicity. We evaluate the MMN in response to oddballs in sequences of complex tones that are either harmonic (consisting of integer multiples of one fundamental frequency) or inharmonic (with randomly jittered partials above the fundamental frequency). The spectral entropy of an inharmonic sound is higher than that of a harmonic sound, therefore any prediction errors associated with inharmonic sounds should theoretically yield weaker MMN responses. However, our previous results suggest an opposite relationship - we have found that pitch deviants produce a larger MMN for inharmonic than for harmonic sounds. In this work we aim to explore this problem further by looking not only at pitch, but also other kinds of auditory deviants. By employing the multi-future oddball paradigm we evaluate MMN in response to pitch, location, intensity, and harmonicity deviants. The data collection for this project is currently under way and the results will be presented during the meeting in Salamanca.

Abstract #43

Enhancing tonic arousal improves voluntary but not involuntary attention in humans

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Arousal and attention are pivotal brain functions for optimizing performance. Several theoretical models of attention theorize a key interplay between attention and arousal, yet this relationship remains poorly understood in human.
Arousal is generally described as the state of physiological reactivity of a subject, and more recently as a general state of excitation of the cortex, modulated by the activity of the Locus Coeruleus – Norepinephrine (LC-NE) system. Neuronal activity in the LC can be characterized by two aspects: tonic activity, that defines the baseline, sustained activity of the system and changes relatively slowly, and phasic activity during which neurons fire at a high frequency (10–15 spikes per second) in response to a salient stimulus. The control of attention requires a good balance between voluntary and involuntary attention processes. Voluntary attention facilitates focused engagement in specific tasks, encompassing processes such as voluntary orienting, anticipation, and sustained attention. In contrast, involuntary attention is elicited by salient, unexpected stimuli outside the intended focus.
The objective of the study is to investigate the impact of tonic arousal on voluntary and involuntary attention and on phasic arousal at behavioral and physiological levels. We recorded the electroencephalogram, pupil dilation, skin conductance and electrocardiogram in 16 healthy young adults performing the Competitive Attention Task, an auditory attention task that simultaneously assesses phasic arousal, voluntary and involuntary attention processes. Tonic arousal was modulated by low or high arousing music, as measured using skin conductance, pupil size, and heart rate.
Pupil dilation responses to distracting sounds highlight an intricate interplay between tonic and phasic arousal. Importantly, increasing tonic arousal does not influence involuntary attention, whereas it does improve voluntary attention, as shown by shorter and less variable reaction times and larger electroencephalographic brain responses to task-relevant targets. This study provides experimental evidence in humans that tonic arousal can influence the attentional balance by improving voluntary attention in a transient and sustained manner, rather than by modulating involuntary attention.

Abstract #44

Asymmetries in cortical processing of auditory temporal resolution

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Differences in frequency perception have been shown to occur depending on laterality of the listening ear, indicating that auditory processes may be lateralized in the brain. Few studies have investigated how auditory temporal processes are lateralized. Some behavioral studies suggested a lateralization of temporal resolution functions in normal hearing subjects (Brown & Nicholls, 1997; Sulakhe et al., 2003) as well as no lateralization at all (Baker et al., 2008; Efron et al., 1985). Additionally, it remains unclear whether combining temporal information from both ears can improve perception, as it has already been demonstrated with intensity summation. Although Baker et al. (2008) suggested a binaural effect on temporal resolution, the study did not provide definitive conclusions.
Our study investigates the electrophysiological markers associated with temporal resolution differences and binaural summation in individuals with normal hearing, employing both behavioral assessments and electrophysiological measures. Asymmetry will be explored using the left/right lateralization in EEG signal.
16 subjects aged from 18 to 40 with verified normal hearing were recruited. All tasks were presented in 3 listening conditions: left, right and binaural. Stimuli used in the study were 200 ms broadband pink noises and presented through ER-2 earphones. Hearing thresholds were determined using a 3 alternative forced choice 1up-3down psychometric staircase procedure. All stimuli were then sent with adapted intensities of 40dBSL for each of the left, right and binaural conditions. A gap detection task was then performed using the same psychometric staircase procedure. The electrophysiological tasks were performed using the optimal multideviant paradigm (Duda-Milloy et al., 2019; Näätänen et al., 2004) with gap deviants stimuli of 2ms, 5ms, 7ms, 15ms and 30ms. All deviants were pseudo-randomized and had a 10% chance of being presented. The EEG was recorded using the BrainVision 64 active electrode cap with ActiChamp and Neuroscan SynAmps 2 amplifiers. The Mismatch Negativity was used as index of electrophysiological temporal resolution. Sources were determined using the brain entropy in space and time plugin in Brainstorm with the ICBM152 2023b head model and connectivity between sources was measured through bivariate Granger causality.
Our results suggest a binaural summation in temporal resolution processes both at the behavioral and electrophysiological level. Although no ear advantage was observed, differences in the functional network were observed. These results indicate a lateralization of temporal resolution in the brain, not constrained to the right or left hemisphere, as well as a binaural central integration of such an early process.

Abstract #45

Neural processing of speech sound changes in preschoolers and its associations with pre-reading skills

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Deviance-related responses elicited by speech sounds can be a promising way to understand preschoolers' language development and to identify early markers of potential reading difficulties such as developmental dyslexia. In our large-scale longitudinal DyslexiaBaby project, 206 Finnish-speaking participants with (n=156) or without (n=50) familial dyslexia risk were followed from newborn to school age. This presentation focuses on neural speech-sound processing and its associations pre-reading skills at 4 years of age (n = 143).

We recorded deviance-related event-related potential responses to various speech sound changes, including vowel identity, vowel duration, consonant duration, and two levels of frequency changes in a pseudo-word. The results showed that significant late discriminative negativities (LDNs) were elicited by all deviants. Mismatch negativities (MMNs) were elicited by vowel duration, consonant duration and two levels of frequency changes, but not by vowel identity changes. Additionally, a positive mismatch response (P-MMR or P3) was found to consonant duration change.

We further divided the children based on their performance in pre-reading skills and compared the groups with high and low performance. We found that children with better letter knowledge exhibited larger MMN and LDN responses to the more apparent (larger) frequency deviant. Those with faster rapid naming skills exhibited larger MMN and LDN responses to the more subtle (smaller) frequency change, and larger LDN responses to the consonant duration change.

The findings contribute to our understanding of the neural basis of language processing in preschool children. Furthermore, the results suggest associations between deviance-related responses and pre-reading skills, giving further implications for early language and reading development.

Abstract #46

The effect of puberty on the development of the central auditory system

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The processing of speech in the central auditory pathway is thought to follow a step-like function with specific changes at the beginning and the end of adolescence. Children with a congenital severe hearing loss experience long-term effects on this developmental process. Recent studies suggest similar lasting alterations in children with a mild-to-moderate hearing loss (MM HL). Notably, a decline or "disappearance" of the MMN response to pure tones and syllables seems to emerge after 12 years of age, possibly coinciding with the beginning of puberty. We suggest that puberty, a pivotal stage in adolescence, might initiate a second sensitive period driving neuronal reorganization in an experience-dependent manner. Puberty, with its hormonal, cognitive, physical, and social changes, seem to influence not only cognitive but also sensory brain areas dedicated to auditory and visual processing. Neurophysiological studies capture the precise processing of speech stimuli, particularly through late auditory Event-Related Potentials (LAERs). To date, no studies have explored the link between LAER development, MMN disappearance, and puberty in children with MM HL, nor in children with normal hearing. As such, we hypothesize that pubertal onset might contribute to (i) LAER maturation in children with and without MM HL, and (ii) MMN disappearance in children with MM HL. In addition, we hypothesize that cross-modal plasticity might be an explanation for the latter. To test our hypotheses, we present an oddball-paradigm with audio(visual) speech stimuli, assessing children and adolescents with and without MM HL, taking their pubertal stage and chronological age into account. We predict step-like changes in LAERs and audio-visual integration associated with pubertal stage transitions, more so than with chronological age. So far, we tested 20 participants without MM HL. We aim to collect data from a cohort of 130 participants without MM HL and 75 with MM HL. The preliminary results suggest morphological changes in the LAER as children go through puberty, possibly revealing pubertal status as an additional predictor of LAER development. At the workshop, we will discuss our preliminary findings in line with the existing literature on the effects of puberty on neural maturation in a multi-level perspective (neurotransmitters, hormones, neural networks).

