IMRF 2025

Abstract booklet

Conference organised at Durham University with Event Durham

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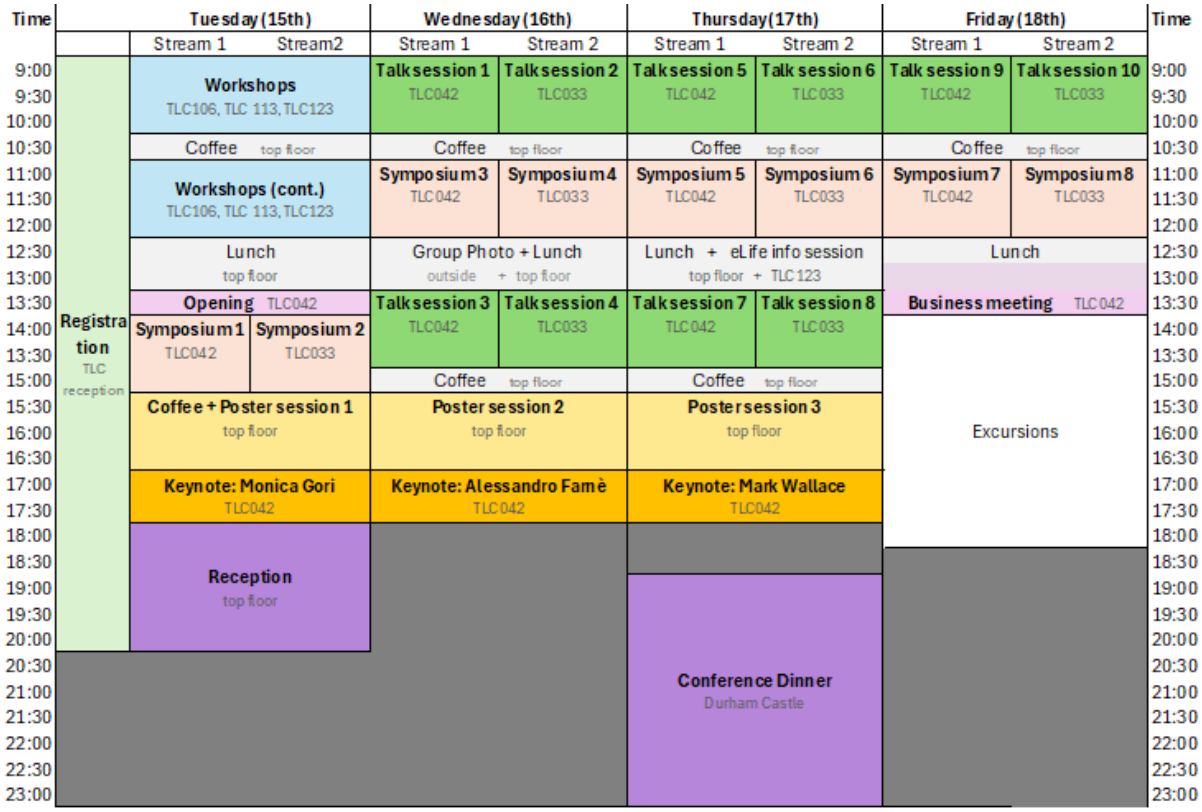

Time	Tuesday (15th)		Wednesday (16th)		Thursday (17th)		Friday (18th)		Time
	Stream 1	Stream2	Stream 1	Stream 2	Stream 1	Stream 2	Stream 1	Stream 2	
9:00	Registration TLC reception	Workshops TLC106, TLC 113, TLC123	Talk session 1 TLC042	Talk session 2 TLC033	Talk session 5 TLC042	Talk session 6 TLC033	Talk session 9 TLC042	Talk session 10 TLC033	9:00
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10:00									10:00
10:30		Coffee top floor	Coffee top floor		Coffee top floor		Coffee top floor		10:30
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12:30		Lunch top floor	Group Photo + Lunch outside + top floor		Lunch + eLife info session top floor + TLC 123		Lunch		12:30
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19:00					Conference Dinner Durham Castle				19:00
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Keynotes

Monica Gori

Istituto Italiano di Tecnologia, Genova, Italy

Building Multisensory Experience: The Role of Sensory Interaction in Development and Accessible Technology

An organism's ability to interact with the external world depends on its capacity to accurately process and interpret environmental information. For example, when walking down the street, vision helps us navigate and locate objects of interest, while hearing provides critical cues, such as an approaching car or the presence of people nearby. These seemingly simple actions are the result of complex multisensory integration processes. The mechanisms underlying multisensory development are still not fully understood. Over the past years, our research has highlighted the fundamental role of sensory interaction in supporting the development of multisensory integration. We have shown that some multisensory skills take time to emerge, and that vision plays a crucial role in shaping both auditory and tactile integration. In the absence of visual input, representations of auditory space and body representations are altered, making sensory integration more difficult, or even impaired, in blind infants and children compared to their sighted peers. Sensory interaction, therefore, represents in many cases a building block of multisensory development. The strong link between sensory interaction and multisensory learning provides a powerful framework for understanding the basic principles that allow us to learn to navigate and interpret a multisensory environment. This understanding also drives the development of science-based technologies aimed at improving the quality of life for individuals with sensory impairments. Our technological solutions translate the world into sound, vibration, and movement, offering children new inputs they can perceive, make sense of, and grow with.

Mark Wallace

Vanderbilt University, Nashville, USA

From Single Neurons to Immersive Environments: A Multisensory Scientist's Journey
We live in a multisensory world, being continually bombarded with stimuli from our various sensory modalities. As such, one of the important functions of the brain is to combine this information into a coherent perceptual gestalt. Multisensory research has provided a good deal of insight into the behavioral and perceptual benefits of having information available from multiple senses, as well as the combinatorial operations and neural circuits involved in multisensory integration. In addition, evidence continues to grow linking altered multisensory function to neuropsychiatric and neurodevelopmental conditions. The talk will focus on several of our lab's contributions to our understanding of multisensory function, as well as its development and plasticity, at the neural, perceptual and clinical levels. It is important to note that much of this work has been carried out in highly controlled laboratory settings, leaving open the question of whether multisensory abilities differ in more naturalistic scenarios. To examine this, we are beginning to use fully immersive environments. In this augmented reality CAVE, we are presenting high definition 3D visual, spatialized audio, and tactile (haptic) stimuli while monitoring eye, head and body movements and recording brain activity via EEG. The focus of this work is to study multisensory development using more realistic settings.

Alessandro Farnè

Lyon Neuroscience Research Centre

The role of vision in grasping and sensing objects with tools

Scientists have long questioned the origin of the exquisite human mastery of tools. How do we manage controlling a tool in the skillful way humans typically do, as a body-part? Grasping objects with tools is a major challenge for the visuomotor system, in that the control of the hand needs to be transferred to the prehensile part of the tool. In the first part of my talk I will present findings suggesting that when we use tools to grasp objects, the tool is incorporated into our body representation. Our more recent work indicates that the lack, or (even late) loss of vision hampers such update of the body state estimation for motor control of tools. The second part of my talk will focus on the perceptual component of tool-use: sensing through tools challenges the somatosensory system, humans being capable of localizing impacts on the entire surface of a hand-held rod with great accuracy. I'll report findings indicating that, contrary to motor control, the lack (or loss) of vision in the latter case does not prevent good tactile localization on hand held tools. These findings help understanding the differential role that vision plays in the sensorimotor control of tools.

Symposia

Symposium 1 - The neural dynamics of temporal processing in multisensory perception

The processing of time and temporal relations is key to the brain's ability to integrate information from the different senses. Only when sensory signals are close in time, typically within a few hundred milliseconds, and have similar temporal dynamics, does the brain relate and integrate the information, leading observers to perceive unified multisensory events. The brain has evolved neural mechanisms to process sensory signals at multiple timescales and different levels of temporal complexity, ranging from relatively simple intersensory properties such as the perception of synchrony and timing, to the multisensory integration of complex temporal structures in audiovisual speech. Time is thus a fundamental dimension of multisensory perception and has been a focus of multisensory research since its inception.

However, critical questions remain about how the brain computes multisensory temporal relations at different timescales and levels of complexity, some of which we will address in this symposium: By combining psychophysical data with computational modelling, Laetitia Grabot will show how top-down biases contribute to duration perception of audiovisual stimuli. Jennifer Bizley will present evidence that the temporal coherence of audiovisual speech stimuli entrains audiovisual neurons and promotes audiovisual speech discrimination. Following this, Daniel Senkowski will present data on postdiction phenomena in audiovisual perception and the possible underlying computational and neural mechanisms. Next, Adrià Marly will focus on how the brain accumulates crossmodal temporal information to resolve the conflict between competing, incompatible audiovisual perceptual hypotheses. Finally, Tim Rohe will focus on the question of how temporal relations of audiovisual stimuli provide the brain with evidence to infer the stimuli's causal structure. Taken together, this symposium will provide a state-of-the-art overview of current research and news insights into how the processing of time and the underlying neural dynamics of the brain shape multisensory perception

Organizers: Tim Rohe, Daniel Senkowski

Computational mechanisms underlying contextual and structural biases in audiovisual time perception.

Grabot, Laetitia [1], Mamassian, Pascal [1], Giersch, Anne [2],

[1] Laboratoire des systèmes perceptifs, Département d'études cognitives, École normale supérieure, PSL University, CNRS, Paris (France)
[2] Strasbourg Translational Neuroscience & Psychiatry, Strasbourg University, Strasbourg (France)

Time perception depends on both idiosyncratic traits and environmental adaptation processes. Distinguishing these two sources of bias allows us to dissociate the predictive mechanisms that generate them. These biases have been observed separately, and low-frequency neural oscillations such as alpha rhythms (8-12Hz) were related to both prior beliefs and structural biases. To disambiguate the impact of structural constraints and adaptive mechanisms on perception, we used psychophysics and computational modeling in healthy human participants. We quantified the structural and contextual biases in a duration discrimination task to constrain models of duration perception. Following the presentation of two consecutive stimuli, participants had to judge which one lasted the longest. The stimuli were either both visual, both auditory or one from each modality. Confirming previous reports, a sound was often perceived longer than a visual stimulus of the same duration, a bias that probably reflects intrinsic properties of audiovisual neural processing. Contextual

biases were manipulated using two distinct duration distributions for each stimulus, a procedure known to modulate the perception of a given duration. Bayesian models are typically used to explain contextual effects, such as regression-to-the- mean. Another mechanism, leading to opposite predictions, is based on rescaling: in order to compare two durations, especially across modalities, the perceptual system aligns them on a common internal scale. The results show that participants' responses are mostly driven by rescaling, not Bayesian mechanisms. This challenges existing literature on contextual effects in duration perception and suggest that the brain operates some amodal rescaling to represent durations.

How and when does audiovisual temporal coherence help listening?

Bizley, Jennifer [1], Norris, Rebecca [1], Alampounti, Lida [1]

[1] University College London, UCL Ear Institute, London, (United Kingdom)

The benefit of being able to visualise a talker's lips when listening in a noisy environment is well known. Undoubtably, the phonetic information conveyed by lip movements constitutes the major component of this advantage. Potentially, however, other non-linguistic cues may contribute to lip reading benefits: Over a series of studies we have been exploring to what extent audiovisual temporal coherence may influence auditory scene analysis. Such a mechanism might not only contribute to lip reading benefits, but offer a more fundamental solution to parsing auditory scenes. I will present data from a number of ongoing studies in the lab designed to address this question. Behavioural experiments in humans required to discriminate speech in the presence of competing speech, demonstrate that lip reading alone does not account for the full benefit obtained from seeing a talker's face. In parallel, we have been developing behavioural paradigms in the ferret, based on our previous work (Maddox et al., 2015). In these experiments subjects are required to detect brief timbre perturbations in an ongoing amplitude modulated target vowel sound, while ignoring those in a simultaneous competing non-target stream. I will present preliminary behavioural data from ferrets trained in this task. We have previously demonstrated that audiovisual temporal coherence can dictate which sound in a mixture neurons in auditory cortex entrain their responses to (Atilgan et al., 2018). By recording in auditory and visual cortex of ferrets we additionally determined what features of the visual stimulus best drive audiovisual responses across cortical fields.

Conflict processing in the temporal integration of crossmodal stimuli

Marly, Adrià [1] Soto-Faraco, Salvador [1] [2]

[1] Multisensory Research Group (MRG), Center for Brain and Cognition (CBC), Universitat Pompeu Fabra (UPF), Barcelona (Spain)
[2] Institució Catalana de Recerca i Estudis Avançats (ICREA), Barcelona (Spain)

The ability to efficiently integrate or segregate sensory information across modalities is a fundamental process in perception. While previous research has extensively explored spatial aspects of multisensory integration, the temporal dimension remains less well understood. The present study investigates the behavioral expression and neural dynamics underlying audiovisual temporal integration/segregation, focusing on the role of the conflict processing mechanisms. We employed a rate discrimination task where auditory flutter and visual flicker were presented concurrently but at different temporal rates, creating conditions of varying temporal disparity. We propose that temporal disparity between auditory and visual stimuli triggers a competition between two mutually exclusive perceptual hypotheses—common vs. independent causes—engaging conflict detection and resolution mechanisms. To examine this, we have conducted two complementary pre-registered studies: a reaction time (RT, planned N=28, https://osf.io/rcv54/) experiment to assess the perceptual decision-making dynamics and an electroencephalography (EEG, planned N=60, https://osf.io/cm8pu/) experiment measuring conflict-related theta-band activity at fronto-central electrodes. We predicted faster RTs with larger disparities, as information accumulates more rapidly when temporal mismatch increases. However, if conflict processing mechanisms contribute to the causal inference process, we

expected a non-linear relationship between disparity and theta power, as the competition between integration and segregation perceptual hypotheses is steepest at intermediate disparities. The results of the planned tests assessing these predictions will be presented. The findings will contribute to our understanding of how the brain arbitrates between integration and segregation across sensory modalities over time, offering insights into the neural mechanisms underlying multisensory temporal integration.

When the future influences the past: the computational and neural mechanisms underlying crossmodal postdiction

Senkowski, Daniel [1], Günaydin, Gökberk [1], Rohe, Tim [2]

[1] Charité – Universitätsmedizin Berlin Dept. of Psychiatry and Psychotherapy, Charitéplatz 1, 10117 Berlin (Germany)
[2] Perceptual Psychology, Institute of Psychology, Friedrich-Alexander Universität Erlangen-Nürnberg, Germany

Perception of our environment is based on the processing of sensory inputs that fall within the temporal window of multisensory integration, which can last several hundred milliseconds. Within the temporal integration window, the perception of a stimulus is shaped not only by past and current information, but also by input that follows a stimulus, i.e., postdiction. In this talk, I will present data from an audiovisual postdiction paradigm that show that the computational mechanisms underlying crossmodal postdiction can be well explained by the Bayesian causal inference framework. I will also present recent data suggesting that ongoing oscillatory mechanisms influence crossmodal postdiction.