Abstract #47

Response of MMN to changes in the second half of two consecutive tones within the temporal window of integration

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Background: The impact of late changes in sound stimuli within the temporal window of integration (TWI) on MMN is unclear. We examined responses to the MMN of the second half of the sound within the TWI by manipulating the second half of the stimulus.
Method: Thirty-six healthy adults participated in the EEG experiment. Two consecutive pure tones were presented as a single pair of stimuli. The experiment was divided into three conditions. The standard stimulus was 3,000Hz - 3,000Hz among all conditions. The deviant stimuli varied in the second half. In small frequency change condition (experiment 1), deviant stimuli were 3000Hz-2800Hz sounds (10%) and 3000Hz-missing sounds (10%). In large frequency change conditions (experiment 2), 3000Hz-500Hz sounds (10%) and 3000Hz-missing sounds (10%) were deviant stimuli. In the omission condition (experiment 3), 3000Hz-3000Hz sounds were standard stimuli, and 3000Hz-missing sounds (10% or 20%) were deviant.
Result: The MMN appeared in all conditions (small frequency change, large frequency change, and omission) by changing the second half of the stimulus. In Experiment 1, the small change frequency MMN had significantly larger amplitudes than the omission MMN. In Experiment 2, the amplitudes of the large change frequency MMN were larger than those of the omission MMN. However, there were no significant differences in omission MMN between Experiments 1 and 3; omission MMN amplitudes were significantly larger in Experiment 3 than in Experiment 2.
Discussion: Experiments 1 and 2 suggest that MMN is elicited in the sound changes at the later timing of TWI. In addition, the omission MMN amplitude in each experiment did not induce an expectedly large MMN from the amplitude increase proportional to the amount of physical change. Previous studies reported that MMN was increased as a function of the magnitude of acoustic change (Tiitinen et al., 1994). In Experiment 2, the MMN amplitude increased with the large frequency change. However, the missing stimulus in Experiment 2 demonstrated a significantly lower amplitude despite a presentation probability like Experiment 3. Comparison of the omission MMN suggests that the power to detect omission is reduced when the stimulus is missing in a series of sounds with varying frequencies compared to when the stimulus is missing in a series of sounds with no change. The brain may consider deviations from the standard stimulus smaller than those in the frequency change condition in the missing condition.

Abstract #48

Modulation of auditory novelty processing by dexmedetomidine and natural sleep: A human intracranial electrophysiology study

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Mismatch negativity (MMN) and other neural responses associated with novel sensory stimuli represent electrophysiologic signatures of predictive coding. These responses are promising biomarkers of consciousness and have clinical importance for assessing depth of general anesthesia, diagnosis, and prognosis of disorders of consciousness. MMN has multiple cortical generators and can be elicited by short-term auditory novelty (local deviance, LD). Suppression of this activity outside canonical auditory cortex induced by propofol may represent a biomarker of loss of consciousness (Nourski et al., J Neurosci 2018, 38:8441-52). By contrast, long-term novelty (global deviance, GD) effects are abolished at subhypnotic doses of propofol. The current study examined these results could be generalized to dexmedetomidine and sleep. Unlike the GABAergic agent propofol, dexmedetomidine is an alpha-2 adrenergic agonist that induces sleep-like sedation.

Intracranial recordings were obtained in neurosurgical patients undergoing monitoring for refractory epilepsy. Stimuli were vowel sequences incorporating within- and across-sequence deviants (LD and GD, respectively). Dexmedetomidine infusion was titrated to reach sedation with responsiveness to command and then to loss of responsiveness (LOR). Neural activity was examined in auditory cortex and other brain regions as averaged evoked potential (AEP) and high gamma (70-150 Hz) band power.

AEP LD and GD effects had a higher prevalence and were more broadly distributed compared to high gamma effects in the awake state. The timing of AEP LD effects was consistent with that previously observed for the MMN. GD effects emerged later and had a timing consistent with the P3b novelty response. As observed previously for propofol, subhypnotic doses of dexmedetomidine reduced LD effects in medial temporal and prefrontal cortex and nearly completely eliminated GD effects both within and outside of auditory cortex. LOR was associated with loss of LD effects in prefrontal cortex and the temporal lobe beyond auditory cortex. Similar changes were observed during daytime sleep. LD effects within canonical auditory cortex were preserved following dexmedetomidine-induced LOR and during sleep.

These results support the generalizability of changes in cortical sensory processing from propofol to dexmedetomidine and sleep. LD effects outside canonical auditory cortex may represent a biomarker of conscious auditory novelty processing and highlight the clinical utility of MMN. The resilience of LD effects in auditory cortex following anesthesia LOR and during sleep demonstrates preservation of low-level novelty monitoring of the acoustic environment at the cortical level.

Abstract #49

EEGNet Analysis of Mismatch Negativity and Selective Attention Event-Related Potentials: Predicting Behavioral Performance in Discriminating Auditory Stimuli

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Mismatch Negativity (MMN), reflecting the brain's automatic response to discrepancies in external stimuli, highlights a passive physiological reaction. The MMN has already been employed to decode behavioral performance such as reaction speed and accuracy during active cognitive processes like selective attention, which allows individuals to consciously focus on relevant stimuli while disregarding others. This study first aims to utilize EEGNet to uncover differences between large and small deviants in MMN waveforms and investigate their correlation with reaction speed and accuracy. Then, we focus on classifying deviant and standard stimuli using EEGNet under conditions of selective attention and subsequently discover whether the classification outcomes could predict behavioral performance. We employed a multi-feature paradigm to record event-related potentials (ERPs) under diverse sound property conditions, including frequency, duration, and intensity, with both large and small deviant levels in each condition. The experiment encompassed two modes: passive, aimed at eliciting the mismatch negativity (MMN), and active, designed to evoke ERP responses reflecting selective attention. Additionally, in active mode, reaction times were also recorded to assess behavioral responses. Subsequently, the single trial waveforms of MMN and selective attention's ERP (SAERP) were subjected to EEGNet analysis using 4-fold cross-validation. This involved three classification pairs: large deviant versus small deviant (LS), large deviant versus standard stimuli (LStd), and small deviant versus standard stimuli (SStd). Finally, the classification accuracy of LS in MMN, and LStd, SStd in SAERP were correlated with reaction speed and accuracy in active modes to explore their relationship with behavioral performance. The results indicate a significant positive correlation ($r=0.42$, $p<0.01$) between LS and reaction speed, alongside a significant negative correlation ($r=-0.37$, $p=0.01$) between LS and reaction accuracy under the duration deviant condition. This indicates that poorer discrimination between large and small deviants in MMN corresponds to quicker reaction speed and higher accuracy in the duration property. Moreover, across all three properties, we observed that the LStd and SStd in SAERP both show significantly negative correlations ($p<0.01$) with reaction speed, as well as significantly positive correlations ($p<0.01$) with reaction accuracy of detecting large and small deviants independently, implying that the SAERP could be seen as a fine predictor of the behavioral performance. These findings underscore the practical utility of EEGNet in analyzing MMN and SAERP as reliable predictors of individual performance in tasks requiring selective attention. Additionally, we also suggest that active SAERP may offer superior predictive performance regarding reaction speed.

Abstract #50

Comparing the effects of using within-channel or between-channel stimuli on Mismatch Negativity responses

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The Auditory Processing Disorder (APD) affect a person's ability to understand speech in noise and to discriminate auditory stimuli despite normal peripheral hearing acuity. Temporal resolution, a central auditory skill, is the focus of this study. It is the ability to detect gaps in noise. However, current electrophysiological tests use wideband noise (WBN) to evaluate this ability, which does not accurately reflect the nature of speech. This study therefore aims to modify this method by using more complex stimuli, namely tests including narrowband noise (NBN) containing gaps in various configurations. In the within-channel configuration, the gap is between two identical stimuli (i.e. WBN-WBN or NBN-NBN) and in the between-channel configuration, the gap is between two different stimuli (i.e. WBN-NBN) (Heinrich et al. 2004).
For this purpose, a multi-deviant paradigm (Duda-Milloy et al., 2019; Näätänen et al., 2004) with three conditions which include a gap – with a WBN (within-channel), a narrowband noise (within-channel) and a noise equal parts WBN and NBN (between channel) – is used to elicit a mismatch negativity (MMN).
A group of adults ages 50 and over without hearing loss watched a subtitled film while ignoring the presented sound sequences featuring a 200 ms standard white noise and 7 silent deviants of 2-40 ms which alternate in a pseudo-random manner. As expected, the results reveal a higher MMN amplitude with the increase of the duration of the gap. This effect is more pronounced for the "within channel" WBN condition than the two other conditions suggesting that the estimates of a person's temporal capacity are underestimated when using stimuli other than WBN.