The role of time in multisensory causal inference

Rohe, Tim [1], Fleischmann, Celine [1]

[1] Perceptual Psychology, Institute of Psychology, Friedrich-Alexander Universität Erlangen-Nürnberg (Germany)

To obtain coherent multisensory representations of their environment, humans integrate signals across the sensory modalities when they infer that the signals originate from a common cause, but they segregate signals from independent causes. To infer the causal structure of multisensory signals, observers accumulate causal evidence from the spatiotemporal disparity and temporal correlation of the signals. Thus, crossmodal relative timing is key for the brain to infer multisensory causal structures. Surprisingly, the temporal dimension has been largely neglected in the formal Bayesian Causal Inference (BCI) model, as have the effects of top-down factors such as observers' attention on temporal relations. In my talk, I will present two studies that show how the BCI model can be extended to model not only spatial, but also temporal relations of audiovisual stimuli when fitting perceptual and causal judgments: In the first study, the BCI model accurately predicted how spatial disparity and temporal correlations jointly inform spatial and causal judgments of audiovisual spatial stimuli. By linking the temporal estimates of the BCI model to EEG patterns, the accumulation of temporal causal evidence could be mapped to the neural dynamics of the brain. In the second study, we found that causal judgments of audiovisual temporal signals depend not only on their temporal disparity, but also on how observers focus top- down endogenous attention and attentional resources on the stimuli. Our results show that the brain estimates and accumulates the relative timing of multisensory stimuli to infer their causal structure, depending on top-down attentional factors.

Symposium 2 - Real bodies in a real world: Multisensory and Embodied signatures of Self-Environment interactions

The development of our models of the self and the world relies on the contribution of exteroceptive, proprioceptive, and interoceptive bodily signals. We usually take the ability to identify our body as our

own for granted, but empirical research in the past few decades has shown that our body representations rely on the cognitive ability to combine information about the body originating from different sensory modalities. This symposium will focus on such multisensory integration processes, and how changes in the environment can influence the perception of internal and external sensory bodily signals in turn. On the one hand, we will discuss the importance of the active exploration of the space surrounding our body, as our first interface with the physical and social world, with a particular focus on the role of auditory, spatial, and tactile signals to the way we represent our body and the reality around us (Prof Ana Tajadura-Jiménez, Prof Chris Dijkerman). On the other hand, we will focus on the role played by internal bodily signal (i.e., thermosensation, heartbeat, respiration and balance) and by interoception-exteroception integration on how we interpret changes in the world as well as changes in the perception of our own body (Dr Laura, Crucianelli, Prof Francesca Ferri, Prof Gerardo Salvato). Across five talks, we will present behavioral and neurophysiological evidence supporting the idea that interoceptive, proprioceptive and exteroceptive signals contributes to create a coherent sense of oneself interacting into a dynamic word. Taken together, this symposium aims to combine and discuss our research lines that, albeit different, converge on the idea that the experience of our body is not a fixed phenomenon but rather an ever changing and dynamic process, which relies on the interplay between environmental and inner bodily signals. Translational clinical implications for some of this evidence will also be discussed.

Organizer: Laura Crucianelli

Hearing the Self: Auditory Signatures in Self-Environment Interactions and Body Transformation Experiences

Ana Tajadura-Jiménez [1] [2] (Presenter: Amar D'Adamo)

[1] i_mBODY lab, DEI Interactive Systems Group, Department of Computer Science and Engineering, Universidad Carlos III de Madrid, Leganés (Spain)
[2] UCL Interaction Centre (UCLIC), University College London, University of London, London (United Kingdom)

Music makes us move, but can sound do even more for our sense of bodily self? While we often consider touch, vision, or interoception as relevant for shaping our bodily awareness, audition also provides rich information about what is happening inside and outside of our bodies: we hear ourselves breathe, our joints crack, our hands clap, or our footsteps blend with others as we walk. Sound is almost always present in our actions and interactions with the environment, yet its influence on body perception is often overlooked. This talk highlights the unique contributions of audition to our sense of bodily self, drawing on our research into how sounds can shape body perception, leading to Body Transformation Experiences. I will also discuss how these insights inform the design of body-centered technologies that support health, while also serving as valuable tools for studying multisensory influences on body perception.

Touch time: the role of body representations in time perception

Dijkerman, H. Chris [1], Stergianni, Chrysi [1], Overvliet, Krista [1]

[1] Helmholtz Institute, Utrecht University (The Netherlands)

Previous studies have shown that changes to the perceived size of body parts can affect spatial tactile judgements. For example, visually enlarging the arm results in an enhanced spatial discrimination ability. Spatial processing has been suggested to be highly related to temporal processing as well. This may also be the case for tactile perception, which is inherently a spatiotemporal modality. Here, we will review some of the evidence for a link between body size perception and tactile time perception. In addition, we will present a study in which we tested whether a visual length illusion of the finger, influences temporal judgements of touches on that finger, while the real tactile distance remains the same. Participants performed a tactile temporal order judgement task, while viewing their hand in a mediated reality set-up (MIRAGE) under two different conditions: while experiencing a finger

stretch illusion, or with an undistorted view of the hand. 10 different stimulus onset asynchronies ranging from -200 to 200 ms were used. We fitted a psychometric curve for each participant and condition and extracted the slope at the inflection point, a measure of the discriminability of the stimuli. The results showed that when the index finger appeared to be longer, the slope was significantly steeper, suggesting that participants were better able to determine the temporal order of the tactile stimuli. This finding shows that a visual illusion of finger size, and thus body perception, influences temporal tactile processing and suggests that time perception and body size perception are linked.

Visuo-thermal contributions to the sense of body ownership

Crucianelli, Laura [1]

[1] Centre for Brain and Behaviour, Queen Mary University of London (United Kingdom)

The feeling that the body belongs to oneself (i.e., sense of body ownership) is the result of sophisticated processes of multisensory integration, whereby exteroceptive, proprioceptive, and interoceptive signals are continuously combined. Illusions of body ownership, such as the Rubber Hand Illusion (RHI), can provide some insight into the interplay between vision, proprioception, and touch. The RHI experience can be modulated by manipulating the characteristics of the tactile input, for example in terms of velocity and softness. However, the contributing role of thermal signals of interoceptive nature to the sense of body ownership and related neural mechanism remains unexplored. In this talk, I will present a series of RHI studies investigating the contribution of skin-mediates signals, such as touch and temperature, to the perception of a body part as belonging to ourselves. Our results suggest that thermosensation contribute to the sense of body ownership, by a mechanism of dynamic integration of visual and thermosensory signals, and further highlight that not only spatial and temporal, but also interoceptive congruency might be necessary for the RHI to occur. The findings will also be discussed in the context of experimental data with clinical populations. Taken together, our data suggest that skin-mediated interoception signals may uniquely contribute to the awareness of ourselves as embodied beings.

Interoceptive Rhythms and Multisensory Integration: Shaping Perception of the World

Ferri, Francesca [1] [2], Saltafossi, Martina [3] [4] [5], Zaccaro, Andrea [1], Kluger, Daniel S [3] [4] Perrucci, Mauro Gianni [1] [2], Costantini, Marcello [2] [4]

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[3] Institute for Biomagnetism and Biosignal Analysis, University of Münster, Münster, Germany
[4] Otto Creutzfeldt Center for Cognitive and Behavioral Neuroscience, University of Münster, Münster, Germany
[5] Department of Psychology, “G. d’Annunzio” University of Chieti-Pescara, Chieti, Italy

The integration of multisensory information is fundamental for constructing models of the self and the external world. Recent research highlights the role of interoceptive signals, particularly those arising from cardiac and respiratory rhythms, in modulating this process. Here, we investigate how interoceptive signals, such as heartbeat and respiration, influence multisensory integration and, in turn, perception.

Empirical evidence suggests that the cardiac cycle phases modulate multisensory integration by selectively influencing the processing of external sensory stimuli. Specifically, multisensory integration involving somatosensory inputs (e.g., visuo-tactile and audio-tactile stimuli) is enhanced during diastole compared to systole. This effect aligns with interoceptive predictive coding models, which propose that heartbeat-related noise suppresses somatosensory inputs during systole, thereby impacting the optimization of neural oscillations governing multisensory integration. Additionally, respiration emerges as a key modulator of sensory processing, influencing reaction times and

multisensory integration phases. Faster responses are observed during peak inspiration and early expiration, whereas the expiration-to-inspiration transition corresponds with reduced multisensory integration. Notably, participants appear to adapt their respiratory cycles to maximize the signal-to-noise balance between interoceptive and exteroceptive signals, suggesting an active, rather than purely bottom-up, modulation of perception.

By extending interoceptive predictive coding to the multisensory domain, our findings support a mechanistic framework in which interoceptive rhythms shape how external sensory signals are integrated. This modulation may contribute to the development of adaptive perceptual models of the world, optimizing responses to environmental changes. Understanding the interoceptive influence on multisensory integration provides valuable insights into the fundamental mechanisms underlying perception and cognition.

When the Self Interacts with the World: The Role of Internal and External Cue Integration

Salvato, Gerardo [1] [2] [3]

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[2] Cognitive Neuropsychology Centre, ASST "Grande Ospedale Metropolitano Niguarda" (Italy)
[3] NeuroMi, Milan Center for Neuroscience, Milano (Italy)

The integration of interoceptive (internal) and exteroceptive (external) signals is essential for constructing and updating bodily self-awareness, enabling individuals to maintain a coherent sense of self while interacting with the world. This process is supported by a specific brain network. Using multilevel kernel density analysis, we identified the supramarginal gyrus bilaterally as a key site of integration, along with a right-lateralized network involving the precentral, postcentral, and superior temporal gyri. This system likely plays a crucial role in continuously updating bodily self-awareness by merging multisensory information from both the body and the external environment. This integration is fundamental to various aspects of human interaction with the world. At a basic level, it helps maintain balance in uncertain situations by coordinating sensory inputs. Our findings indicate that individuals with higher interoception exhibit greater postural stability when faced with equilibrium uncertainty. On a more complex cognitive level, interoception influences decision-making. Revisiting the Somatic Marker Hypothesis, we demonstrated that interoceptive signals play a pivotal role in risky decision-making, particularly when the body is directly involved in the choice. Understanding the multisensory integration of internal and external signals is crucial, as disruptions in this process have been linked to neurological and psychiatric conditions. This knowledge could provide valuable insights into future targeted interventions aimed at improving cognitive and emotional functioning in individuals with impaired bodily self-awareness.

Symposium 3 - Blindness as a window into fundamental principles of brain organisation: Moving beyond absolutist frameworks

Decades of research demonstrated that congenital blindness results in profound structural and functional changes of the brain: the visual cortex exhibits increased cortical thickness, higher resting-state activity, and responds to input from nondeprived modalities. These findings have given rise to two competing theoretical frameworks on cortical specialization: one proposing that the visual cortex is cognitively pluripotent and capable of assuming a wide range of cognitive functions, while the other argues that it maintains its task-specificity regardless of the input modality.

In this symposium, we move beyond these frameworks by presenting evidence on how sensory experience refines large-scale brain networks and discuss how task demands may repurpose existing computations to process non-visual input in blind individuals. This symposium is chaired and composed of researchers across multiple career stages, with strong representation from early-career scientists and individuals from traditionally underrepresented countries in neuroscience.

Lénia Amaral will demonstrate that resting-state functional connectivity in congenitally blind individuals remains stable over time, yet is highly individualized. Anna-Lena Stroh, using connectome gradient analyses of resting-state functional connectivity, will highlight the crucial role of sensory input in refining the functional connectome and for structure-function coupling to develop. Rashi Pant will show that transient congenital visual deprivation leads to an altered E/I ratio of the visual cortex. The symposium will then shift to studies on cross-modal plasticity: Katarzyna Rączy will examine the neural adaptations associated with tactile reading, demonstrating how the brain repurposes its computations to meet novel task demands. Paul Matusz will show how inferotemporal cortices are among the first regions engaged in sound-mediated face sensitivity in blind individuals, aligning with participants' reports of "seeing with sounds". Dominika Radziun will show that interoceptive processing is enhanced in blind individuals and that this enhancement is linked to increased thickness of their occipital cortex.

Organizers: Katarzyna Rączy, Anna-Lena Stroh

Stable, but unique: individualized connectivity in the blind V1 over time

Amaral, Lénia [1] [2], Thomas, Peyton [1], Amedi, Amir [3] [4], Striem-Amit, Ella [1]

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[4] The Ruth & Meir Rosenthal Brain Imaging Center, Reichman University, Herzliya (Israel)

In blindness, the primary visual cortex (V1) undergoes neuroplastic reorganization, engaging in diverse sensory and cognitive functions, including audition, touch, language, and memory. However, whether these changes follow a consistent pattern across individuals or reflect unique, stable reorganization remains unclear. Previous studies suggest that V1 functional connectivity (FC) varies significantly among blind individuals, but it is unknown whether these differences persist over time. In this recent study, we examined the long-term stability of V1 FC in congenitally blind individuals by tracking FC patterns over a two-year period. Our findings reveal that each blind individual exhibits a distinct and highly stable V1 connectivity profile. Using multivoxel pattern analysis, we further demonstrate that these unique FC patterns reliably identify individuals across time. This suggests that while blindness leads to cortical reorganization, the specific ways in which V1 adapts remain remarkably individualized and consistent rather than transient or flexible.

These findings have important implications for understanding the principles of neuroplasticity in blindness. The existence of stable, individualized FC profiles in blind V1 could help identify neuromarkers for guiding personalized interventions, including sight restoration and assistive technology fitting. By recognizing that V1 plasticity follows distinct individual trajectories, future research can better tailor rehabilitation strategies to take advantage of each person's unique neural adaptations.

Atypical functional connectome in congenitally blind humans

Stroh, Anna-Lena [1], Koba, Cemal [2] Falcó-Roget, Joan [2], Collignon, Olivier [3] [4], Rączy, Katarzyna [1] [5], Bedny, Marina [6], Tian, Mengyu [6] [7], Szwed, Marcin [1]

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The cortex is organized along macroscale structural and functional gradients that extend from unimodal to transmodal association areas and from somatosensory to visual regions. Whether this core organizational axis represents an intrinsic neuroarchitecture immune to sensory experience or depends on sensory input has not been tested. To address this question, we conducted connectome gradient analyses using resting-state functional Magnetic Resonance Imaging in congenitally blind individuals and sighted controls. In both groups, we observed a principal gradient (G1) extending from unimodal to transmodal areas, a second gradient (G2) spanning from somatosensory to visual regions, and a third gradient (G3) separating the frontoparietal network from the rest of the brain. These findings indicate that the macroscale organization of the cortex develops largely independently of sensory experience. However, in blind individuals, the sensorimotor network was more distanced from the visual network (G2), while the visual network was more integrated with transmodal (G1) and frontoparietal (G3) networks. The hierarchical organization within the early visual cortex (EVC) was also altered, and structure-function coupling was reduced in visual and temporal areas of blind individuals. These results suggest a critical role of sensory input in shaping the macroscale functional and structural organization of the brain.