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Abstract #51

Test-Retest Reliability of Passive Auditory ERPs and Gamma-Band Auditory Steady-State Responses

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Background: Auditory steady-state responses (ASSRs) and event-related potentials (ERPs) are two important neurophysiological measures that reflect auditory processing in the brain. In recent years, some experimental paradigms have been developed to simultaneously elicit ASSR and ERPs, providing a more comprehensive evaluation of auditory processing. However, the test-retest reliability of ASSR and ERPs obtained from these simultaneous elicitation paradigms has not been thoroughly investigated, which is crucial for their clinical application.
Methods: Twenty adults with normal hearing (5 females) participated in three repeated EEG experiments, with each session spaced approximately 48 hours apart. During each session, participants were presented with a total of 3720 binaural stimuli using an oddball paradigm, with the following proability: standard stimulus (70%), frequency deviation (6.67%), duration deviation (6.67%), loudness deviation (6.67%), and participant's name (10%). The average stimulus onset asynchrony was 1.25 seconds. The standard stimulus had a pure tone carrier at 525 Hz and amplitude modulation frequencies of 37 Hz and 81 Hz combined. The other stimuli differed from the standard in either frequency (625 Hz), duration (250 ms), or loudness (20 dB reduction). Participants watched a silent movie during the experiment. EEG data were recorded using a 64-channel system. The amplitude and latency of ERPs, including N1, P2, mismatch negativity (MMN), and P3a, were measured in the time domain. The induced power and inter-trial phase coherence (ITPC) of ASSR were examined using wavelet transformation. Intra-class correlation coefficients (ICC) were calculated to assess the stability of the ERP amplitude, ERP latency, ASSR power, and ASSR ITPC across the three experimental sessions.
Results: Across the three experimental sessions, the amplitude and latency of N1 and P2 components demonstrated satisfactory stability, with ICCs exceeding 0.6. The latency of MMN induced by frequency deviation also showed satisfactory stability. However, the stability of MMN induced by other deviation stimuli (duration and loudness) was poor, with ICCs below 0.4. The ITPC and induced power of ASSR in the gamma frequency band were consistently significant in each experimental session. Moreover, the stability of power amplitude remained at a high level, with ICC ranging from 0.5 to 0.6.
Conclusion: The present study demonstrates that auditory ERPs and gamma-band ASSR can be reliably elicited simultaneously using a modified oddball paradigm, supporting their potential applications in clinical research, particularly in the assessment of auditory processing and the diagnosis of related disorders.

Abstract #52

Rapid context-specific plasticity induced by active learning task

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Neuroscientific research on experience-induced plasticity in the cortex has shown that passive learning task engagement enhances mismatch negativity (MMN) responses. However, how active learning task engagement modulates sensory MMN component or later cognitive components (P3a, LPP) remains less explored – which we aimed to investigate.
We used magnetoencephalography (MEG) to record auditory responses from 30 healthy participants in a roving oddball paradigm before and after engaging in a one-arm bandit task, an active learning paradigm where pure tones, used in the oddball tasks, were associated with small or large monetary losses. The one-armed bandit allowed examining effects of active task engagement and condition spesificity (small or large losses) on auditory processing. We correlated the change in auditory responses (calculated RMS values, gradiometer sensors) between pre- and post-learning oddballs with win rates in the learning task, separately for small and big loss conditions. For the early MMN window, correlations were marginally significant for both conditions, suggesting limited predictive power of learning outcomes on sensory plasticity. However, in the P3a window, a strong negative correlation emerged specifically for the small loss condition ($p=0.005$, $rho=-0.3$) but not big losses ($p=0.2$, $rho=-0.1$). This context-specificity lingered into the late LPP window but with reduced significance and strength.
The context-specific modulation surfacing in the P3a, rather than the earlier sensory MMN, points towards fast attentional plasticity changes rather than low-level sensory plasticity. Moreover, the lack of such specificity for the high-loss condition hints at potentially different mechanisms compared to successful learning of less aversive outcomes. These results suggest that active attentional engagement during learning may induce rapid, context-specific plasticity effects primarily impacting higher-order cognitive processing stages like the P3a.
The current findings, while providing initial insights, should be regarded as preliminary oservations.
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Abstract #53

Disentangling voluntary attention through the existence of ERPs under the violations of auditory regularities

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Voluntary attention, referring to the cognitive process of actively focusing one's mental resources on a specific stimuli or task, is a crucial cognitive function associated with consciousness. Research has shown that P3a and P3b are considered as reliable indicators for detecting involuntary and voluntary attention. A diverted task proved to be more efficient than passive listening in lessening P300 response to deviant tones compared with the active counting condition. However, this diminished P300 effect was only manifested through the significant difference between focused and diverted condition, rather than being proven by the existence of P3a and P3b.
To disentangle voluntary attention from involuntary attention in healthy participants, we proposed a paradigm that assesses cerebral responses to local violations in time and global violations across times. Thirty healthy participants were presented with the two sessions: (a) silent counting of target stimuli (focused condition), (b) visual distracting task (diverted condition) under the same auditory sequences with the following probability: 1000Hz standard stimuli (70%), 1500Hz deviant stimuli (20%) and numerical target stimuli (10%), which were respectively paired with 1000Hz stimuli. The stimulus onset asynchrony (SOA) between sounds within stimuli pairs was 350ms. Pairs of stimuli were separated by a variable interval of 1000-1300ms. We applied temporal generalization to investigate how well the patterns associated with P3a and P3b can be transferred across different time points and to confirm the time window of P3b individually, in order to avoid confusion between P3a and P3b.
The results indicated that the focused and diverted condition shared the common components including N1, mismatch negativity (MMN) and P3a for the local effect. The focused condition elicited P3b, whereas the diverted attention did not demonstrate the existence of P3b at the grand-averaged level for the global effect. At the individual level, 22/30 healthy participants showed P3b in the focused condition and only 4/30 showed P3b in the diverted condition. The local effect showed N1, MMN and P3a corresponding to primary auditory function, whereas the global effect fitted with higher auditory function associated with voluntary attention.
In conclusion, our study demonstrates a robust measurement of N1, MMN, P3a and disentangles voluntary attention from involuntary attention through the existence of P3b under the violation of auditory regularities, extending the effects of voluntary attention to consciousness.

Abstract #54

Stimulus-Specific Adaptation in the Hippocampus of the Anesthetized Rat

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The hippocampus is well known for its role in spatial and episodic memory. A broader function has been proposed including aspects of perception and relational processing. Recently, the hippocampus has also been associated with the detection of auditory novelty. Neural bases of sound analysis have been thoroughly described along the auditory pathway up to the auditory cortex (AC), and beyond in the prefrontal cortex (PFC). However, wider networks supporting auditory cognition are still elusive. The human brain can automatically detect auditory changes, as indexed by the mismatch negativity (MMN) event related potential. MMN is a key biomarker of automatic deviance detection, thought to emerge from the AC and PFC. At the neuronal level, stimulus-specific adaptation (SSA) is considered the cellular counterpart of MMN. It is well established that the hippocampus has pathways that interconnect with the AC and PFC. The existence of these pathways further emphasizes the potential role of the hippocampus in the cortical manifestation of MMN. Recent studies showing similarities between neuronal SSA and behavioral habituation hint at the possibility that SSA interacts with, and may be part of, the brain's memory systems.
In the current study, we used the classical oddball paradigm, as well as two control sequences (many-standards and cascade) in anesthetized rats. Stimuli were pure tones 75 ms long, presented at a rate of 1 Hz. We recorded neuronal spiking activity related to auditory mismatch responses, in the hippocampal regions CA1 and Dentate Gyrus (DG), using tungsten electrodes and 32-channel probes. We found that a subset of neurons in the hippocampus show long-lasting auditory responses with latencies ranging from 125-325 ms after stimulus onset. Around 70% of DG neurons and 50% of CA1 neurons showed auditory responses. In both cases, about one third of auditory responding neurons also presented a significant amount of SSA. SSA levels were higher in DG than in CA1.
These results demonstrate that hippocampus plays a significant role in SSA modulation and should be considered as part of a distributed network for deviance detection.

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Abstract #55

Comparison of the new-generation OPM with traditional MEG sensors using MMN

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Auditory Mismatch Negativity (MMN) is a well-established neural marker of perception. It is widely studied because its sensitivity to contextual or cognitive modulations of perception, as well as its sensitivity to various pathological states. MMN measured with magnetoencephalography (MEG) is known to provide complementary information to MMN observed with electroencephalography (EEG), due to the very high spatial resolution of MEG over auditory regions (Lecaignard et al., 2021b). However, an issue with MMN-MEG in patients is that current MEG systems use cryogenic sensors (SQUIDs), which require a shielded room and subject immobility, hindering bedside use.

Over the last few years, a new MEG sensor technology has rapidly developed and holds the promise of wearability. Optically-pumped magnetometers (OPM) operate at room temperature and have quickly evolved from a prototype state to concrete acquisitions, as evidenced by motor and visual data from our group (Gutteling et al., 2023). Therefore, it appears essential to evaluate the performance of MEG-OPM against traditional MEG-SQUIDs, so that refined clinical applications can emerge in the near future.

We conducted a passive frequency oddball paradigm in 17 subjects over 2 sessions. The first session involved MEG-SQUIDs (n=275) and EEG sensors (n=17), while the second one used left fronto-temporal MEG-OPMs (n=4) and the same EEG montage. All data were cleaned from eye artifacts and 2-20 Hz bandpass filtered.

At the group level, we observed a typical MMN with an expected spatial distribution and statistically significant activity over the 120-200 ms post-stimulus interval using MEG-SQUIDs, and in the 150-200 ms interval in both EEG sessions. However, in session 2, EEG amplitude was found to be reduced and the posterior cluster failed to reach significance. Regarding OPMs, we report data measuring the magnetic field in the radial direction. The two left-temporal OPMs showed an MMN peaking in the 120-190 ms interval; however, only the most posterior one proved significant.

We also investigated individual MMNs for potential clinical applications. Using whole-head MEG-SQUIDS, 17/17 participants showed a significant deviant-standard difference. Using temporal clustering statistics per channel with Bonferroni correction, MMN was found in 11/17 in EEG-session 1, 13/17 in EEG-session 2, and 11/17 with OPMs.

These group-level results confirm the potential of OPM sensors to measure a reliable MMN and preliminary analyses at the individual level are encouraging for future clinical applications. Next steps will soon involve empirical evaluations of whole-head OPM systems (n=48), as well as finer experimental manipulations (Lecaignard et al., 2021a).

Abstract #56

The relationship between mismatch negativity and personality

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The aim of this research was to investigate the relationship between the Big Five personality traits and the auditory and visual mismatch negativity (MMN). Participants were 125 volunteers (18-59 years, 65% females). Based on the scientific literature and previous research on the subject, three hypotheses were set. To achieve the goal, auditory frequency MMN (1000 Hz and 1200 Hz) and visual MMN for letters (letters B and T) was registered (reversed design, oddball paradigm, 20:80 proportion for deviants and standards for both tasks, and 2-back memory task as a main task). Personality traits were identified using Estonian Personality Item Pool NEO; (Mõttus et al., 2006), and correlation analyses were used to study their relationships. Data on the MMN and personality of 125 participants were taken for analysis. As a result of the study, no links between Big Five personality traits and mismatch negativity were identified, but there were some associations between mismatch negativity and impulsivity. Gender, 60 personality items and risk scores for anxiety and depressiveness (measured with Emotional State Questionnaire 2; Aluoja et al., 1999) were inserted to regularized linear regression. Female gender and items of conscientiousness were identified as predictors of both auditory and visual MMN amplitudes.

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Abstract #57

Novelty detection and predictive processing impairments in an animal model of Alzheimer's disease

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As individuals age, peripheral processing accuracy diminishes, leading to a greater dependence on top-down predictions over bottom-up processing of sensory input. Furthermore, the reliability of auditory predictions may be significantly impaired in dementia. For instance, Alzheimer´s disease (AD) patients show affected temporo-parietal areas, which may lead to impaired adaptation to auditory stimuli. Consequently, dementia-related cognitive and behavioral alterations to the predictive process may further compromise auditory processing in aging patients.

To study how dementia could affect deviance detection, we trained 20 rats (16-months-old, TgF344-AD) from both sexes, to discriminate deviant tones in an oddball paradigm presented in a conditioning chamber. TgF344-AD rats manifest age-dependent AD related lesions such as amyloid plaques and hyperphosphorylated tau.

To evaluate the discrimination ability of the animals, we presented various iterations of the oddball paradigm. We manipulated the interstimulus interval (1.5, 2 and 4 seconds) and tested the influence of frequency contrast relative to the standard tone (0.5, 1.0 and 1.25 octaves). We also presented a modified oddball paradigm, where the frequency contrast between standard and deviant tones varied randomly between 9 possibilities. Different deviant probabilities (10 % and 30 %) were tested. Animals' responses were evaluated using the d' index.

After the behavioral experiments, we recorded the neuronal spiking activity to mismatch responses in the auditory cortex and the hippocampus. We used the classical oddball paradigm, as well as two control sequences (many-standards and cascade). Stimuli were pure tones 75 ms long, at the frequencies used during the behavior experiments, presented at a rate of 0.25 Hz for the auditory cortex and 1 Hz for the hippocampus.

Aged TgF344-AD male rats displayed higher d' values than females. Additionally, aged TgF344-AD exhibited slower learning rates in the behavioral task compared to young (control) Long Evans rats. Nevertheless, aged rats showed better d' values than young Long Evans, while displaying a higher percentage of correct rejections and lower hit rates, which indicates lower engagement. Notably, performance in young Long Evans rats was high at the beginning of each session and declined with time, whereas aged TgF344-AD rats showed the opposite trend. In conclusion, deviant detection is strongly influenced by the disease progression, age, and sex.

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Abstract #58

Attenuation of Evoked Responses Elicited by Hand Action Words During EEG Mismatch Negativity Recordings in Children with Motor Impairments

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Arthrogryposis multiplex congenita (AMC) and obstetric brachial plexus palsy (OBPP) are motor disorders that result in highly limited mobility of the extremities. Previously, we showed that in response to auditory speech stimuli, AMC/OBPP children exhibited altered MMN responses compared to healthy controls. Moreover, these alterations were semantically specific. Given that the distribution of ERPs evoked by linguistic stimuli is known to be non-stationary over time, we hypothesized that altered processing of action words related to the impaired limb observed in AMC/OBPP children might result not from constantly decreased deviant ERP amplitudes in response to the hand-related action words, but rather from altered dynamics of the amplitude shift in these responses throughout the experimental session.

To track this effect, we split each of the MMN paradigm EEG recordings into three consecutive non-overlapping fractions with identical amounts of epochs locked to standard and deviant stimuli. We used two oddball series: (1) the hand condition with hand action-related imperative verb as deviant stimulus and matched pseudoword as standard stimulus; (2) the control condition with a meaningless pseudoword that sounded like an imperative verb as deviant stimuli and a matched pseudoword with no phonological similarity to any imperative verb as standard stimulus. All stimuli were disyllabic. The first syllables varied across the stimuli series but remained identical within them, whereas the onset of the second syllabus defined the disambiguation time. 27 AMC/OBPP patients (11 females; 8.63±3.35 y.o.) and 32 control children (16 females; 10.03±3.16 y.o.) participated in the study.

Remarkably, the topographical pattern of the difference in deviant ERPs between the first and the last third recording fractions was similar to the typical spatial distribution of the MMN. We believe that this similarity might reflect some kind of "standardization" of the deviant stimulus that occurs throughout the experimental session as a result of the response attenuation. Specifically, deviant ERP amplitudes in the last fraction of the recording were decreased compared to the beginning of the recording in the hand condition in AMC/OBPP patients (frontal cluster of electrodes at 80-120 ms). No effect was observed either in the control pseudoword condition in AMC/OBPP patients or in both conditions in the control group, highlighting the semantical specificity of the effect. Overall, our findings suggest that altered processing of hand action-related verbs in AMC/OBPP children might result from altered dynamics of the MMN-response attenuation.

Abstract #59

Fatigue and Mismatch Negativity

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Fatigue has considerable impact on human information processing and may cause (fatal) mistakes. Here we study the effects of fatigue on information processing in the lab environment. We concentrate on simple pre-attentional information processing, operationalized by parameters of mismatch negativity (MMN) both in visual and auditory modality.
We explored the dynamics and correlates of fatigue throughout a 2-hour series of experiments. We used the following fatigue measures: self-ratings, critical flicker fusion (CFF), eye blink amplitude, frequency and duration. Participants ($n = 66$, $M_{age} = 28.29$, $SD_{age} = 8.68$) took part in a cognitive battery including stop-signal, reaction time, memory, and pre-attentional information processing (with 1000 Hz and 1200 Hz for auditory, and letters “T” and “B” for visual mismatch negativity, 20:80 reversed design) tasks. All tasks were performed twice, at least one week apart.
ANOVA revealed that participants’ subjective fatigue ratings increased during both lab visits, as indicated by a robust main effect ($F(1.71, 95.87) = 65.41$, $p < 0.001$). The difference between CFF ascending and descending thresholds increased during both lab visits ($F(1,64) = 5.84$, $p < .05$) suggesting an accumulation of fatigue. Blink frequency did not change consistently neither within ($F(3.29, 203.70) = 1.66$, $p = 0.17$) nor between recording sessions ($F(1.90, 117.62) = 2.36$, $p = 0.10$), however the frequency was lower in visual modality ($F(1.91, 118.37) = 11.52$, $p < 0.001$). Blink amplitudes decreased both within ($F(2.11, 130.84) = 21.64$, $p < 0.001$) and across recording sessions ($F(1.76, 109.15) = 24.87$, $p < 0.001$), while blink durations increased both within ($F(3.38, 209.60) = 15.29$, $p < 0.001$) and across sessions ($F(1.45, 89.63) = 4.67$, $p = 0.021$). Blink frequency and duration went up between two lab visits ($F(1, 62) = 7.53$, $p = 0.008$, and $F(1, 62) = 4.32$, $p = 0.042$, respectively), while blink amplitudes went down ($F(1, 62) = 11.64$, $p = 0.001$).
MMN amplitudes increased within experimental sessions in both visual ($F(1, 64) = 4.29$, $p < 0.05$) and auditory ($F(1, 64) = 10.66$, $p < 0.01$) modality. Overall, the results suggest that MMN amplitudes increase with fatigue, which could mean that the inhibition processes are compromised in a tired state and one is less able to ignore distractors.

The study is a part of a project that aims to compare different measures of fatigue and relate them to objective cognitive performance measures and was funded by the Estonian Research Council grant PRG1151.