Altered visual cortex excitatory/inhibitory ratio following transient congenital visual deprivation in humans

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Non-human animal models have indicated that the ratio of excitation to inhibition (E/I) in neural circuits is experience dependent, and changes across development. Here, to test for dependence of the E/I ratio in humans on early visual experience, we assessed 3T Magnetic Resonance Spectroscopy (MRS) and electroencephalography (EEG) markers of cortical E/I ratio in ten individuals who had been treated for dense bilateral congenital cataracts, after an average of 12 years of blindness. First, participants underwent MRS scanning at rest with their eyes opened and eyes closed, to obtain visual cortex Gamma-Aminobutyric Acid (GABA+) concentration, Glutamate/Glutamine (Glx) concentration and the concentration ratio of Glx/GABA+, as measures of inhibition, excitation, and E/I ratio respectively. Subsequently, EEG was recorded to assess aperiodic activity (1-20 Hz) as a neurophysiological measure of the cortical E/I ratio, during rest with eyes open and eyes closed, and during flickering stimulation. Across conditions, congenital cataract-reversal individuals demonstrated a significantly lower visual cortex Glx/GABA+ ratio, and a higher intercept and steeper aperiodic slope at occipital electrodes, compared to agematched sighted controls. In the congenital cataract-reversal group, a lower Glx/GABA+ ratio was associated with better visual acuity, and Glx concentration correlated positively with the aperiodic intercept in the conditions with visual input. We speculate that these findings result from an increased E/I ratio of the visual cortex because of congenital blindness, which might require commensurately increased inhibition to balance the additional excitation from restored visual input. The lower E/I ratio in congenital cataract-reversal individuals would thus be a consequence of homeostatic plasticity.

Hierarchical coding of Braille letter-strings is specific to auditory language areas in blind individuals

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Following blindness, several high-level visual regions preserve their underlying computations despite receiving input from other sensory modalities. For example, the ventral visual stream (VOTC) of blind individuals responds to tactile and auditory object recognition, body shape perception, and tactile reading. In fact, tactile Braille reading in blind humans activates the exact location of the sighted Visual Word Form Area (VWFA). It has been thus proposed that, despite differences in how information enters the system (via sight or touch), reading relies on similar neural mechanisms in blind and sighted individuals. A key feature of sighted VWFA is its sensitivity to orthography: responses increase with the letter-strings frequency downstream visual hierarchy. Preliminary research suggests a lack of a similar -posterior–anterior VOTC letter processing gradient in blind individuals, however these authors only tested shapes, consonant strings, and words. We extended these findings, by investigating congenitally permanently blind adults while they read 5-letter strings of varying approximation to Polish words (5 conditions) or listened to corresponding sounds (2 conditions). We found that the VOTC differentiated Braille letter strings from nonsense Braille but lacked a clear anterior–posterior processing gradient. Instead, the VOTC responses followed a V-shaped pattern, with the highest response for low- and high frequency letter-strings. In fact, the preference towards frequent- over infrequent auditory letter-strings was found in the anterior VOTC. Crucially, the superior temporal sulcus was robustly activated in both conditions. These findings suggest that tactile reading may require different computations than sighted reading and to rely more on spoken language processing.

The brain dynamics of the congenitally blind seeing faces with sound

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Sensory substitution devices (SSDs) involve translation of image to sound, with the aim to equip blind individuals with functions traditionally considered “visual”, like face detection. Previous work showed that image-to-sound SSDs recruit cortices specialised for visual functions. However, the brain dynamics of these activations, and thus, of SSD-supported perception, remain unknown. Visual cortices specialized for specific categories might be the first locus (or one of the loci) of perception of SSDmediated objects. Alternatively, the activation of those cortices may be a byproduct of perceptual processes unfurling first in auditory cortices. Resolving this uncertainty is critical for understanding to what extent the blind truly “see” via SSDs. Analyzing with electrical neuroimaging the EEG data from congenitally blind adults, we show for the first time that inferotemporal visual cortices are some of the earliest sites of face mediated by SSDs. These activations onset at ˜450ms, i.e., within the first 1/3 of the sweep through the 1,500ms face soundscapes. No earlier effects were detected, including with univariate methods. Interpreted together with subjective reports of blind SSD users, our results suggest to be the evidence that the blind can “see” with SSDs. Control analyses showing the

specificity of these effects are presented. By identifying the temporal dynamics of SSD perception, our findings offer new support for the hypothesis that brain cortices are characterised by task-contingent functional organisation.

Cross-modal plasticity in the occipital cortex supports interoceptive processing in blindness

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While cross-modal plasticity enhances exteroceptive perception in blind individuals, it is unclear to what degree this phenomenon extends to interoceptive processing and how it relates to structural brain adaptations. In a behavioral study, we examined cardiac interoceptive ability in 36 blind and 36 sighted individuals. Both groups exhibited similar confidence in their interoceptive judgments and comparable heart rates, yet the blind group demonstrated enhanced interoceptive accuracy, suggesting an adaptation to sensory loss. To explore the neural basis of this adaptation, we conducted a structural MRI study in 23 congenitally blind and 23 sighted individuals. We found a significant positive correlation between cardiac interoceptive accuracy and occipital cortical thickness in the blind group, whereas the opposite pattern emerged in sighted individuals. These findings challenge the notion that increased occipital thickness in blindness merely reflects atrophy due to deafferentation. Instead, they suggest that a thicker occipital cortex in blind individuals supports interoceptive processing through cross-modal compensatory plasticity. The observed relationship between interoceptive accuracy and cortical thickness in blindness parallels previous findings linking occipital recruitment to nonvisual processing, reinforcing the functional relevance of this plasticity. In contrast, the negative correlation in sighted individuals may reflect distinct mechanisms governing interoceptive processing in the presence of intact vision. Taken together, these results indicate that cross-modal plasticity in blindness is not limited to exteroception but extends to interoception, demonstrating a broader role of the occipital cortex in sensory and physiological processing.

Symposium 4 - Metacognition in Multisensory Decision Making: Confidence, Awareness, and Uncertainty

Perceptual decisions are inherently uncertain and come with a sense of confidence. Metacognition—our ability to evaluate our perceptual accuracy and uncertainty— plays a fundamental role in multisensory perceptual decisions. When deciding whether to cross a street, we should integrate the sight and the roaring sound of a rapidly approaching truck, crossing only when confident that we will reach the other side safely. This symposium will present recent findings from psychophysics, computational modelling and neuroimaging that investigate how human observers form perceptual confidence in multisensory environments. In a 2nd step, we will examine how confidence and subjective experience influence how we weight and integrate signals across the senses.

The first two talks address how the brain forms confidence in multisensory perception. Jutta Billino demonstrates that confidence precision is comparable across vision and touch and reveals individual differences in metacognitive efficiency shaped by age and cognitive control. These findings support a general confidence monitoring system across modalities.

Using the McGurk illusion, Uta Noppeney shows close relationships between perceptual and causal confidence consistent with Bayesian causal inference models, with some individuals computing confidence optimally, while others rely on suboptimal or heuristic strategies.

Building on this understanding of confidence formation, the subsequent talks explore how metacognitive confidence and subjective experience, influence multisensory integration.

Brian Odegaard investigates the role of subjective confidence in multisensory integration. He shows that highly confident but unreliable visual stimuli can strongly bias auditory motion perception, suggesting confidence can outweigh sensory reliability.

Jason Samaha challenges the idea that subjective awareness is needed for multisensory interactions. Using metacontrast masking, he shows that unconscious visual stimuli, no longer decodable from EEG after 300 ms, influences observers' sound localization.

This symposium will provide insights into the mechanisms underlying perceptual confidence and its role in multisensory processing, combining perspectives from psychophysics, computational modeling, and neuroimaging.

Organizer: Uta Noppeney

Individual differences in visual and tactile metaperception

Billino, Jutta [1]

[1] Experimental Psychology, Justus Liebig University Giessen (Germany)

Perceptual decisions are accompanied by a subjective sense of (un)certainty. There is robust evidence that observers have access to a reliable estimate of their own uncertainty and can judge the validity of their perceptual decisions. However, there is still a debate to what extent these metaperceptual judgements underlie a common mechanism that can monitor perceptual decisions across different sensory modalities. Moreover, factors such as cognitive control and aging may influence metaperceptual efficiency. We will present findings from three experiments focusing on visual and tactile confidence. Using a confidence forced-choice paradigm we were able to estimate confidence efficiency, i.e., the ability to distinguish between good from bad perceptual decisions, in unimodal and crossmodal conditions. Our findings consistently showed that higher confidence was associated with better perceptual performance, supporting the validity of metaperception. Crucially, participants demonstrated comparable precision in confidence judgments across visual and tactile modalities, with no costs to metaperceptual sensitivity. Additionally, unimodal confidence judgments successfully predicted cross-modal confidence, reinforcing the notion that perceptual confidence operates on a supramodal scale. However, we also observed substantial individual differences in metaperceptual efficiency that are driven by age and shaped by cognitive control capacities. In conclusion, our findings provide strong evidence that perceptual confidence is computed on an abstract scale, allowing for reliable confidence judgments across sensory modalities. Furthermore, age-related declines in confidence efficiency may be attributed to diminished cognitive control resources, highlighting their role in metacognitive performance. These insights contribute to our understanding of the mechanisms underlying perceptual confidence and its variability across individuals and sensory domains.

Perceptual and causal confidence in the audiovisual McGurk illusion

Noppeney, Uta [1], Beurskens, Jochem [1], Meijer, David [1], Wlaszczyk, Agata [1]

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Perceptual decisions come with a sense of confidence. The Bayesian confidence hypothesis posits that confidence corresponds to the posterior probability of being correct. Despite extensive research, it remains unclear how observers compute confidence in complex real-world scenarios with multiple sensory signals, requiring the selection of relevant features and the attribution to their underlying causes. In this study observers were presented with spoken syllables, their corresponding articulatory lip movements or their congruent and McGurk combinations (/Ba/+/Ga/). In a dual-task paradigm, observers identified the first letter of the syllable they heard ignoring the 2nd vowel. They

also judged whether the video and audio originated from one source (i.e. causal decision) and reported their confidence for both judgments. Our results show that participants had limited metacognitive access to conflicting unisensory components, experiencing the McGurk illusion and congruent stimuli as causal and perceptual metamers. Perceptual and causal confidence were closely related, consistent with predictions of Bayesian causal inference models. However, Bayesian modelling showed that observers did not marginalize over the irrelevant second-letter vowel when computing perceptual confidence. Moreover, while some observers computed Bayesian confidence optimally, others employed suboptimal strategies, either comparing only the two most likely decision options or applying simple heuristics directly to the sensory space. Our findings highlight deviations from normative Bayesian Causal inference and substantial inter-individual differences in confidence computations in rich naturalistic multisensory environments.

Multisensory integration follows subjective confidence

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Across many domains in perception, a straightforward relationship exists between objective and subjective judgments: in general, the better participants perform in a task, the more confident they are. However, innovative manipulations of visual stimuli demonstrate it is possible to produce stimuli which dissociate objective and subjective ratings. For example, changing the signal to noise ratio of Gabor patches, or changing the ratio of dots moving in dominant and non-dominant directions, can produce pairs of conditions with similar discrimination performance, but different confidence (Odegaard et al., 2018; Morales, Odegaard, Maniscalco 2022). These paradigms present an opportunity to ask a unique question: in multisensory integration, are interactions between auditory and visual modalities driven by objective estimates or subjective confidence? To answer this question, Gao et al. (2025) created two types of visual motion stimuli: high-energy stimuli where 50% of dots moved in the dominant direction, and low-energy stimuli where 25% of dots move in the dominant direction. As expected, confidence ratings were higher for high-energy stimuli despite higher accuracy for the low-energy stimuli. Importantly, in an audiovisual motion condition, high-energy visual stimuli influenced auditory motion judgments more strongly than low-energy visual stimuli, consistent with their higher confidence. This finding indicates that multisensory integration follows subjective confidence rather than objective performance. In this talk, I discuss this finding among other empirical work that shows the importance of metacognition in multisensory integration, including new results showing confidence distinguishes congruent and incongruent information, and additional results suggesting a possible role for confidence in sensory recalibration.

Subjective Perception and Multisensory Integration

Samaha, Jason [1]

[1] Department of Psychology, University of California, Santa Cruz (United States)

The degree to which integration of information across distinct sensory modalities depends on subjective perception of sensory stimuli as opposed to objective stimulus properties remains controversial. For instance, some theories have proposed that subjectively invisible stimuli are not processed to the point of being integrated with other sensory modalities. In other words, unconscious sensory information may remain relatively confined to respective sensory cortex. The ventriloquist effect refers to the misperception of a sound location towards that of a concurrent visual stimulus, such as perceiving the voice of a ventriloquist actor as coming from the moving dummy. We modified a paradigm from Delong et al. (2018) by using meta-contrast masking to render the location of a brief flash stimulus unconscious while participants performed a sound localization task. We found that, despite being at chance performance in discriminating the flash location, participants were nevertheless biased to localize sounds towards the unconscious flash locations. Decoding analyses

of concurrently recorded EEG signals showed that the non-conscious flash location information was present up until around 300ms but not after; confirming that the visual influence on sound perception likely occurred before widespread broadcasting of the visual information. Our findings suggest that subjective perception is not required for the integration of signals originating in distinct sensory modalities prompting new questions about the role of subjective and objective perception and uncertainty in multisensory integration.

Symposium 5 - Sensorimotor and action brain plasticity

The sensorimotor and action representation system of the brain is relatively well studied in healthy humans. However, these systems are incorporated in and affected by their multisensory context and experience. How are these brain representations changed or preserved in individuals with sensory or motoric differences? Here, we give an overview of studies looking at brain plasticity related to sensorimotor representations when individuals either lack a limb or are deaf or blind.

Ella Striem-Amit will talk about how the action representation system is organized in the brains of people born without hands. Dorothy Cowie will talk about children with limb differences and their behavioural and neural adaptations. Tamar Makin will explore how the sensorimotor cortex of acquired amputees retains and interprets information of the missing hand beyond somatosensory maps, from kinematics to semantics. Velia Cardin will show how somatosensory features and tasks are represented in the auditory cortex of deaf individuals. Stephanie Badde will present evidence on the flexibility of interactions between tactile perception and body posture in congenitally blind individuals whose cataracts were reversed. Petra Vetter will show how actions are represented in early visual and dorsal stream brain areas in congenitally blind individuals. Together, the presented evidence will give insights into the impact of multisensory experience and interaction, as well as the extent of brain reorganization for somatosensory and motor representations in the brain of individuals with sensory or motoric differences.

Organizer: Petra Vetter

Motor metamodal theory? The action system is organized by action types

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We perform most of our daily actions with our hands, and vast portions of the action system in the brain are dedicated to them. What does this system do in people born without hands who use their feet instead? Parallel to the idea of metamodal organization in blindness or deafness, I'll present fMRI evidence that much of the association motor system is organized by action-types rather than by the acting body parts. These higher-level representations allow us to understand actions we cannot perform ourselves, and to perform comparable actions with different parts of our body. These higher-level representations can also arise without motor experience even with the dominant, typical body part. Further, these representations extend to non-ethological actions, unique to humans, such as tool use, suggesting a broad action-mapping principle exists in the motor domain. Last, such research can open new avenues to use high-level action representations for motor rehabilitation.

Neural and behavioural adaptations in children with limb differences

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Children with congenital upper limb differences must develop novel motor solutions to achieve everyday tasks, often using alternative effectors. This study asks how these motor solutions are acquired through a process of motor exploration; and how this novel behavioural repertoire shapes the developing somatosensory homunculus.
One- and two-handed children (3-9 years old, total n=111) completed a battery of motorically challenging tasks such as opening jars and separating Lego bricks. While two- handed children completed these bimanually, children with limb differences used a variety of alternative effectors, most commonly the legs or torso alongside the intact and residual arms. The choice of effector depended on the laterality of limb difference: children missing a right hand employed more unusual strategies involving the feet, suggestive of an innate handedness persistent in the face of limb difference. For some effectors (e.g. torso), their use was determined by their effectiveness in solving a task, while others (e.g. legs) were habitually used irrespective of their efficacy. Finally, exploratory behaviour reduced with age: older children found fewer, more efficient behavioural strategies than younger.
In an fMRI study with a subset of these children (5-7 years old), we mapped body-part representation in primary somatosensory cortex (S1). We observed global topographic shifts across the deprived (contralateral) sensory homunculus, already evident early in life and stable into adulthood. Nevertheless, behavioural adaptations exerted a modulatory influence on somatosensory organisation. Our findings indicate that congenital deprivation triggers large-scale cortical remapping early in life, with subsequent sensory experience refining rather than restructuring these maps.

Beyond Movement: How does Primary Sensorimotor Cortex Maintains Body Representations After Amputation?

Makin, Tamar [1]

[1] MRC Cognition and Brain Sciences Unit, University of Cambridge, UK

The brain's ability to maintain a representation of the body, even in the absence of sensory input, challenges traditional models of plasticity. I will first present evidence from a pre- and post-amputation study demonstrating that sensorimotor hand representations persist despite the loss of the limb. This raises a critical question: what kind of information is being maintained? To explore this, I will present a new study showing that primary sensorimotor cortex not only encodes movement kinematics but also action semantics, with activity patterns aligning with models derived from large language models (LLMs). I will also show first evidence from the deprived sensorimotor cortex of an amputee, showing that semantic representations may persist even when kinematic signals are lost.
Finally, I will revisit the long-documented phenomenon of referred sensations and propose an alternative explanation—rather than reflecting cortical remapping, our findings suggest they may emerge from demand characteristics, shaped by expectation and suggestion. Collectively, these findings redefine how we think about sensorimotor cortex—not as a passive map of the body, but as a resilient hub integrating action, meaning, and perception.

Crossmodal representations in the auditory cortex of deaf and hearing individuals

Cardin, Velia [1]; Konstantin Grin, Martin Eimer, Samuel Evans, Luigi Tame, Bencie Woll, Rita Bertani, Dilay Ercelik, Lucy Core, Yueming Gao, Matthew Longo, Valeria Vinogradova, Barbara Manini

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Human congenital deafness shapes sensory and cognitive processing, providing unique

insights into our understanding of the brain. Crossmodal plasticity research in deaf individuals has shown that regions of the superior temporal cortex, usually considered auditory-processing regions, are recruited for executive processing tasks in the visual and somatosensory modalities. These are not functions usually associated with sensory cortices. What is the role of sensory regions during such executive processes in deaf individuals?
To address this question, we conducted a delay-to-match experiment in the visual or somatosensory modality in deaf and hearing individuals. In our experiment, each trial consisted of a visual or somatosensory display that varied in its pattern (spatial component) or frequency of stimulation (temporal component). Participants were asked to remember either the pattern or the frequency, while ignoring the other domain. With this design, we were able to analyse information about difference sensory features, tasks and
sensory modalities, while maintaining the overall properties of the stimuli constant.
Results from a representational Similarity Analysis (RSA) showed that the auditory cortex of deaf individuals contains information about higher-level processes such as task and sensory modality. We also found significant representations of somatosensory frequency. Critically, task and modality representations were also found in the auditory cortex of hearing individuals. These results suggest that sensory areas can adapt their functional profile in response to sensory experience, and enhance their processing of information from other modalities. They also suggest active roles for sensory areas in cognitive processes, beyond the representation of sensory features.

A sensitive period for automaticity rather than ability: Congenitally but not developmentally blind humans flexibly use tactile reference frames following sight restoration.

Badde, Stephanie [1], Suddha Sourav, Kabilan Pitchaimuthu, Bhavana Kolli, Waqar Khan, Ramesh Kekunnaya, Brigitte Röder

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Visual experience can profoundly shape tactile perception. Sighted and late blind but not congenitally blind humans automatically link touch to a visuospatial reference frame–evidenced by a tendency to assign tactile stimuli to the wrong hand when the hands are crossed. Here, we tested the use of tactile reference frames in two groups of sight-restored individuals who were temporarily deprived of pattern vision due to bilateral dense cataracts that were either present at birth or developed in childhood. Participants reported the location of the first of two successively presented tactile stimuli—one on each hand—while placing their arms in a crossed or uncrossed position. In Experiment 1, only tactile stimulus pairs were presented. In Experiment 2, pairs of tactile stimuli were interleaved with tactile-auditory and auditory stimulus pairs. Like congenitally blind individuals, in Experiment 1, sight-restored participants who formerly had congenital cataracts performed indistinguishably with crossed and uncrossed hands. However, in Experiment 2, this group's perception of tactile stimuli resembled that of sighted participants: performance was markedly impaired when the hands were crossed. By contrast, sight-restored participants whose removed cataracts had developed during childhood and typically-sighted participants showed comparable effects of hand position on tactile perception across sensory contexts. The context- dependent use of visuospatial coding in individuals with reversed congenital cataracts suggests that rather than the ability to use visuospatial coding of touch, the automaticity of doing so develops during a sensitive period.

Action representations in early visual and dorsal stream areas in congenitally blind individuals

Vetter, Petra [1], Lukasz Bola, Mohr Wenger, Amir Amedi

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Different motor actions like reaching and grasping elicit decodable fMRI activity patterns in sensorimotor and dorsal parieto-frontal brain areas as well as in early visual cortex of sighted participants. How and where are actions represented when the brain has undergone plastic changes due to lifelong sensory deprivation, i.e. in congenital blindness? Here we showed that, in congenitally

blind individuals, the action of reaching in different directions can be reliably decoded from fMRI activity patterns in early visual cortex as well as in dorsal stream areas involved in visuo-spatial and visuo-motor integration in the sighted. In blind early “visual” cortex, we find a gradient of decoding accuracy with better decoding in foveal than peripheral regions, suggesting a potential preserved feedback mechanism of action-related information being sent to high-resolution foveal visual areas for precision grasping. Overall, our findings in congenitally blind individuals show that the development of action representations in the brain might be largely independent of visual experience.

Symposium 6 - From Perception to Prediction: The Multisensory Dynamics of Multimodal Language

This symposium aims to present cutting-edge research on the multisensory processing of audiovisual speech, a critical topic in multisensory research. Focusing on face-to-face communication, we aim to challenge traditional psycholinguistic models by examining how the brain represents multimodal language — not as separate sensory components, but as a dynamic, integrated multisensory phenomenon. Current models often fail to reflect the complexity of multisensory neural representations and their role in predictive language processing, especially in sub-optimal auditory and visual conditions such as those experienced by deaf and blind individuals.

We will present recent insights into how the brain represents and integrates auditory, visual and tactile language, extending beyond classical regions to involve a broader multisensory network. This will be explored through the lens of typical and atypical language processing, examining how multisensory cues can compensate for degraded auditory or visual input. By critically reassessing existing evidence, we aim to provide a more accurate understanding of how the brain processes language in optimal and sub- optimal conditions.

Bringing together experts from neurocognitive, sensory and psycholinguistic research, this symposium offers an interdisciplinary perspective on the unfolding, development and adaptability of multisensory language processing. We will discuss the potential for these insights to improve communication strategies for individuals with hearing impairments and contribute to the broader field of language processing.

This symposium represents a timely opportunity to advance our understanding of multisensory integration in language processing. The diverse lineup of speakers promises a rich, multifaceted discussion that will engage the scientific community. Furthermore, it has the potential to foster new interdisciplinary collaborations, advancing research in multisensory and predictive speech processing.

Organizer: Stefania Benetti

Multisensory linguistic representation beyond the core language network

Collignon, Olivier [1]

[1] Université catholique de Louvain (Belgium)

Language enables humans to share information across minds and brains relying on a diverse array of multisensory signals. Traditionally, these signals have been thought to converge onto a core "language network" primarily orchestrated by temporo-frontal regions. However, recent evidence suggests that occipito-temporal areas also play a fundamental role in language processing beyond their classical function in visual reading. In this talk, I will present a series of fMRI studies from my lab demonstrating how the occipito-temporal cortex encodes linguistic signals across multiple modalities: visual and tactile Braille in expert readers, sign language in proficient signers, and visemes and phonemes in all individuals. These findings highlight the crucial role of the ventral occipito-temporal stream in attributing linguistic value to both symbolic and non-symbolic multisensory information.

Anticipating the Unseen: How the Brain Predicts Mouth Cues to Comprehend Speech During Multisensory Integration.

Piazza, Giorgio [1], Vespignani, Francesco [1], Gastaldon, Simone [1], Peressotti, Francesca [1]

[1] DPSS, University of Padova (Italy)

Humans excel at understanding spoken language during face-to-face interactions by leveraging linguistic and extra-linguistic cues to predict incoming information. This study investigates multisensory processing during speech comprehension in naturalistic communication.

We examined the role of mouth cues in shaping language predictions during speech comprehension. Thirty Italian participants watched videos of an actor narrating two stories in Italian, with the mouth either visible or covered (~45 minutes), while EEG data were recorded. Using Temporal Response Function analysis, we mapped stimulus features to neural responses under natural listening conditions, enabling the simultaneous examination of multiple input features. Our analysis focused on the encoding of mouth movements, visemic surprisal (the unpredictability of visual phonemes), and semantic surprisal (the unpredictability of lexical elements) over time.

Results revealed that the brain encoded visemes, refining their predictions, even when the mouth is not visible. Additionally, lexical predictions, reflected in brain responses to semantic surprisal, were more effective with visible mouth cues, demonstrating enhanced integration of visual and linguistic information. Together, these findings indicate that visual input does not merely supplement auditory processing but actively shapes predictive mechanisms in speech comprehension.

These novel findings, grounded in the predictive processing framework, highlight the critical role of multisensory integration in speech prediction and comprehension.

Rethinking Phonological Representations in the Human Brain: Multisensory Insights into the Neural Architecture of Language

Benetti, Stefania [1], Rabini, Giuseppe* [1], Tommasini, Mirko [1], Pavani, Francesco [1], Franz Nikolaus Wurm, Moritz [1]; * presenter

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Recent research has challenged traditional models of language based on auditory speech alone, revealing a more extensive brain network involved in multisensory language processing. However, many studies assume that conventional phonetic features, such as manner of articulation or voicing, directly reflect physical and perceptual phonological properties, when in fact they primarily capture articulatory aspects—introducing potential confounds in interpreting neural representations of speech.

In this talk, I will argue for a reassessment of phonological representations in multisensory speech processing, proposing a framework that moves beyond articulatory-based traits to better capture how the brain encodes spoken language at perceptual, and cognitive levels. By implementing a Representational Similarity Analysis in combination with physical, perceptual and categorical phonological models to investigate the neural underpinnings of audiovisual speech, we uncover a more dynamic and distributed network, spanning early sensory, multimodal, and motor regions. Our findings suggest that speech perception is not merely an auditory-driven process but involves crossmodal interactions that shape phonological representations in ways not fully accounted for by classical models.

I will discuss how these insights challenge existing assumptions about audio-motor integration and the role of sensory cortices in speech processing. By integrating behavioral and neural evidence, this work highlights the need for a broader, multimodal perspective on phoneme representation—one that accounts for both the physical properties of speech signals and their higher-level cognitive organization.

Ocular Speech Tracking in age and hearing diverse populations

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Recent studies performed by our group, revealed that tracking of attended speech is not only reflected by neural activity but also in a listener's eye movements. This newly discovered phenomenon, termed Ocular Speech Tracking, shows a connection to speech intelligibility; yet the nature of its link to behavioural characteristics remains open. Moreover, Ocular Speech Tracking seems to partly account for the frequently observed connection between speech intelligibility and Neural Speech Tracking. So far, since most of the subjects in preceding studies were healthy hearing, younger individuals, the relationship with moderate hearing loss and aging remains unexplored. Yet these two factors are of highest importance when observing mechanisms of multisensory speech processing. This raises the question of how Ocular Speech Tracking manifests in individuals with impaired hearing ability and how it changes over the lifespan. Our current projects are tackling the limitations in the current research, following the overall aim to extend our knowledge about hearing and aging in diverse populations, and shedding light on unknown aspects of Ocular Speech Tracking functionalities. To achieve this goal, one step is to use a subset of the Paracelsus 10 000 study, a large scaled overall health study project in Salzburg, to investigate the effect of aging and hearing status on Ocular Speech Tracking.

The impact of early auditory experience on neural speech tracking

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Language acquisition relies on biological predispositions and exposure to appropriate input during specific developmental windows. In this talk, I will present data from our lab investigating the role of early auditory experience in the development of neural speech tracking. We assessed speech tracking in cochlear- implanted (CI) children with congenital (CD) or acquired deafness (AD), as well as in hearing control (HC) children. The CD and AD groups differed in their access to functional hearing during their first year of life. Neural synchronization with basic properties of speech, i.e., the speech sound envelope and lip movements, was measured using uni and multivariate encoding models of EEG data. Findings indicate that the absence of perinatal auditory experience does not impair neural tracking of speech sound envelope. However, tracking associated with higher- order speech processing was dampened in all CI children, contributing to their speech comprehension deficits. In contrast, early auditory experience was crucial for audiovisual (AV) speech processing. Neural synchronization with speech was significantly enhanced in the presence of AV input in both HC and AD groups. At short-latency of brain activity, speech tracking was markedly anticipated when visual cues (i.e., the speaker's face) were available. This multisensory facilitatory effect was absent in the CD group, stressing the critical role of early auditory and audiovisual input in shaping neural processes underlying AV speech perception. These findings identify neural biomarkers of distinct developmental trajectories along the speech processing hierarchy, shaped by early auditory experience.