Abstract #60

Stopping criteria and MMR detection sensitivity and specificity in a paediatric population

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Background: The Mismatch Response (MMR) has the potential to offer a clinically feasible objective index of sound discrimination, which is a long-standing goal in infant hearing aid fitting applications. A prerequisite for clinical applications is the reliable identification of MMRs in individual infants. Recent work in our lab has focused on strategies to maximise SNR such as use of complex tones, noise-weighted averaging, a narrow filter passband and the Hotelling's T2 objective detection tool. We demonstrated MMR detection sensitivity of around 98% in adults using this approach. The objective of this present study was to extend this investigation to infants as infants with hearing loss are our target population.
Methods: An oddball paradigm featuring four spectrally complex tonal signals was used to elicit MMRs in 16 normally hearing infants (aged 3-13 months). The standard was centred at 0.5 kHz and occurred with a probability of 70%; three deviants centred at 1, 2 and 4 kHz and each occurred with a probability of 10%. Signals were delivered through the soundfield at 70 dB SPL using a Genelec 6010A speaker, and responses were captured using an Interacoustic Eclipse EP device using a nasion-to-mastoid montage. Responses were analysed offline by filtering (2-10 Hz) and weighting each epoch by the inverse of its noise power before averaging. Response presence or absence was determined objectively via the Hotelling's T2 statistic applied to the difference waveforms.
Results: The presence of a reliable waveform was confirmed by the Hotelling's T2 statistic for 88% of the recordings to the standard and deviants. For the 40 deviants with reliable responses the Hotelling's T2 statistic applied as a 'one shot' test at the end of the 28-minute run revealed a reliable MMR in 39 instances (97.5%). We also performed the test sequentially at pre-determined residual noise intervals. Using this approach, responses were detected on average after 13.5 minutes, a significant shortening of test time. After correcting for multiple comparisons the number of clear responses dropped to 92.5% but was still clinically acceptable.
Conclusion: Results indicate that complex tones in conjunction with optimised recording and analysis parameters offer the potential to elicit robust MMRs, supporting future utilisation of MMRs for clinical audiological applications. However, further investigations involving infants with hearing loss are required, and clinical applications would benefit from further exploration of stopping criteria that could be used to optimise efficiency whilst not compromising MMR detection specificity and sensitivity.

Abstract #61

Rhythm-based temporal expectations: Unique contributions of predictability and periodicity

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Flexibly adapting to our dynamic surroundings requires anticipating upcoming events and focusing our attention accordingly. Rhythmic patterns of sensory input offer valuable cues for these temporal expectations and facilitate perceptual processing. However, a gap in understanding persists regarding how rhythms outside of periodic structures influence perception.
Our study aimed to delineate the distinct roles of predictability and periodicity in rhythm-based expectations. Participants completed a pitch-identification task preceded by different rhythm types: periodic predictable, aperiodic predictable, and aperiodic unpredictable. By manipulating the timing of the target sound, we observed how auditory sensitivity was modulated by the target position in the different rhythm conditions.
The results revealed a clear behavioral benefit of predictable rhythms, regardless of their periodicity. Interestingly, we also observed an additional effect of periodicity. While both periodic and aperiodic predictable rhythms improved overall sensitivity, only the periodic rhythm seemed to induce an entrained sensitivity pattern, wherein sensitivity peaked in synchrony with the expected continuation of the rhythm.
The recorded event-related brain potentials further supported these findings. The target-evoked P3b, possibly a neural marker of attention allocation, mirrored the sensitivity patterns. This supports our hypothesis that perceptual sensitivity is modulated by temporal attention guided by rhythm-based expectations. Furthermore, the effect of rhythm predictability seems to operate through climbing neural activity (similar to the CNV), reflecting preparation for the target. The effect of periodicity is likely related to more precise temporal expectations and could possibly involve neural entrainment. Our findings suggest that predictability and periodicity influence perception via distinct mechanisms.

Abstract #62

The effect of Benzodiazepine Anxiolytic Dosage on Mismatch Negativity (MMN)

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Aims
Benzodiazepines (BZs) are known as drugs with high dependence and abuse risk, and also to be possible causes of cognitive decline due to its use. The purpose of this study was to objectively determine whether BZ dosage affects inattentive auditory discrimination reflected by mismatch negativity (MMN).
Methods
The subjects for this study were 15 patients 20s years older who were taking BZs (BZ group), and 15 age-matched healthy controls (HC). The stimuli were randomly presented; 100ms standard tones of 1000Hz, and two types of deviant stimuli: 100ms tones of 1200Hz and 50ms tones of 1000Hz, 4000 times at a ratio of 8:1:1, and frequency MMN and duration MMN were measured. MMN (Fz) peak latency and peak amplitude were in comparison BZ group with HC using Mann–Whitney U test. Additionally, the statistical analysis was conducted with Spearman to test the correlation between the BZ dosage and MMN.
Results and Conclusions
The BZ group showed significantly attenuated amplitude of duration MMN and significantly shortened latency of frequency MMN compared to HC. In the BZ group only, there was a significant correlation between an increase in the daily dosage BZ and shortened latency of duration MMN. It suggests that the effect of BZ dosage may be reflected on MMN latency.

This study was approved by the Ethics Committee of Fukushima Medical University, and written consents were obtained from all subjects. There is no COI to be disclosed.

Abstract #63

Neural encoding of sensory "surprise" in the mouse brain

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Sudden sensory stimuli trigger a large and widespread electrocortical activity in the mammal brain – the vertex potential (VP) – that is coupled with marked changes in behavioral output. The fast activation of diffuse cortical targets in response to "surprising" stimuli is presumably mediated by the extra-lemniscal pathway via non-specific thalamic nuclei, hence bypassing relatively slower canonical pathway via core thalamic nuclei to the primary sensory cortices. It is, however, still unclear how "surprise" signals are represented at different hierarchical levels of cortical and subcortical processing, as well as at different spatiotemporal scales, ranging from individual neurons to populations. Moreover, it remains elusive if the VP modulates early sensory processing, and how surprise at individual neuron level relates to the widespread surprise-related VP, widely studied in humans. To answer those questions, first we recorded single neuron activity from different hierarchical levels of cortical processing in awake mice, i.e. from primary sensory cortices to parietal and prefrontal cortical areas, in response to sensory stimuli of multiple sensory modalities (auditory, somatosensory and visual) with different temporal sequences from more unexpected to predictable; the first evoked responses much bigger in amplitude and duration compared to the latter, suggesting the presence of an habituation mechanism. Second, we presented auditory sensory stimuli (surprising modality) delivered at variable intervals (0.1 - 0.17 Hz) and, at the same time, we recorded early somatosensory evoked potentials (SEPs) in response to continuous tail nerve stimulation at 9.5 Hz (probing modality). Our preliminary data suggest that neural activity in primary sensory cortices is highly sensitive to abrupt changes in stimulus intensity or pattern, both at the single-cell and population levels, regardless of the sensory modality. This indicates that such activity is a consequence of a thalamocortical drive from multi-modal, non-specific thalamic nuclei. Moreover, sudden sensory changes transiently affect canonical lemniscal cortical processing of ongoing sensory stimuli and motor output. These results indicate that detection mechanisms for quick changes in the environment already exist at the subcortical stages of sensory processing. Comparing data across different scales and species will lead to a better understanding of how the brain detects and responds to surprising environmental events.

Abstract #64

Auditory Stimulus-Specific Adaptation in the primary visual cortex of the Anesthetized Rat

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As humans and other living organisms interact with their environment, the brain tries to generate an elaborate model of the world in the most efficient manner, continuously integrating information from different sensory inputs and adapting to change in their surroundings. It is known that primary sensory cortices respond to cross-modal stimuli, such as auditory responses in the primary visual cortex (V1), which may be relevant for multisensory representation.
The human brain can automatically detect auditory changes, as indexed by the mismatch negativity (MMN) event related potential. At the neuronal level, stimulus-specific adaptation (SSA) is considered the cellular counterpart of MMN. Recent studies of cross-modal MMN in animal models suggests that cross-modal information processing influences MMN without significant involvement of strong top-down effects, such as those stemming from prior knowledge and attention.
In an effort to understand the role of V1 neurons in auditory deviance detection, first, we recorded frequency response areas to auditory stimuli in V1 neurons to check if they were sensitive to auditory stimuli and then, we used the classical auditory oddball paradigm, and two control sequences (many-standards and cascade) to test deviance detection. Stimuli were pure tones 75 ms long, presented at a rate of 1 Hz. We recorded neuronal spiking activity related to auditory mismatch responses in layer 6 of V1 using tungsten electrodes and 32-channel probes. We found distinct and significant SSA in response to pure tones, as well as long-lasting auditory responses with latencies around 175 ms after stimulus onset, with a maximum peak latency at around 400 ms. Approximately 60% of the recorded V1 neurons exhibited this type of auditory response, with 50% of these neurons displaying an SSA index greater than 0.3, on a scale where 1 represents the highest possible SSA index.
The existence of significant auditory SSA in V1 demonstrate that V1 neurons are part of a distribute network for deviance detection across sensory modalities and evidence the intricate nature of the circuits engaged in sensory integration and MMN.