Symposium 7 - Multisensory Contributions to Postural Control, Self-Motion, and Verticality Perception Across the Lifespan in Healthy and Clinical Populations

Self-motion, postural control, and verticality perception are key for daily life and are tightly linked to each other. Multiple sensory cues contribute in different ways to achieve efficient balanced behaviour. Visual cues are crucial, providing both static and dynamic signals (e.g., optic flow); in line with this, visually impaired people often report decreased stability and impaired spatial navigation. Vestibular information anchors the body to the Earth-vertical, providing continuous cues about gravity (i.e., what is vertical) and head acceleration in the 3D space. Proprioception provides information about how our muscles and joints work synchronously, contributing, for example, to recovering from sudden instability.

Although less studied, research has revealed the influence of auditory cues on postural control and balance as well. Beyond their single-cue contributions, it has been shown that, when multiple senses are engaged together, they lead to optimal performances even in challenging conditions. This symposium will explore the multisensory contributions to verticality perception, postural control, navigation and self-motion from perceptual to cognitive perspectives. Throughout development, individuals' ability to integrate sensory information for balance improves, and this developmental trajectory is shaped by both sensory experience and neural maturation. At the same time, even though sensory integration abilities generally decline with aging, older adults increasingly exploit multisensory information for balance and spatial navigation. The diverse contributions from the participating researchers will address key issues such as the role of perceptual and cognitive factors involved in verticality perception, dynamic aspects of multisensory postural control and self-motion, and the impact of sensory loss on balance and spatial navigation. The symposium will offer deeper insights into how the brain integrates and processes sensory information to maintain stability. It will also examine how disruptions in this process can affect balance and postural control across the lifespan.

Organizer: Silvia Zanchi

Perceiving Gravity: Multisensory Integration and Cognitive Influences

Ferre, Elisa Raffaella [1]

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Gravity has played a central role in shaping the evolution of life on Earth, and our ability to accurately perceive the gravitational vertical is essential for interacting successfully with our environment. Verticality perception refers to the human ability to distinguish the orientation of the gravitational vertical - defining what is "up" and "down" - and to detect any deviation from this orientation. Humans are exceptionally accurate in perceiving verticality, estimating the vertical to within two degrees of the physical gravitational vector. This ability is crucial for postural stability, spatial awareness, and motor coordination. While the vestibular system is a key player in detecting head orientation relative to gravity, verticality perception is the result of a dynamic integration of multiple sensory inputs, including proprioceptive, somatosensory, and visual cues. In this presentation, I will discuss our recent findings on the interaction between vestibular and visual signals in verticality perception, demonstrating that reductions in the reliability of these cues impair sensitivity, with visual cues having a particularly strong influence. Furthermore, I will explore how semantic knowledge modulates verticality perception, revealing the complex interplay between sensory processes and higher-order cognitive functions in shaping our experience of gravity.

Investigating Postural Control Manipulation during Standing through Nonlinear Analysis of Variability and a Neurocomputational Model

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Postural control relies on merging sensory inputs from vestibular, proprioceptive, visual, and auditory systems. Biological systems are inherently nonlinear; thus, entropy is fundamental to determining the state of a system, and it helps assess the predictability of postural sway. However, the specific contribution of each sensory system to entropy remains unclear. Eight healthy adults (mean age ± SD: 24.3 ± 1.3 years old) stood on a Nintendo Wii Balance Board. Wearing Microsoft HoloLens, headphones, and vibrational devices, they experienced various sensory conditions: baseline with no additional cues, moving and static sounds, lateral and medial Achilles tendon vibrations, and combinations of vibration and auditory stimuli. These conditions were tested with eyes open, eyes closed, and blurred vision. The entropy of the centre of posture data was measured and compared across conditions. The interaction between sensory systems influences the system entropy. Specifically, vibration stimulation significantly increased entropy, regardless of the visual condition, causing disturbances to proprioception. As a result, our system becomes more unpredictable. In contrast, blurred vision led to a decrease in entropy, likely because although still available, vision offered a less reliable input, which caused the system to become more rigid. To further understand these findings, we developed a biologically plausible computational model to simulate the observed results and propose possible neural mechanisms underlying postural control. Understanding how sensory cues affect stability, entropy, and the neural mechanisms involved is crucial for assessing system dynamics.

The Perception of Self-motion: Differences in the Effectiveness of Optic Flow in Different Parts of the Field When Standing and During Active Walking

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When seated, optic flow seen exclusively in the far periphery causes people to feel they have moved further than when the same motion is seen full field or in the central field only (McManus et al., J. Vis. 17(8), 2017). Is this also the case when actively walking? Here, we used a very-large-field (±110°) display to provide optic flow while participants were standing stationary or actively walking on a treadmill. Optic flow simulating forward self-motion was presented either full field, in just the central field (±20°), or in just the far periphery (beyond ±90°). Participants indicated their simulated travel distance by stopping at the location of a previously seen target (Move-To-Target Task) or by adjusting the position of a target to indicate the distance of a previous movement (Adjust-Target Task). In the Move- To-Target task, peripheral optic flow led to higher gains (perceived travel distance / actual travel distance) compared to the central and full-field conditions during both the visual-only and visual-and treadmill conditions. In the Adjust-Target task, however, there were no significant differences between the visual field conditions. This implies that different brain processes might be used to estimate travel distance in the Move-To-Target and Adjust-Target tasks but that optic flow in different areas of the visual field affects passive and active walking conditions equally. These findings highlight the importance of the far periphery in self-motion processing and emphasize the importance of visual cues in perceiving travel distance.

Postural Adaptations to Eccentric Viewing Across Adulthood and in Central Visual Field Loss

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The visual, vestibular, and oculomotor systems are tightly linked, with vestibular responses calibrated to the fovea in primates. Gaze orientation is known to impact body stabilization and control in young adults: whole-body adaptations occur to enhance gaze/body stability during visual tasks, and postural responses are gaze- direction dependent. Central visual field loss (CFL, e.g., due to macular degeneration) is very common in older age causing high-acuity vision loss, mobility difficulties, and increased fall risk. Those with *binocular* CFL often adopt eccentric viewing strategies, but how these adaptations interact with low vision and other sensory-motor signals for body coordination and control remains unclear. We begin addressing this by examining how eccentric viewing impacts body stabilization and postural control in young and older adults with and without CFL.

In one experiment, participants stepped in place with and without a visual search task. In another, participants viewed a fixation target with or without the presence of a full-field (58°x48°) laterally oscillating optic flow stimulus while standing under different gaze-to-screen orientations.

Preliminary data suggest that postural adaptations driven by the demands of the search task persist in older adults with and without CFL, e.g. through modulations in step width. In the standing task, we observe an interaction in the effects of optic flow and gaze eccentricity, e.g. on center of pressure velocity, that vary between individual profiles. These findings highlight how CFL affects integration across sensorimotor systems, while the preserved adaptations we observe suggests avenues for training that exploit ecological relationships between these systems.

Multisensory Integration in Ego-Motion and 3D Navigation: Insights from Blindness, Blindfolding, and Sight Restoration

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Ego-motion and 3D navigation rely on multisensory integration, particularly between vision, vestibular cues, and proprioception. Under low-visibility conditions or without vision, errors accumulate over time, affecting spatial perception and navigation performance. This talk presents recent studies examining errors in vestibular and proprioceptive integration during ego-motion and navigation. We investigated blindfolded (sighted) participants, blind individuals, and children who regained sight after congenital cataract removal. Blindfolded participants initially navigate well over short distances, but errors quickly accumulate, leading to deviations and 'circling'—turning in circles while attempting to walk straight. Longitudinal analysis over several days suggests this result from vestibular noise accumulation. Blind individuals exhibit similar errors, indicating their vestibular system is not inherently better trained. In 3D environments with slopes, participants effectively integrated their path but struggled to find back to their starting point, largely overestimating slope angles. These errors diminished when slopes were replaced by steps, suggesting proprioceptive misperception as the cause. Children who regained sight after cataract removal initially behaved like blind participants, failing to weight the visual input for the control of balance and ego-motion. Interestingly, this made them also less susceptible to vision-induced motion illusions such as optic flow affecting balance. Over time, visual weighting increased to improve control of balance and ego-motion. Following the development of performance errors over different time scales from minutes (lab experiments), to days (longitudinal study) and years (cataract removal studies) helps us to understand the different contributions of the sensory systems to ego-motion and 3D navigation.

Symposium 8 - The influence of vision and body representations on tactile perception

Which factors determine what we feel? The tactile stimulus itself? Neural connections across body part representations? Prior experience with specific body parts? Visual information regarding the body and/or stimulus? This symposium will present a series of studies that examine these questions. First, past results claiming that informative vision enhances tactile perception have two potential explanations: perceptual enhancement or a liberal response bias. Jared Medina presents research from comparative and equality judgment tasks providing evidence for an enhancement account. Medina also presents evidence for a novel illusion showing that participants feel a viewed stroke moving across the hand, even if the actual unseen stroke is moving in the opposite direction. Second, viewing one's body enlarged has been shown to enhance tactile perception. However, the mechanisms that underlie these findings are unknown. Catherine Preston will present work on somatosensory blurring, discussing how changes in perceived body size via illusory stretching may alter tactile perception. Third, Valeria Peviani will present an electrophysiological investigation examining the coordinate systems used by the brain to represent the spatial position of touch. Fourth, Luigi Tamè will present new work showing that tactile information on the hand can influence perception of tactile stimuli presented to the foot on the same side of the body. Finally, Sophia Grekin will present results from a series of experiments demonstrating that tactile temporal perception is influenced by the stimulated body part. Their results suggest that these differences are caused not only by physiological differences between the body parts but also by past experience with touch specific to the stimulated body part.

Organizer: Jared Medina

Visual Contributions to Tactile Perception: Multisensory Enhancement and Conflict

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We examined how perception is influenced when tactile stimuli are consistent with, or conflicting with, visual information. First, past experiments have shown that individuals are more likely to detect tactile stimuli when viewing touch in the same location. However, prior results could be explained by individuals using a more liberal response criterion when seeing viewed touch. Participants watched videos of a hand being touched on the index or ring finger while simultaneously being stimulated on these fingers at different intensities. Participants indicated which stimulus was more intense (comparative judgment task), and whether stimulus intensities were the same or different (equality judgment task; more resistant to response bias). Vision enhanced tactile performance on both tasks, providing evidence that informative touch enhances tactile perception. Second, we present results from a novel version of the mirror box illusion in which tactile and visual information strongly conflict. Both hands (one in front of, and one behind the mirror) were stroked simultaneously across the entire hand dorsum in congruent or incongruent directions (stroke disparity ranging from 45-180°). Participants then reported the perceived stroke direction on their hidden hand. Across multiple experiments, participants frequently perceived touch in the seen direction rather than the actual direction. When the angular disparity was 180° (e.g., viewed stroke towards the fingers, felt stroke towards the wrist), we observed an all-or-nothing effect, such that participants reported both either the actual touch or complete visual capture. These results provide evidence that visuotactile temporal congruence can override visuotactile spatial incongruence, leading to illusory percepts.

Tactile processing in somatosensory cortex and its modulation through multisensory stimuli

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Previous studies have demonstrated that vision of the body and multisensory illusions that enlarge the perceived size of a body part can enhance tactile acuity and also reduce the experience of pain. A neural mechanism proposed to underlie this involves somatosensory blurring, in which the neural representation of the body part is diffuse (blurred) and visual information, particularly from resizing illusions, may sharpen these neural representations in the somatosensory cortex. Here we directly test this hypothesis as well as investigate neural processes that may underlie this effect using Somatosensory Steady State Evoked Potentials (SSSEPs) with EEG. In study one we investigate vibrotactile neural summation across fingers, highlighting how the integration of tactile stimuli across multiple digits influences perception. The findings show probability summation when all fingers are stimulated, with detection thresholds decreasing, and an increase in SSSEP amplitudes, suggesting enhanced tactile sensitivity. However, suppression occurs when targets and masks are presented at different frequencies, indicating inhibition between digits. The second study focuses on somatosensory changes of multisensory finger stretching illusions. Although pre-registered confirmatory analysis found no significant differences, exploratory analysis accounting for the non-parametric data suggests possible "sharpening" of neural representations in response to illusory stretching. Together these results are compatible with somatosensory blurring, for which the brain integrates or suppresses tactile inputs across fingers, potentially reducing the differentiation between body part representations. This provides a framework for understanding how multisensory stimuli may alter body representations via modulation of neural summation in the fingers.

A mirror symmetric spatial code maps touch on both hands in the human brain

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Extensive research showed that the somatosensory maps in the parietal lobe are organized somatotopically, representing the body surface in a structured manner. While such anatomical coding of touch is well understood, its functional coding is still rather unclear. Everyday actions, such as swatting a mosquito, require mapping the tactile input in skin-based coordinates onto a spatial reference frame that takes into account changes in body posture. Research so far has primarily compared neural responses to tactile stimuli in crossed vs. uncrossed arm positions, limiting insights into understanding which functional codes are used to represent the spatial location of touch. Here, we used EEG and high-density postural sampling to test whether tactile space is encoded in an absolute external coordinate system or a mirror-symmetric, joint-based coordinate system. We delivered electrocutaneous stimuli to the hands in varying spatial positions. Using univariate and multivariate analyses we found evidence supporting a mirror- symmetric spatial code emerging at 150 ms after stimulus onset. In the ERP analysis, this manifested as an amplitude gradient modulated by the spatial position of touch. The RSA further revealed a statistical relationship between the spatial distances among tactile stimuli and the associated neural activity patterns. These findings suggest that tactile localization relies on body-based representations rather than absolute spatial coordinates. These findings provide new insights into how the brain integrates somatosensory and proprioceptive information to guide action.

Tactile coding on the fingers and toes: insights from double simultaneous stimulation across limbs

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It has been shown that there are common representations of homologous fingers of the two hands (i.e., index and middle fingers) suggesting the presence of specific interactions between homologous body parts of the upper limbs of the two sides of the body. However, it is unknown whether such interactions are also present across different limbs that are morphologically similar such as hands and

feet. Here, we investigated the effect of tactile double simultaneous stimulation (DSS) between the fingers and toes to explore between-limb tactile interactions. Participants performed a go/no-go task to detect a tactile stimulus on a target digit (e.g., left index finger) in isolation or with a simultaneous stimulus distractor on a non-target digit, either on the hand (e.g., left middle finger) or on another limb (e.g., left big toe = homologous; left second toe = non-homologous). In different blocks the target digit could be a digit on the left hand (i.e., index finger, middle finger) or on the left foot (i.e., big toe, second toe). Results showed that DSS of homologous digits across the upper and lower limbs does not alter tactile sensitivity, regardless of the stimulated body parts (hand and foot). By contrast, there is a selective interference when DSS is applied on non-homologous digits when the target is a digit on the foot, but not when it is a digit on the hand. These findings provide behavioural evidence in humans regarding the presence of common representations for homologous digits across hand and foot.

Tactile Temporal Perception across the Body

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The perceived timing of events rarely mirrors their physical timing; temporal perception varies with the characteristics of the stimulus as well as prior knowledge about the duration of events. Here, we investigated whether the perceived duration of tactile stimuli and tactile temporal resolution depend on the stimulated body part, and the factors that might underlie such differences across the body–specifically the role of experimental and environmental priors. Participants compared the perceived duration of a tactile test stimulus presented on the index finger, the forearm, or the forehead either to that of a tactile standard stimulus on the other index finger (Expt. 1) or to an auditory standard stimulus (Expt. 2). Analysis of the psychometric curves revealed that tactile stimuli on the index finger were perceived as longer than tactile stimuli on the forehead or forearm, revealing default biases in tactile temporal perception across the body. Next, we established that participants can learn body-part specific experimental priors for tactile duration by varying the distribution of tactile durations across the finger and forehead (Expt. 3). Finally, we measured tactile temporal resolution across multiple body parts, using a temporal gap detection task (Expt. 4). Our results reveal that tactile temporal perception varies across the body reflecting not only the properties of the stimulated skin site but also prior experience with touch on that body part.

Talks

Talk session 1

Crossmodal interaction of flashes and beeps across time and number follows Bayesian causal inference

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Keywords: Multisensory perception, Bayesian inference, Causal inference, Computational model

Multisensory perception requires the brain to dynamically infer causal relationships between sensory inputs across various dimensions, such as temporal and spatial attributes. Traditionally, Bayesian Causal Inference (BCI) models have generally provided a robust framework for understanding sensory processing in unidimensional settings where stimuli across sensory modalities vary along one dimension such as spatial location, or numerosity (Samad et al., 2015). However, real-world sensory processing involves multidimensional cues, where the alignment of information across multiple dimensions influences whether the brain perceives a unified or segregated source. In an effort to investigate sensory processing in more realistic conditions, this study introduces an expanded BCI model that incorporates multidimensional information, specifically numerosity and temporal discrepancies. Using a modified sound-induced flash illusion (SiFI) paradigm with manipulated audiovisual disparities, we tested the performance of the enhanced BCI model. Results showed that integration probability decreased with increasing temporal discrepancies, and our proposed multidimensional BCI model accurately predicts multisensory perception outcomes under the entire range of stimulus conditions. This multidimensional framework extends the BCI model's applicability, providing deeper insights into the computational mechanisms underlying multisensory processing and offering a foundation for future quantitative studies on naturalistic sensory processing.

Multisensory enhancement in detection and localization is reliable, robust, and consistent with an optimal computation

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Keywords: Reliability, Reproducibility, Cross, Modal, Visual, Auditory, Computational

Multisensory integration is a crucial neural process that can significantly enhance perception and behavioral decisions. However, estimates of its impact are often variable within and between studies involving different contexts, tasks, and response measures. To address the reliability and magnitude of multisensory effects, an analysis was conducted on data from a benchmark visual-auditory detection and localization task used in seven animal studies spanning 35 years. This extensive dataset enabled a robust evaluation of the magnitude, consistency, and optimality of multisensory integration while including common sources of experimental variability. The results revealed that the multisensory behavioral performance was consistently above the most stringent referent criteria, the sum of the unisensory performance levels. In operational terms, the multisensory effect reflected a quantitatively consistent enhancement in behavioral performance over this additive standard, with minimal variance across testing sessions and minimal sensitivity to factors such as animal sex, stimulus location, and trial history. This "superadditive" multisensory effect was consistent with the

predictions of an optimal model in which visual and auditory input signals are summed before being nonlinearly transformed into observable behaviors by a decision-making process. This psychophysical model closely matched the integrative operations identified within single neurons in the superior colliculus that support this behavior. These parallel observations provide a robust framework for understanding the relationship between the observed physiology and behavior, highlighting the utility of this paradigm for evaluating the efficiency of this neural process in enhancing functions that are essential for survival.

A Bayesian causal inference model for postdictive audiovisual perception

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Keywords: Crossmodal postdiction, Bayesian causal inference

Information from different sensory modalities is processed in a temporal window of multisensory integration that can last several hundred milliseconds. Within this window, the processing of a stimulus is influenced not only by preceding and concurrent input, but also by input following a stimulus. A previous study using beep-flash pairs showed that auditory or visual stimuli presented shortly after a stimulus can retroactively influence the perception of the first stimulus, resulting in an illusory or invisible flash (Stiles et al., 2018; PloS One 13:e0204217). A single beep presented between two flash-beep pairs can induce an illusory flash, whereas a single flash presented between two flash-beep pairs can be perceptually suppressed. In this behavioral study, we used a Bayesian Causal Inference (BCI) framework to investigate the mechanisms underlying the two multisensory postdictive illusions. We replicated both illusions and found that audiovisual stimuli with a temporal asynchrony with auditory and visual leading stimuli sequences reduced the illusions. The BCI model could explain crossmodal postdiction better than competing forced-fusion and forced-segregation models and accurately predicted the postdictive illusions. Taken together, our study shows that the BCI framework is applicable to characterize postdictive perception within the temporal window of multisensory integration.

Evidence for Bayesian Causal Inference Mechanisms for Multisensory Integration in Full-Body Ownership Illusions

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Keywords: Visuotactile integration, Self, perception, Sensory uncertainty, Body ownership

Body ownership—the multisensory perception of limbs and body parts as one's own—has been extensively studied in the contexts of vision, touch, and proprioception. Bayesian causal inference models have recently been employed to explain ownership illusions towards a body part, such as the visuotactile rubber hand illusion, suggesting that observers compute the probability that visual and tactile signals originate from a common source. However, it remains unclear whether similar computational processes underlie the perception of ownership over the entire body. To address this question, we developed a detection task relying on the classic full-body illusion paradigm. Participants reported whether the body they observed (a mannequin's body) felt like their own (yes or no answer). We systematically manipulated the asynchrony between visual and tactile stimuli delivered to the mannequin and the participant's real body, alongside varying levels of visual noise. Our results revealed that the probability of experiencing the full-body illusion was accurately predicted by a causal inference model, wherein observers estimate the likelihood that visual and tactile signals arise from a common source. This model outperformed a non-Bayesian alternative that did not account for sensory

uncertainty, even though the behavioral effects of visual noise were relatively weak. These findings provide evidence that Bayesian causal inference mechanisms extend to whole-body ownership illusions. We discuss the implications of these results for understanding the relationship between part-based and whole-body ownership in multisensory awareness.

Binding voices and faces. How the brain uses prior expectations to integrate multisensory signals in communication

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Keywords: Multimodal communication, Social perception, Prior expectations, Bayesian inference, Lateral processing pathway

Face-to-face communication is complex: what we say is coupled with bodily information, often offset in time, which may or may not work in concert to convey meaning. Yet, we rapidly determine which multisensory signals belong together and which must be kept apart. How do we achieve this fundamental and extraordinary feat? Combining psychophysics, computational modeling, and fMRI multivariate decoding, we investigated how the brain arbitrates between multisensory integration and segregation during face-to-face communication. In a spatial localization task, participants saw audiovisual clips of a speaker where voice and bodily cues were sampled from either congruent positions or increasing disparities. We manipulated the pragmatic value of the signals (communicative: direct gaze, head orientation, and speech; noncommunicative: downward gaze and a meaningless vocalization) and quantified audiovisual integration via the ventriloquist effect. Consistent with Bayesian Causal Inference principles, audiovisual integration broke down at higher spatial disparities, where signals are less likely to come from a common source. Remarkably, participants showed a stronger prior tendency to integrate communicative than non-communicative signals. Neurally, this effect emerged not only in early regions of the dorsal visual pathway but also in hMT—a region classically considered a unisensory motion-sensitive area, now implicated in a potential lateral multisensory pathway for social perception. This suggests that from the earliest stages of sensory processing, the brain relies on deeply ingrained prior expectations to bind multisensory signals that carry converging communicative meaning. Our findings provide key insight into the sophisticated, and largely unknown, computational and neural mechanisms underpinning efficient multimodal communication.

Cross-modal serial dependence biases and the modulatory effect of attention and task relevance

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Keywords: Serial dependence, cross, modal biases, vision, audition, perception, audio, visual integration

Serial dependence reflects a ubiquitous bias whereby current percepts are attracted towards past stimuli – that is, a current stimulus appears to be more similar to its preceding one than it actually is. Although serial dependence affects every aspect of perception, whether it could operate across different sensory modalities remains unclear. Here we address the existence of cross-modal serial dependence across vision and audition, and the potential modulatory role of task-relevance and attention. We first used a discrimination task of sequential numerosities, whereby serial dependence

is induced by task-irrelevant “inducer” stimuli. The inducers could be either sequences of tones or visual flashes. Additionally, the task could be either uni-modal (compare two visual sequences) or cross-modal (compare visual and auditory sequences), in separate conditions. The results of the uni-modal task show significant biases from both visual and auditory inducers. In the cross-modal task, however, we observed a suppression of unimodal effects and an enhancement of cross-modal effects. In a second experiment, we presented auditory and visual sequences together, cueing the task-relevant modality in a trial-by-trial fashion. Doing so, we found a strong suppression of the effect from the preceding task-irrelevant modality. These results overall suggest that serial dependence can occur across different sensory modalities, and that the effects are determined by the relevance of signals from different modalities. Our findings thus demonstrate that serial dependence originates at a processing level sufficiently abstract for the effect to transfer across sensory modalities, and that the effect is gated by attention and task relevance.

Talk session 2

Developing a Sensory Representation of an Extra Robotic Body Part

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Keywords: Somatosensory, Somatosensation, Sensory integration, Tactile, perception, Sensory feedback, Artificial feedback, Embodiment, Sensorimotor learning, Wearables, Augmentation, Artificial limbs

Somatosensory feedback is crucial for motor control, yet artificial limbs are thought to lack such feedback. We investigated whether the physical interaction of artificial limbs with the body generates informative sensory signals, and whether such natural feedback can drive a distinct representation of an artificial limb. We examined the perceptual, neural and phenomenological bases of this natural somatosensory representation using a robotic hand augmentation device (‘Third Thumb’; Dani Clode Design). We first compared the perceptual representation of naturally mediated somatosensory signals via the Third Thumb against state-of-the-art artificial touch feedback systems. Across material discrimination tasks, participants performed comparably, or outperformed, with natural feedback, demonstrating versatile and intuitive interpretation of natural sensory signals. To then study the emergence and refinement of the Thumb’s neural representation, we examined representational similarity patterns in primary somatosensory cortex (S1) using fMRI. Even with minimal motor experience to use the Third Thumb, the brain immediately organised tactile input from the Thumb topographically relative to the hand, and distinctively from the palm (where it is attached). Following seven days of Thumb-hand collaboration motor training, this representation refined as it became more similar to the biological fingers. This integration was also reflected in increased subjective somatosensory embodiment post-training. Our findings demonstrate that wearable devices naturally provide a powerful source of behaviourally-relevant feedback, which is immediately integrated with our hand representation. While such a representation is already accessible with minimal experience, motor training contributes to stronger integration and embodiment of the artificial device with our somatosensory body representation.

Embodiment and adaptation to an extendable arm in children and adults

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Keywords: visuomotor, embodiment, virtual reality, movement, kinematics, developmental

Virtual Reality (VR) and motion capture confers the ability to alter multi-sensory experiences of the world and one's own body in an immersive environment. We examined the Go-Go technique, which extends the virtual arm, allowing users to interact with items typically beyond reach. To make successful reaches, the user must adapt to novel multi-sensory pairings between proprioceptive and visual senses. We tested how children and adults adapted to this novel visuo-motor control scheme and how it affected their sense of embodiment. In a first experiment, adults, younger children (5-7 years) and older children (8-10 years) made forward reaching movements to feed a virtual animal. The virtual arm was either slightly reduced (F-, 80%), slightly increased (F+, 120%) or greatly increased (F++, 400%) in terms of its visual gain and functionality. Compared to a baseline condition with no visual gain, only adults in the F++ condition felt a reduced sense of ownership over the virtual hand. In addition, following enhanced 'GoGo' experiences participants of all ages judged they could reach further than at baseline, while these reach affordances were similar under conditions of decreased visual gain. Reach kinematics showed that all ages adapted well to the new arm, increasing reach velocity in the enhanced GoGo conditions while maintaining safely controlled reaches. However, different age groups found specific movement solutions, with children adopting more cautious movements and longer decelerative phases for F++ conditions. In a planned second experiment, a training paradigm will test how adaptation to the Go-Go arm builds over time.

Frequency-tagging EEG reveals crossmodal interactions between visual and somatosensory body maps

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Keywords: EEG, body maps, visuotactile interactions, frequency, tagging, multisensory integration

The brain builds a coherent body representation by integrating multisensory information, in particular visual and somatosensory inputs. Although relevant research suggests that visual and somatosensory body maps are functionally interconnected, the nature of this interaction remains unclear. Here, we employed frequency-tagged EEG to investigate whether visually activating a body representation modulates somatosensory processing. Seventeen adults received periodic tactile stimulation either on the hand or the foot while simultaneously viewing images of hands or feet, all presented at 3Hz. This resulted in four experimental conditions where the visually-activated body map could either be congruent or incongruent with the somatosensory-activated body map. Crucially, when analyzing frequency-tagged responses over somatosensory regions at 3Hz, we found that neural responses differed according to the congruency between the visual- and tactile-activated body maps (Main Effect of Congruency: $F1,17=15.340$, $p=0.002$). In particular, we observed greater responses to tactile stimulation (irrespective of the tactile stimulated body-part) when visual stimuli activated a congruent body part, with responses to touch on the hand being higher when viewing images of hands compared to feet ($p=0.038$), and responses to touch on the foot being higher when viewing images of feet compared to hands ($p=0.030$). Our results confirm the presence of cross-modal interactions between visual and somatosensory body maps. Furthermore, the validation of this paradigm, which

has a high signal-to-noise ratio with a very short stimulus presentation, opens the way to explore the development of visual and somatosensory body maps in infants, providing evidence about when these maps emerge and how they interact during early development.