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Abstract #65

Propofol-mediated loss of consciousness disrupts predictive routing and local field phase modulation of neural activity

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Predictive coding is a fundamental function of the cortex. The predictive routing model proposes a neurophysiological implementation for predictive coding. Predictions are fed back from deep-layer cortex via alpha/beta (8-30Hz) oscillations. They inhibit the gamma (40-100Hz) and spiking that feed sensory inputs forward. Unpredicted inputs arrive in circuits unprepared by alpha/beta, resulting in enhanced gamma and spiking. To test the predictive routing model and its role in consciousness, we collected data from intracranial recordings of macaque monkeys during passive presentation of auditory oddballs before and after propofol-mediated loss of consciousness (LOC). In line with the predictive routing model, alpha/beta oscillations in the awake state served to inhibit the processing of predictable stimuli. Propofol-mediated LOC eliminated alpha/beta modulation by a predictable stimulus in sensory cortex and alpha/beta coherence between sensory and frontal areas. As a result, oddball stimuli evoked enhanced gamma power, late period (> 200 ms from stimulus onset) spiking, and superficial layer sinks in sensory cortex. LOC also resulted in diminished decodability of pattern-level prediction error signals in higher order cortex. Therefore, auditory cortex was in a disinhibited state during propofol-mediated LOC. However, despite these enhanced feedforward responses in auditory cortex, there was a loss of differential spiking to oddballs in higher order cortex. This may be a consequence of a loss of within-area and inter-areal spike-field coupling in the alpha/beta and gamma frequency bands. These results provide strong constraints for current theories of consciousness.

Abstract #66

The role of prediction error in auditory perception

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Perception is often cast as an inferential process in which the brain combines noisy sensory input with predictions generated by internal models. One popular algorithmic incarnation of the predictive processing ideas is predictive coding, in which the brain implements a hierarchy of generative models. Along this hierarchy, feedback connections carry predictions from higher level to lower level areas, and feedforward connections carry prediction errors, which result from the comparison between the predicted and actual activity at the lower levels. The brain would minimize these prediction errors by updating its internal models.

In the predictive coding framework, it has been proposed that the contents of conscious experience are determined by the current hypothesis about the state of the world that has the highest posterior probability. Following the above, the content of our conscious experience should be determined by the interactions between predictions and prediction errors, but there is currently no agreement regarding how these signals are combined to form a percept.

Here, we aimed to test the hypothesis that, in line with predictive coding, the detection of expected tones should be associated with low levels of prediction error, because sensory evidence matches with the prediction at hand. Instead, the detection of unexpected tones is only possible when they elicit enough prediction error to successfully update the mistaken prediction.

We designed a task in which expected and unexpected auditory stimuli were presented against a noisy background, rendering their detection challenging, and therefore bringing to the foreground the inferential nature of perception. By acquiring magnetoencephalography (MEG) and behavioral data during the execution of this auditory detection task, we can relate the amplitude of the mismatch response (a putative prediction error signal) to the detectability of expected and unexpected tones. Preliminary behavioral results from three pilots show that when compared to expected tones, unexpected tones are associated with higher criterion values ($t(29) = 7.75$, $p = 7.7e-09$, $g = 1.02$ [0.68, 1.40]), and slower reaction times ($t(29) = 7.25$, $p = 2.8e-08$, $g = 0.75$ [0.48, 1.04]). Reaction times are also slower for missed, compared to detected unexpected tones ($t(29) = 4.50$, $p = 5.1e-05$, $g = 1.00$ [0.52, 1.52]). Neural data that are linked to these behavioral effects will be presented. With this study, we hope to clarify how predictions and predictions errors interact to determine the conscious perception of sounds.

Abstract #67

Quantifying sustained attention and susceptibility to distraction – evidence from EEG

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Listening in complex natural environments requires the concurrent ability to focus attention on target sounds (e.g. an announcement at the train station) whilst simultaneously ignoring task-irrelevant distractors (e.g general speech in the crowd). Uncovering the brain mechanisms which underly these abilities, and how they relate to variability in performance outcomes, is critical for understanding the challenges of real world listening.

Here we developed an objective test of individual susceptibility to auditory distraction, validated using behavioural, electroencephalographic (EEG) and oculomotor (eyetracking) measures. The aim is to quantify fluctuations in attentional state and elucidate the relationship between target enhancement and distractor suppression.

Young, typical hearing listeners (N=30; in progress) performed a continuous performance task in the presence of frequent distractors. Subjects were tasked with identifying 'target' sounds (different across dimensions of frequency and duration) amongst a rich attended stream populated by pure-tone frequency deviants, length deviants and standard tones. As the task unfolded, EEG and oculomotor data were obtained simultaneously. Alpha and Theta activity, tonic arousal (via the pupil dilation response) and ERPs were measured at points in time preceding either a correctly identified 'target' or a miss. It was found that, in the 3 second intervals preceding a hit, evoked responses to sounds contained in the attended stream (standard tones, length deviants) were significantly greater than the distractor streams. Additionally, alpha power was significantly higher and pupil diameter was larger, consistent with an overall heightened state of arousal. Examining responses to the distractor stream revealed greater activity in time periods preceding misses – implying that an unsuccessful suppression of the distractor led to missed targets. Together our results reveal an interplay of brain processes including concurrent distractor suppression and target enhancement that support successful listening. Further analyses will focus on individual variability, connectivity, and correlations between these measures to determine whether distractor suppression and target enhancement are independent neural processes.

Abstract #68

Quantity perception among Estonian kindergarten children with developmental language disorder

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Developmental language disorder (DLD) affects about 7-10% [1, 2] of children and is the most common neurodevelopmental disorder. Previous studies have shown delayed language processing in this population [3]. This includes difficulties in prosody perception at young age that predict later impairments in language development [4, 5] and which persist till school-age [6, 7]. Estonian's unique three-way quantity distinction in prosody combines tonal and durational components [8]. There is no neurophysiological data about processing the three-way quantity system by children.
This study focuses on the neurophysiological differences in perceiving Estonian's quantity distinctions between 4.6-6.5-year-old DLD and typically developing children (N=50). The methods included psychometric testing on language ability and non-verbal intelligence, computerized quantity discrimination tasks, and auditory event-related potentials measured in a passive Optimum-1 paradigm with naturally produced stimuli: (a) sada (Q1 deviant; 'hundred.sg.nom'); (b) saada (Q2 standard; 'send.sg2.imp') and (c) saada (Q3 deviant; 'get.inf').
Here we present the results of the first phase of longitudinal study. The data was pre-processed using the MADE pipeline [7]. The findings of the cluster-based permutation tests [8] revealed no discrimination for the Q3 deviant where the difference between the standard and the deviant manifest in the F0 contour. However, in both groups a significant Mismatch response was present for the Q1 deviant where the discrimination is done based on syllable duration ratio. We identified two significant clusters: (a) positivity at 240-340 ms after stimulus onset at fronto-central region; (b) negativity at 590-690 ms after stimulus onset at central region. Linear regression model of the mean amplitude of the first cluster revealed a significant interaction between age and general language ability, indicating that with the increase of age and language test score the mean amplitude becomes more positive. Further, the model of the mean amplitude of the second cluster revealed an interaction between group and the d-prime score of the behavioral task, indicating that when the d-prime increased (marking a better result) then the mean amplitude decreased in the DLD group. An additional model was done for the obligatory response of the Q1 deviant which revealed a main effect of the non-verbal intelligence test score. We further inspected the discrimination of the Q1 deviant with complex Morlet wavlet extracting the time-frequency power and using cluster-based permutation tests to find significant change in power. This analysis revealed no significant clusters. Further analysis will be done on the peak latency measure.

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Abstract #69

Distributed sources of neural oscillations at pitch rates: a communication mechanism within the pitch control network?

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Successful pitch perception and production are crucial in everyday human life, particularly for speech and music. Pitch refers to the perceptual attribute of the repetition rate of a sound waveform and, albeit still under debate, it is assumed to be represented in the brain both by a place code (tonotopy; periodotopy) and by a temporal code (phase-locked neural firing to sound periodicity). Temporal coding of pitch can be measured non-invasively through the Frequency Following Response (FFR), a sustained auditory event-related potential recorded with M/EEG to periodic sound stimulation, with presumed neural generators located in cortical (e.g., auditory cortex) and subcortical (e.g., inferior colliculus) regions of the auditory system. The FFR is modulated by linguistic and musical experience and appears disrupted in numerous developmental disorders, such as dyslexia. However, to date, the functional role of the responses measured by the FFR, or whether they are merely epiphenomenal or redundant with place coding, remain unknown. Recent functional imaging studies (fMRI) have identified a network of brain areas involved in pitch control beyond auditory regions, including the cerebellum, known for sensorimotor learning. In line with the communication-through-coherence hypothesis, we here propose that temporal coding might serve as a communication mechanism between brain areas within the pitch control network to fine-tune pitch perception and production, complementing classical place coding in the auditory system. To test this, we collected EEG data from young participants during a non-vocal pitch matching task. We manipulated the audio-motor map between the position of the finger on a pad and the pitch of the delivered sound to create conditions of high versus low mapping predictability. Using state-of-the art source localization methods, we reconstructed the sources of oscillatory activity at the exact pitch of the sound delivered (in a range between 120 and 240Hz). Our results show localized activity in brain areas consistent with the pitch control network (e.g., auditory cortex, dlPFC, ACC, IPS and Cerebellum), suggesting the exploitation sound pitch as a synchrony communication channel. Furthermore, behavioral results indicated better performance in the high predictability condition, and the contrast between high vs. low predictability conditions showed increased cerebellar activation. These results suggest that cerebellar activity at pitch rates may be critical for effective pitch production following sensorimotor learning. Overall, our study contributes to understanding the communication dynamics within a widespread network of regions oscillating at sound pitch rates to foster successful pitch production.