Aligned representation of visual and tactile motion directions in hMT+/V5 and fronto-parietal regions

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Keywords: Vision, Touch, Motion, Frame of reference, hMT+/V5

Moving events on the skin can be perceived through vision and touch. How does the brain create a unified multisensory representation of motion directions initially acquired in different coordinate systems? We show that the middle occipito-temporal region (hMT+/V5), along with a fronto-parietal network, encodes visual and tactile directions using a common external frame of reference independent of body posture. We characterized brain activity using fMRI in participants exposed to directional visual and tactile motion stimuli across different hand postures. We first demonstrate that individually and functionally defined hMT+/V5 shows univariate preference for both visual and tactile motion and encodes motion directions in distributed activity patterns. Unlike somatosensory regions, information about tactile directions was enhanced in hMT+/V5 when mapped using an external as compared to a somatotopic frame of reference. Crossmodal decoding showed that tactile directions defined using an externally centered coordinate system, but not a somatotopic one, align with the representation of visual directions in hMT+/V5 (both MT and MST). A whole brain searchlight group analysis confirmed these individually defined regions-of-interest results and extended the presence of an aligned visuo-tactile code for directional motion in external space to the parietal and dorsal prefrontal cortex. Our findings reveal a brain network involving hMT+/V5 that encodes motion directions in vision and touch using a common external frame of reference.

The Mario-Cart Effect – Misattribution of Agency in Continuous Control

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Keywords: Sense of Agency, Continuous Tracking, Sensorimotor Control

A Sense of Agency (SoA) connects our intentions and actions to their multisensory consequences and is fundamental for identifying ourselves in our environment. Agency is often differentiated into two levels: a higher, reflective level measurable with explicit reports and a lower, sensorimotor level that is quantified through behavioral correlates. Here we present a novel experimental paradigm to quantify both levels of Agency in continuous sensorimotor control using confusion between multiple agents as a metric. Using a gamepad, participants steered an object on a screen left and right through obstacles moving down towards them. Additional objects controlled by different artificial controllers performed the same task acting as potential confounders. In experiment one, upon a collision of any object with an obstacle participants had to judge, which object they were controlling. In experiment two, objects vanished when they collided. To make their own object reappear, participants had to press a button once they noticed their collision (collision-realization-time). Results from experiment one showed that confusion judgements were influenced by task difficulty but not the presence of confounders. However, we found evidence that alignment between participants' actions and confounders' dynamics drove confusion between them. Initial results from experiment two showed that the collision-realization time varied with the number of confounders, how they were controlled and

their visual similarity to the participant's object. These results align with the comparator-model of Agency underlining the applicability of our approach that measures sensorimotor-level Agency misattribution in behavior.

Talk session 3

Examining the effect of multi-modality perceptual training protocols

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Keywords: Examining the effect of multi, modality perceptual training protocols

Perceptual learning (PL), which enhances sensory processing through practice, reveals plasticity in adulthood. However, prior research has mostly focused on examining PL within sensory modalities, leaving gaps in understanding the interactions between visual PL and auditory PL, and their impact on untrained multisensory tasks. Here, we examined whether and how perceptual plasticity in one modality relates to another, thus testing whether perceptual plasticity abilities are similar across modalities. We examined three groups of young adults who underwent 10 sessions of training and testing (N = 45): (1) auditory training followed by visual training, (2) visual training followed by auditory training, and (3) a control group who trained on an unrelated task. Participants were tested on visual tasks (motion direction task and spatial frequency task), auditory tasks (pseudowords in noise task and frequency discrimination task), cognitive tasks (NIH toolbox), and a multisensory task (McGurk effect), both before and after each type of training. Results revealed significant improvements in both auditory and visual PL for the training groups, whereas no improvement for the control group, illustrating the potential of multimodality training to improve sensory abilities.

Integrators and non-integrators? An exploration of individual differences in multisensory integration.

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Keywords: Audiovisual integration, Localisation task

Humans are generally able to benefit from multiple sensory cues by integrating them, reducing sensory uncertainty. However, this general finding could mask major differences in individuals' performance. In a series of experiments, we studied the ability to integrate familiar and newly learned cues to depth across two sessions. First, we investigated multisensory performance after participants (N=60) learned to use the new cue within a 1hour training session. Half of the participants exhibited a multisensory benefit whereas the other half did not. Repeatability analyses suggest that this was due to variability between, rather than within, participants. Individual-level analyses of eight observers in a longer, 10-12 hours training phase confirmed the existence of individual differences: Half of the participants showed significant multisensory benefits before and after training, whereas the other half was consistently not integrating. Overall, these results showed that multisensory benefits vary from one individual to another, and that these differences seem to persist over time. The varying levels of multisensory benefits in different pairs of cues also hints at substantial intra-individual variability in integration. These two kinds of variability suggest that the ability to optimally integrate multisensory signals may depend on both the individual and the types of cues. We will present preliminary results from a large-N study, in which participants perform a localisation task using multiple audiovisual pairs of cues over two sessions. This study will characterise more precisely the stability and domain-generality of the tendency to integrate multisensory signals, exploring which factors are associated with inter-individual differences.

A New Audio Cue to Object Weight Resembles a Naturalistic Visual Weight Cue During Movement Planning but not During Weight Illusions

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Keywords: perceptual decision making, multisensory perception, perceptual learning, sensory augmentation, size weight illusion

When a person picks up an object, naturalistic cues inform fine motor planning that is reflected in early spikes in force rate changes. Naturalistic cues to weight can also create a multisensory illusion whereby a non-tactile signal to being heavier leads to the object being perceived as lighter – for example, the size-weight illusion. The present study asked to what extent an arbitrary new auditory cue, one that signals object weight, participates in these effects. In Experiment 1, participants used the new audio signal alongside vision to adjust both their peak grip force rates and peak load force rates while lifting an object, consistent with their use for efficient motor planning. In Experiment 2, a new audio cue to heavier weight led to a heavier reported weight – the opposite of a size-weight illusion, and opposite to how the same participants used a naturalistic visual size cue. Thus, while the newly learned audio-weight mapping had similar functional properties to its more familiar visual counterpart, it did not show the same signature of automatic/perceptual processing – instead, it was in the direction of averaging the cues from touch and hearing. These results have implications for understanding the flexible use of new cues and for targeting the underlying mechanisms in order to augment human abilities.

Spatiotemporal Neural Signatures of Multisensory Learning in Perceptual Decision-Making

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Keywords: perceptual learning, multisensory learning, multisensory decision making, EEG, Linear Discriminant Analysis (LDA), neurally informed models, Drift Diffusion Model (DDM), Reinforcement Learning

Converging evidence from neuroimaging and theoretical modelling suggests that perceptual learning involves changes in neural signatures across the decision processing timeline. Here, to dissect the constituent processes and test their dependence on the available sensory information, we designed a multisensory learning task, wherein 22 participants categorised noisy visual (V), auditory (A), or audiovisual (AV) stimuli of faces and cars over three days while undergoing 64- channel Electroencephalography(EEG) recordings. Single-trial Linear Discriminant Analysis(LDA) identified temporally and spatially distinct learning-related components. A and V trials exhibited a single peak (~250- 300ms) localised to occipital regions, indicating that early learning-related changes occur within shared sensory encoding dynamics. In contrast, AV trials demonstrated a bimodal pattern: an early(~150ms) occipital peak aligning with unisensory responses and a later (~400ms) frontoparietal peak. This shift suggests an evolving top-down control mechanism, with multisensory learning first engaging lower-order sensory areas before recruiting higher-order networks for integration and decision-making. Reliable Component Analysis (RCA) confirmed these findings, while functional connectivity and spatial frequency-based analyses further revealed distinct networking dynamics in modality-specific learning, suggesting differential mechanisms of neural adaptation. Crucially, these neural components were behaviorally relevant. Reinforcement learning-based Drift Diffusion Modelling (RLDDM) revealed that identified LDA signatures predicted learning rate on the final day. Neurally-informed HDDM showed that these components modulated the rate of evidence accumulation (drift rate) across days, further linking neural dynamics to the observed behavioural

facilitation of learning. Overall, these findings indicate a hierarchical reorganization in multisensory learning, with sensory-encoding and decision-processing networks dynamically adapting to enhance modality-specific decision-making.

Improving Multisensory Integration in Post-Stroke Hemianopia. Behavioural and Functional Outcomes of VR Audiovisual Training

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Keywords: Hemianopia, Audio, Visual, Neurorehabilitation, Functional Connectivity

Hemianopia following a stroke impairs visual capabilities and everyday activities. Training in audiovisual integration could potentially facilitate rehabilitation. This research examines the impact of a six-week, home-based audiovisual training regimen using virtual reality (VR) on both the behavior and brain function of patients with chronic hemianopia. A group of fifteen patients suffering from long-term hemianopia (more than three months poststroke) participated in an immersive VR-based audiovisual training for six weeks. Evaluations included pre- and post-training MRI scans with task-based and functional connectivity (FC) analyses, alongside behavioral tests to measure visual performance changes. Results from behavioral tests showed notable enhancements in visual performance after the training, evidenced by quicker reaction times. Functional MRI analyses during tasks (active versus resting state) revealed increased activity in crucial areas of the unaffected hemisphere related to visual, auditory, and multisensory processing. Additionally, FC analyses indicated a significant rise in connectivity between areas involved in visual and auditory processing after the training. These outcomes imply that VR audiovisual training promotes neuroplasticity in patients with post-stroke hemianopia, enhancing multisensory processing and visual performance. The alterations in brain activity and connectivity underscore the potential of immersive VR training as a viable rehabilitation method for hemianopia sufferers.

Mirroring the Multisensory Brain. Fine-Tuning Multimodal AI with Human Embeddings

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Keywords: Multimodal AI, Perception, Embeddings, Fine tuning, Multisensory integration

As AI systems evolve, they are increasingly mirroring the inherently multisensory way humans experience the world. Our natural perception seamlessly weaves together diverse sensory inputs to form coherent, meaningful representations. In this study, we investigated how various multimodal AI models, each employing different architectures that integrate sensory modalities at different stages, mimic human sensory processing across modalities. We first evaluated which architectures best capture human behavioral responses to visual and auditory stimuli, along with their neural underpinnings as revealed by fMRI data. We found that architectures such as ONEPEACE, which interlace sensory modalities through self-attention layers throughout the processing stream, achieve better alignment compared to models that combine modalities only at later stages. Building on these findings, we sought to further align the multimodal model with human sensory embeddings while probing for crossmodal effects. To this end, we fine-tuned the multimodal self-attention layers of ONE-PEACE using human visual embeddings, examining whether enhancements in the visual pathway could also drive improvements in auditory alignment. We found that this approach not only improved visual alignment but also led to significant crossmodal improvements in both early and late auditory processing areas, with the greatest enhancements observed in multisensory regions. These findings underscore the potential of designing and finetuning multimodal architectures that mirror the brain's continuous crossmodal interactions. Additionally, using human embeddings to fine tune multimodal

models provides a way to ultimately enhance AI interpretability, especially in situations where data in certain sensory modalities is limited.

Talk session 4

Auditory and tactile processing in the mouse inferior colliculus

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Keywords: Inferior colliculus, Auditory processing, Vibrotactile processing

The inferior colliculus is a crucial auditory midbrain processing center. In addition to auditory inputs, the lateral cortex of the inferior colliculus (ICx) also receives non-auditory input in an organized fashion. Previous literature shows several somatosensory regions form direct input connections with the ICx; and peripheral stimuli such as whisker stimulation have been found to elicit responses in the ICx. Moreover, somatosensory stimuli can modulate sound-evoked responses in both awake and anesthetized animals. Recently, a candidate pathway relaying tactile input originating at the paws to the ICx was discovered, raising the question how the ICx responds to vibrotactile stimuli and what their influence on sound-evoked responses might be. In vivo electrophysiological recordings were done in the mouse ICx using multielectrode silicon probes. Anesthetized animals were presented with a variety of stimuli including auditory stimuli (pure tones, white noise, and amplitude modulated noise) and tactile stimuli (pressure and vibrations delivered to the hind paw), both separately and simultaneously. Preliminary data show that a subset of units encode the on- and offset of continuous pressure stimuli. An overlapping group responds to low frequency (10-50Hz) sinusoidal vibrotactile stimuli in a phase specific manner as well as to the on- and offset of higher frequency (100-400Hz) vibrations. When paired with broadband noise, the cyclic response to the vibrotactile stimuli attenuated but the firing rate during this period remained elevated compared to broadband noise alone. This shows that (vibro)tactile stimuli alone can drive neural activity in the ICx while also modulating ongoing sound-evoked responses.

Neural bases of haptic enhancement of speech comprehension in a multi-talker scenario

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Keywords: Multitalker, Multisensory, Audiotactile, Haptic, Speech Perception, Speech, In, Noise

Understanding speech in the presence of multiple talkers is challenging. In such adverse auditory scenes, rhythmic, suprasegmental speech cues can be extracted and transmitted haptically, improving intelligibility. Whether this enhancement relies on auditory cortices' improved synchronization with the attended speech stream (cortical tracking of speech, CTS) and their strengthened coupling with multisensory areas–as demonstrated for audio-visual speech–remains unknown. Here, magnetoencephalographic data from 30 normal-hearing listeners was recorded while they attended to naturalistic, connected speech presented in quiet or embedded in multi-talker noise. Speech was presented either unimodally (audio-only, A) or bimodally, with two types of supplemental non-auditory input: speech-derived vibrations (audio-tactile, AT) or the original video of the speaker's face (audio-visual, AV). In AT conditions, vibrations were transmitted to the participants' left palm in congruence (ATc) or incongruently (ATi) with the speech signal. Across conditions, comprehension was assessed using yes/no questions, while CTS was quantified through speech-brain coherence at

phrasal (0.2–1.5 Hz) and syllabic (2–8 Hz) levels. Comprehension in multi-talker noise significantly improved in ATc conditions (vs. A), which corresponded to enhanced syllabic CTS at the right supratemporal cortex. This improvement was associated with increased functional connectivity from this region to the right angular and inferior temporal gyri, alongside reduced connectivity with the precuneus. These findings underscore the crucial role of syllabic CTS in speech comprehension and reveal that, in multi-talker conditions, speech-based haptic input not only enhances CTS of attended speech but also promotes broader synchronization with high-level, multisensory areas previously implicated in semantic processing.