Abstract #70

Spectro-spatial encoding of lexical surprise in natural speech processing

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Until now, the "dual-stream" model has defined speech processing in separate and parallel neuroanatomical pathways. This perspective is not sufficient to elucidate the dynamic cognitive algorithms and representational inferences that are at play at these stages. Here our focus is on how the brain constructs ongoing expectations about the upcoming word, and the underlying dynamics of their neural substrate. To explore these dynamics, we collected stereo-electroencephalography (sEEG) data from 24 clinically implanted pharmaco-resistant epileptic patients while they listened to a 10-minute story in French. We derived stimulus-specific lexical predictions from a Large Language Model (CamemBERT) and investigated the neural correlates of predictions, namely surprise and entropy values. We performed a multivariate Temporal Response Function (mTRF) analysis to investigate the spectrally-resolved encoding of these linguistic features and to explore their temporal dynamics and spatial characteristics. This flexible framework allows us to evaluate the encoding of such features in specific frequency bands, but also to assess the relevance of more fine-grained physiological processes, such as phase-amplitude coupling. As surprise is directly elicited during bottom-up perception whereas entropy is defined at a higher-level of abstraction, representing uncertainty, we anticipate that reconstructed responses to surprise will be relatively earlier and more focused in early stages of processing than entropy responses. Finally, we are considering future work involving adding phoneme- and syllable-level predictions, which would provide additional insights into the dynamic hierarchy linking the different linguistic processing stages. Importantly, this work serves important theoretical goals by offering a critical test to determine the extent to which neural oscillations play a fundamental role in the computational processes of speech processing. It has the potential to define the intricate mapping between speech and neural timescales, shedding light on how expectations and neural dynamics support language processing.

Abstract #71

Subcortical contributions to the origin of individual differences in learning the specific sounds of a second language

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Abstract
People differ in their ability to master second language (L2) specific sounds. Previous research has shown that such individual differences appear even when people have the same linguistic background and are driven by speech-specific mechanisms in both early (Díaz et al., 2008) and late (Díaz et al., 2012; 2016) bilinguals. Studies systematically reported smaller mismatch negativity (MMN) responses for speech sounds in L2 poor perceivers. However, the role of subcortical brain structures in such individual variability has not yet been investigated. The aim of this study is to determine to what extent perceptual differences are already present at lower levels of the auditory pathway than those cortical processes captured by the MMN. We assessed the MMN and the frequency-following response (FFR) in two groups of participants that differed in their ability to discriminate the German speech contrast /u:/-/y:/ (unknown to all of them). The MMN is a brain potential primarily originating from cortical areas, whereas the FFR is a brain response reflecting mostly neural activity in the subcortical auditory pathway. Thus, these two brain responses allow us to assess cortical and subcortical contributions to individual differences in L2 phoneme learning. For the MMN, participants were tested on both native phonemes and non-linguistic auditory stimuli matched in complexity to the native phonemes. For the FFR, they were presented with the native /da/ and the non-native /oa/ syllables. Preliminary analysis revealed that the two groups of participants differed in their MMN and FFR responses to speech sounds. Good perceivers of the unknown German speech contrast showed larger MMN and FFR responses than poor perceivers, meaning that, besides differences in discriminating the novel German contrast, they also differently perceived native phonemes, for which it is commonly assumed we are all excellent at. Our preliminary results indicate that individual variability in perceiving speech sounds may be influenced not only by experience-based brain plasticity, but also by an intrinsic individual component related to how subcortical brain structures automatically process sound.

Abstract #72

Human single-neuron responses to a local-global oddball paradigm

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Introduction:
Under the hierarchical predictive processing framework, top-down attentional and expectation processes shape the priors that affect prediction error signals. Despite the vast literature, evidence still lacks regarding the detection of single-neurons specifically encoding prediction errors, particularly in humans. This work investigates this using a task that independently manipulates stimuli predictability at two hierarchical levels (global and local).
Methods:
Invasive recordings were obtained from 8 patients with drug resistant epilepsy undergoing presurgical evaluation. Behnke-Fried electrodes were implanted in the hippocampus (HPC), amygdala (AMY), and anterior insula (AI). Procedures were conducted with informed consent and ethics committee approval.
An inter-aural local-global oddball paradigm was used (Chennu et al., 2013), where participants listened to sequences of five tones. In two different tasks, they counted either the number of deviant sequences, or deviant tones. The last sequence's tone determined the global and local nature of the stimuli. Local deviants could be of different (i) pitch or (ii) side (an inter-aural deviant). Within blocks, the sequence's occurrence probability determined the global rule (12% for global and interaural deviants each).
Results:
Preliminary results come from 30 implanted probes (8 contacts each). For the tones and sequences tasks, there were sorted 19 (1 AI, 2 AMY, 16 HPC) and 11 (5 AMY, 6 HPC) single-units respectively, and 13 (1 AI, 6 AMY, 6 HPC) and 8 (2 AMY, 6 HPC)) multi-units. For tones and sequences tasks, 11/32 (34%), and 5/19 (26%) units were responsive to the sounds, respectively.
In the tone deviant detection task, 2 AI units showed early (100-300 ms) sensitivity to local deviants, and one of these included late (300 – 600 ms) response components. No units responded to global deviants, and 4 units showed (2 AI, 2 HPC) early responses to interaural deviants.
In the sequences task, one unit showed sensitivity to local deviants, both in early and late periods. Another unit (HPC) showed a late component response to global (tone) and interaural deviants.
Conclusion:
Despite literature evidence showing the involvement of hippocampus in auditory processing, our results show limited neuronal recruitment. Contrary to what we expected, few units showed sensitivity to local and global tone deviants, and slightly more to interaural deviants. Robust responses were observed in Insular cortex, which gives further evidence on the role of this structure in deviance detection and the salience network. These preliminary results will be expanded by further data with better unit yield.

Abstract #73

The 'me' and the 'I': how prediction errors shape self-voice perception

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The ability to parse afferent sensory input into reafferent and exafferent components establishes the basis for self-other distinction. One proposed mechanism that might contribute to this distinction is described in the internal forward model as the rapid differentiation of incoming information as self- vs. externally-generated. Any decision about the voice as self- vs. other generated depends on how much sensory feedback deviates from the expected voice. In voice perception, this distinction implies I can recognize my own vocal expression as I recognize the words that I intentionally chose to communicate (agency) that are expressed by my own voice (ownership). However, these two components of the self-voice have only been studied in isolation, and it remains to be specified how they dynamically interact in voice perception.
The current study used electroencephalography (EEG) to identify and characterize the independent and interactive effects of agency (SA) and ownership (SO) in voice processing. Forty-six healthy young adults (25 female) were recruited. Initially, a voice recording session took place to obtain self-voice stimuli from each individual. Due to possible individual variability in thresholds for self-other voice attribution, each participant underwent psychometric testing to determine individual points of maximal uncertainty on a continuum from the self to other voice. In the EEG task, two words were displayed on the screen and participants were asked to choose one of them. Sensory feedback could be either the chosen or an unchosen word (agency mismatch condition) spoken in the self- or in the other-voice (ownership mismatch condition).
While the N1 was overall more sensitive to unexpected self-voice quality ($p = .039$), the P2 was more sensitive to agency violations ($p = .037$). These findings inform on the mechanisms underlying the discrimination of internally and externally controlled voice stimuli. They may be particularly relevant for understanding of the externalization of the self-generated voice in phenomena such as auditory hallucinations.

Abstract #74

Impact of lateral Prefrontal Cortex lesion on distracting sound processing

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Previous studies have shown, with different paradigms, the involvement of the lateral prefrontal cortex in both voluntary and involuntary attention processes. The main purpose of the present work is to study the role of the lPFC in the balance between voluntary and involuntary auditory attention. We used the Competitive Attention Task (CAT), an adaptation of the Posner paradigm detection task using central visual cues and monaural auditory targets. Visual cues trigger the deployment of voluntary attention in anticipation of auditory targets. In 25% of the trials, an unexpected task-irrelevant distracting sound (phone ring, bell ring...), played between the cue and the target, triggers involuntary attentional capture. We recorded EEG in 11 patients with lesion of the lPFC and 11 matched controls. We investigated the event-related-potentials (ERPs) elicited by the distracting sounds in each group: N100, P3 complex, Reorienting Negativity (RON). The patients present a larger P3 complex and a reduced RON than the control participants. These results suggest enhanced involuntary capture of attention and difficulties in orienting back attention towards the task at hand after lesion of lPFC.
Therefore, the lPFC would play a crucial role in controlling both involuntary attention towards unexpected task-irrelevant distracting sounds and voluntary attention reorientation back to the task.

Abstract #75

Unheard Surprises: Attention-Dependent Neocortical Dynamics Following Unexpected Omissions Revealed by Intracranial EEG

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Neocortex may encode and relay sensory input as Bayesian surprisal, or prediction error (PE). By this view, unexpected sensory absence results in PEs that mirror prior expectations. Predictive processing is, however, multi-layered, and knowledge on how attentional states influence hierarchical integration of endogenously generated PE is limited. To address this gap, we used intracerebral field potentials to investigate the interplay between expectation and attention following auditory omissions.
Methods: Stereo-electroencephalography (SEEG) was recorded from 20 patients with drug-resistant epilepsy undergoing presurgical evaluation. Sound sequences containing predictable and surprising omissions were played during attentive listening and a distraction task. Population-activity (HFBA, 65 - 250 Hz) was extracted from channels in auditory cortex (AC) along with temporal, cingulo-opercular, and frontoparietal cortices, and analyzed with cluster-based permutation tests.
Results. Responses to unexpected omissions depended on attentional state. When unattended, responses were primarily limited to AC, although notable modulations occurred in frontal operculum (Fop). In the attended state, responses were broadly distributed, with short-latency responses in AC and cingulo-opercular network (CON), followed by long-latency, sustained activity in frontoparietal and somatomotor networks (FPN/SMN).
Conclusions. Macroscale neural dynamics induced by PEs are strongly determined by selective attention. Early integration in AC is followed by prominent attention-modulated responses in Fop. Higher integration levels in FPN and SMN fully determined by attention. Integration with the literature suggests a three-stage model of sensory deviance processing where PEs are monitored by the CON which implements network transitions based on estimated task relevance.

Abstract #76

Mapping Deviance Responses across Mouse Auditory Cortex using High-Speed, High-SNR Optical Imaging

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The natural environment contains a large amount of predictable structure, which can be utilized by neural systems to optimize their behavior. This ability requires an internal representation of the external, predictable information, and neural mechanisms to make use of the predictions, for example to efficiently detect deviations from predictions, i.e. mismatches. While decades of behavioral research has convincingly demonstrated that humans and animals make use of predictions, the underlying mechanisms have only been partially understood. We used a combination of recent neural recording techniques to study the representation of predictable information in the auditory system of mice.

We transfected adult CBA mice to express the fast and bright calcium indicator GCaMP8m in the auditory cortex and performed widefield and 2-photon fluorescence imaging of the entire auditory cortex and surrounding areas at a spatiotemporal resolution sufficient to resolve fast auditory sequences (30-100Hz). We presented both sound and omission oddball sequences as well as many-standards control sequences, at different presentation rates. We analyze the data in a region- and layer-specific way on the widefield and neuronal level. We find characteristic differences in stimulus and omission responses (OR) across the auditory cortex which show an anterior-posterior dependence.

The results provide a novel, auditory-cortex-wide, but still temporally well resolved complement to electrophysiological recordings, which usually provide a less spatially organized and complete coverage of the activity in auditory cortex. Together with optogenetic manipulation, this approach provides a powerful method for studying the basis of predictive coding and mismatch negativity in the auditory system.

Abstract #77

The inferior colliculus is not innervated by several non-auditory cortical areas

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The inferior colliculus (IC), a major center for the integration of auditory information, is the lowest level in the auditory pathway where prediction error occurs. It is known that the IC receives this predictive information through descending projections from the auditory cortex. Recently, two works have described that the IC also receives descending projections from several non-auditory cortical areas (Olthof et al. 2019 and Gartside et al. 2024). This observation has strong functional implications, e.g., it could suggest that the IC receives predictive information from other sensory modalities.

In the work by Olthof et al. (2019), numerous retrogradely labeled neurons were found in the visual, somatosensory, motor, and prefrontal cortical areas on both sides after injecting retrograde tracers into the IC. Anterograde tracer injections were also performed in these same cortical areas, which resulted in densely labeled puncta in all regions of the IC on both sides. However, given that there are evident contradictions between these results and those described in the extensive literature on cortico-collicular projections, and the strong functional implications derived from these findings, we decided to replicate this work.

To this end, we injected a well-known tracer that is transported in an anterograde direction, the biotinylated dextran (BDA), in the auditory, visual, somatosensory and motor cortical areas of adult rats. In our experiments, only the cases with injections of BDA in the auditory cortex revealed labeled fibers in the IC. Therefore, we conclude that the IC is not innervated by non-auditory cortical areas. We do not know the origin of the results shown by Olthof et al. (2019) and Gartside et al. (2024), but it is possible that they are due, at least in part, to technical artifacts. Our study reinforces the importance of reproducibility of research, which is essential for the advancement of the discipline.

NOTES

FLOOR PLAN OF THE CONFERENCE VENUE

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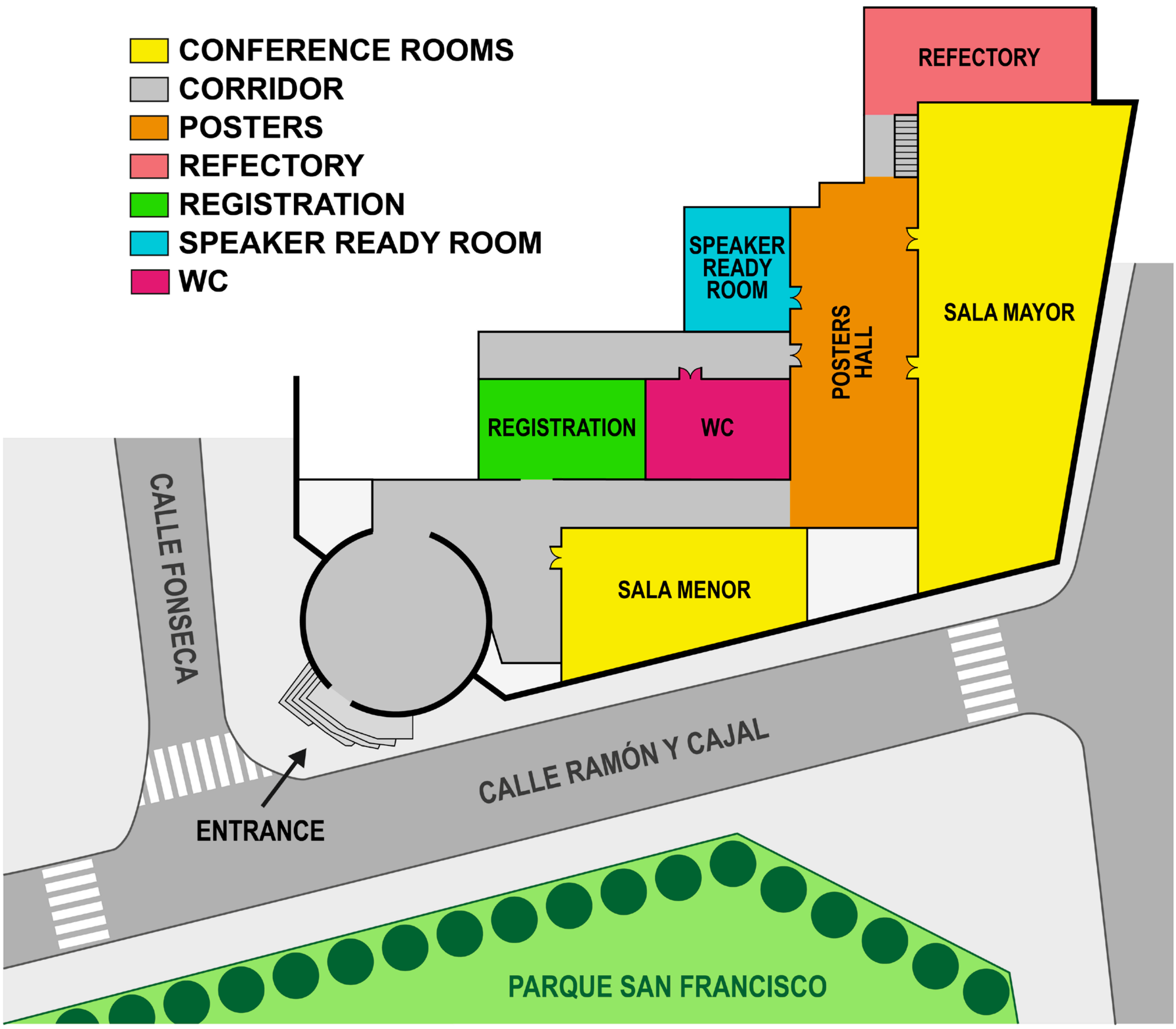

MAP OF SALAMANCA