Dynamic interaction between active and passive movement and temporal perception in childhood

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Keywords: development, movement, audio, tactile, TOJ, children

The ability to accurately perceive the temporal relationship between sensory stimuli is essential for multisensory integration and interaction with the environment. In adults, temporal precision during an audio-tactile temporal order judgment task (TOJ) is improved during active movements compared to static and passive conditions, suggesting that voluntary actions enhance audio-tactile temporal integration and temporal resolution. However, it remains unclear whether the same enhancement occurs in children and how it develops. Here, we investigated differences in temporal perception between active and passive movements during development. We collected behavioral data with an audio-tactile TOJ task in 87 blindfolded children (ages 6–11) while they moved their arm either actively or passively, and in the static condition. Two stimuli, one auditory and one tactile, were provided on the hand, and participants had to evaluate which one arrived first. We observed that temporal precision (i.e., Just Notable Difference - JND) during active movement is higher than in the passive condition only in younger children (6 age-years-old). This difference disappears with age, with the JND in the passive condition decreasing. We did not observe any difference between the static and active conditions. These data suggest that in younger children, the predictive sensorimotor feedback of the active condition might support time estimation during movement, as compensatory strategy to maintain stability in a developing sensory system. However, this fades around 7 years since sensory-motor signals refine. Literature data suggest that this effect then reappears in adulthood, indicating a dynamic interaction between sensorimotor maturation and temporal perception development.

Auditory parsing. The effect of head movement on the perceived direction of a moving sound source

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Keywords: audition, auditory motion, head movements, vestibular system, proprioception, speed processing

The movement of moving objects seen during self-motion is incorrectly perceived as a result of errors in parsing the visual motion arising from the two sources (Warren et al. 2009). The perception of motion in audition appears to be more complex than in vision, as previous research suggests that the auditory system lacks dedicated low-level speed-processing mechanisms. This study investigates how the perception of a moving auditory sound source is influenced by concurrent head movements,

drawing comparisons with established visual motion perception findings and illusions, such as the Filehne Illusion. Participants were asked to move their heads at a fixed speed, either horizontally (left to right or right to left) or vertically (up to down or down to up), while indicating the perceived direction of a moving sound source using a joystick. Physical sound sources were moved silently with constant speed in fronto-parallel 2D space using a 3x3x3m cable robot. Results showed that head movements created a perceptual bias of the moving sound source in the opposite direction to the head movement. The magnitude of the illusory shift varied depending on the direction of head movement but remained consistent across horizontal and vertical movements. These findings suggest that similarly to how visual motion perception is distorted by extraretinal signals and the movement of the eyes, so too is auditory motion perception influenced by movement of the ears, integrating proprioceptive, vestibular and auditory cues to distort the perceived direction and speed of a moving sound source.

Saccadic Eye Movements Alter Auditory and Tactile Time

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Keywords: saccades, audition, touch, temporal, apparent motion, oculomotor actions

Perception and action are inherently intertwined. Saccadic eye movements influence the visual perception of time, space, number, and motion. These features are distinctly multimodal and can be experienced through various senses, raising the possibility that distortions linked to saccades are not confined to visual perception. We investigated whether eye movements affect the perceived timing of auditory and tactile stimuli. Participants judged the spatiotemporal order of pairs of auditory and tactile stimuli presented sequentially, one on each side while simultaneously making saccades towards a target stimulus that moved from one side of a distant screen to the other every four seconds. They tended to perceive the spatiotemporal order of auditory and tactile stimulus pairs as reversed for stimuli presented around the onset of a saccade but not for those presented at other times, or those combined with a verbal task. The saccadic suppression effect also emerged for tactile stimulus pairs that elicited apparent radial rather than horizontal motion. Additionally, in a stationary fixation task, auditory and tactile spatiotemporal perception was distorted around the onset of microsaccades – tiny involuntary saccades observers were not aware of. These effects of ballistic eye movements on auditory and tactile perception align with reports of saccadic suppression effects in multisensory areas, specifically the superior colliculus and the intraparietal sulcus, and reveal cross-modal links between action and perception.

Multisensory Perception in Congenitally Hearing Impaired. tactile cues for enhanced performance

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Keywords: Audio, Tactile, Hearing impaired, Sensory loss, Multisensory sensory binding, Spatial perception

We investigate various perceptual and multisensory aspects in congenitally hearing impaired adults. In particular we consider the impact of integrating tactile feedback into auditory experiences. We combine our tactile device that translates spatialized auditory cues into vibrations on the fingertips, using intensity-weighted level mapping across four actuators with Higher-Order Ambisonics, enabling precise 3D presentation through both audio and haptics. Using this setup, we examine spatial motion perception, orientation confusions, audio-tactile binding in complex environments and music enjoyment. While hearing-impaired participants exhibit severely reduced auditory spatial tracking, their tactile spatial motion perception was comparable to that of typically hearing individuals. Combined audio-tactile capabilities showed similar results. Auditory direction reversals, which are quite common, also show significant improvement when tactile feedback is provided. Moreover, the group demonstrates immediate audio-tactile binding in complex auditory scenes containing multiple

spatially moving sound sources, with rapid improvement despite no training. Music enjoyment was also enhanced in almost all participants. These findings highlight the amodal nature of multiple capabilities and experiences normally associated with auditory perception. They further contribute to the ongoing discourse of nature versus nurture in sensory development, suggesting that an external 3D spatial understanding can emerge even in the absence of auditory experience. Regardless of auditory deprivation and spatial hearing in particular, the ability to acquire externalized spatial information through touch challenges the notion of strict modality dependence during critical periods. These insights have significant implications for multisensory rehabilitation, assistive technology, and our broader understanding of crossmodal plasticity.

Talk session 5

Supranormal 6th, proprioceptive sense in legally-blind individuals with residual vision

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Keywords: Human, Visual impairment, Proprioception, Kinesthesia, Laterality, Metacognition, Residual vision, Sensory recalibration, Blindness

Previous research on sensory changes in blindness has led to two competing hypotheses. On one hand, the *cross-modal compensation* hypothesis suggests that a visual impairment results in enhanced perceptual processing in other modalities, potentially leading to improved proprioception in blind individuals. On the other hand, given the critical role of vision in calibrating non-visual senses, the *general-loss hypothesis* suggests that proprioception may be impaired without visual calibration. To directly address these views, we assessed proprioceptive perception using an ipsilateral passive matching task (Abi Chebel et al., 2022,2023) in two groups of blind (n = 31) and matched sighted individuals (n = 31) who were blindfolded. Results revealed that proprioception is most accurate in individuals who are considered legally blind but have some limited residual vision. Such supranormal proprioceptive acuity was found at both the elbow and wrist joints for both the preferred and non-preferred arms. We also found a mismatch between metacognitive judgments and actual proprioceptive performance in both blind and sighted individuals. The finding that proprioception is supranormal in blind individuals with residual vision but not in totally blind individuals highlights how visual experience critically tunes proprioception. Overall, our findings provide novel insights into the specificity of cross-modal recalibration principles. Moreover, the observed discrepancy between self-evaluated and actual performance leads to a new theoretical, four-layer model of proprioceptive function.

Sleep, Plasticity, and Sensorimotor Development in Blind and Sighted Infants

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Keywords: Sleep, EEG, spindles, blindness, children, infants, audio, tactile

Sleep has gained increasing interest in recent years, but remains undervalued in vulnerable populations, such as children with visual impairments. Therefore, in a first study, we examined sleep macro- and microstructure in 64 sighted and 50 severely visual impaired (SVI) children (5 months to 6 years), to explore how blindness affects the development of brain structures involved in sleep. We hypothesized that blindness induces plastic reorganization, influencing sleep spindles maturation. Results showed that SVI children lacked the typical age-related evolution of fast spindles, which are linked to sensorimotor performance, while slow spindles, associated with general cognitive abilities, remained similar across groups. In the SVI group, spectral fast-spindle activity correlated with clinical indices predicting perceptual and motor disorders. Our findings suggest that fast spindles are pivotal biomarkers of developmental deviations in SVI children and anticipates evidence of brain plasticity in sleep processes due to blindness. To better characterized this plastic role, we explored whether sensory experiences are consolidated differently during sleep in SVI and sighted infants. We recorded video-EEG in 7 sighted and 7 SVI infants during auditory and tactile hand stimulations before and after a 50-minute nap. Preliminary results revealed group-specific EEG spectral modulation in post-nap session: the SVI group showed modulation in the tactile condition, while the sighted group exhibited modulation in the auditory condition. These findings suggest that sleep preferentially

consolidates tactile information in blind children and auditory information in sighted children. The discussion will address how sensory deprivation shapes brain plasticity and affects daily performance.

Temporal dynamics of sound representation in the brain of sighted and blind

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Keywords: Congenital Blindness, Sound Processing and Categorization, EEG, Mutivariate Pattern Analysis, Acoustic, to, categorical transformation, Deep Neural Network

Early blindness triggers a reorganization in brain networks supporting sound processing. How the temporal dynamics of auditory representations are impacted by visual deprivation remain however unknown. Using time-resolved multivariate pattern analyses applied to electroencephalic recordings (EEG), we reveal how blindness impacts the cascade of acoustic to semantic coding of natural sounds. Decoding analyses revealed a protracted enhancement of sound representation in congenitally blind (CB) in comparison to matched sighted controls (SC), predominantly localized to occipito-temporal regions. We then contrasted the ability of acoustic, categorical, behavioral, linguistic and sound-to-event deep neural network (DNN) representational models to predict neural responses to different sounds. We first show that models of early acoustic processes explained brain representations early in time with no differences between the two groups. Correlations between neural activity and some layers of DNN were enhanced in CB around ~200 ms after sound offset, likely representing modulations in intermediate acoustic processing that mostly mapped onto temporo-frontal regions. The categorical and behavioral representation of sounds were also enhanced in CB, peaking at 600 ms, and mostly mapped onto occipito-temporal regions. Finally, linguistic models peaked later in EB (around 1 sec) with no group differences observed. These results reveal that blindness triggers a selective reorganization of certain sound representations at specific timing of information processing, and mapping on to specific brain regions over time. This particular pattern of reorganization in brain networks coding for natural sounds in CB provides new insights on the reorganized dynamics of sound processing in absence of sight.

Neuroplasticity in a rod-only visual system receiving cone rescuing gene therapy

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Keywords: vision, sight rescue, plasticity, psychophysics, MRI, colour vision

Recent advances in cell- and gene-therapies offer the potential to halt or reverse vision loss, but understanding how rescued retinal signals integrate into developing brain function remains crucial. One promising treatment targets achromatopsia, a congenital condition causing cone dysfunction. In a typically developing brain, cones mediate fast, chromatic vision and provide all foveal input. As part of pioneering gene therapy trials, we measured cone recovery in seven children (ages 8–16) with achromatopsia. This provides a unique opportunity to explore how early experience shapes neural specialization for rod-vs. cone-mediated vision. Using photoreceptor-specific pRF mapping (fMRI), in the majority of the patients we found robust and consistent cone-mediated signals in the visual cortex after treatment—signals that were absent before. Crucially, patients could now detect cone-selective

stimuli previously invisible to them. In two patients, we used high-precision psychophysics to determine which new visual functions the rescued retinal signals could support, focusing on cone-specific functions not available through rod-only vision: high-speed, foveal, and chromatic (colour) vision. Visual processing speed improved substantially post-treatment. However, foveal cortex showed limited cone function, consistent with prior reports of inconsistent acuity benefits. Several complementary tests for colour vision (lvvCCT, Ishihara, Rayleigh, Stockman) revealed different recovery patterns and perceptual experiences across the two patients. Together this work provides novel insights into how a brain that has developed and organised with one set of retinal signals (rods) can incorporate a whole new parallel set of signals (cones) into its existing structures, and which novel functions can be restored.

Ultra-high-field fMRI (7T) reveals layer-depending feedforward auditory motion processing in the hMT V5 of blind people

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Keywords: Crossmodal, Plasticity blindness motion 7t fMRI layers multisensory

The hMT+/V5, a region long thought to be specialized in visual motion, also responds to auditory motion in sighted and even more so in congenitally blind people. However, the mechanisms behind auditory motion information transfer to the "visual" motion area in sighted and congenitally blind individuals remain unknown. In this study, we characterized submillimeter activity in hMT+/V5 using ultra-high-field fMRI (7T) coupled with BOLD and VASO acquisition while sighted and congenitally blind processed visual and auditory motion information. More precisely, we inferred whether crossmodal motion-related information is processed through feedforward or feedback pathways by identifying circuitry from layerdependent activity of hMT+/V5. Our study reveals that in sighted individuals, visual motion elicits a predominantly feedforward response within hMT+/V5, consistent with its role in the early visual motion processing. Interestingly, in congenitally blind individuals, we observe a similar feedforward response pattern for auditory motion, suggesting that in the absence of vision, auditory inputs engage hMT+/V5 in a manner analogous to visual motion processing for sighted individuals. These findings indicate that hMT+/V5 maintains a feedforward processing profile for motion despite crossmodal plasticity, with its sensory input shifting from vision to audition in the absence of early visual experience.

How Visual Experience Alters Cortical Myelination of The Visual Cortex. Insights from Combined 3T and 7T MRI Studies

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Keywords: Blindness, Cross, modal plasticity, Cortical Layers, 7T, Myelin

How does sensory experience shape the fine-grained structure of brain regions? Investigating how regions typically supporting vision reorganize their circuits in congenitally blind individuals provides compelling information on the role sensory experience plays in shaping brain structures. One potential biological mechanism that modulates regional information exchange and circuit complexity is myelin. Here, we investigate how the lack of visual experience impacts the fine-grained structure of the visual cortex. We combine two MRI datasets acquired at 3T and 7T in congenitally blind and matched sighted subjects to map cortical tissue properties using T1w/T2w ratio at the whole-brain level (3T) and quantitative T1 relaxation at the layer level in the occipitotemporal cortex (7T). We show that while whole-brain myelin maps between blind and sighted subjects look remarkably similar, blindness nevertheless triggers a reduction in myelination throughout the occipitotemporal cortex. Despite this reduction, our 7T data reveal that the layer distribution and the gradient in myelin content across occipital regions are preserved in blind people. These results show that while the 'global' cortical myelin might be impacted by the lack of visual experience during development, 'local' gradients within and across regions are retained, suggesting an interplay between hardcoded and plastic aspects of human brain structure.

Talk session 6

The balance between clashing visual and idiothetic cues during path integration with redirected walking

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Keywords: Path integration, Redirected walking, VR, Triangle completion, Multisensory integration

As we walk we perceive our motion by external channels such as vision, and by internal ones such as vestibular and proprioceptive. But what happens when these two channels offer contradicting information? Previous work has shown that by manipulating visual gain during movement the user's path can be redirected, a procedure known as redirected walking. While the dominance of visual cues on the immediate path has been well demonstrated, potential residual effects of the internal senses on path integration have not been well quantified - will it disrupt participant's visual answer or even bias it towards the correct answer by internal cues? Here, we use the classic triangle completion task with immersive virtual reality and redirected walking to quantify this balance and test for accuracy in the visual reference frame and residual idiothetic effects. We find that as expected vision dominates participants' conscious perception, and that accuracy within the idiothetic reference frame is low compared to the control of performing the tasks without redirection and is modulated by the level of redirected gain. We find a strong indication for stable individual differences in reliance on visual input across gain levels. Additionally, we observed a relation between the perceived difficulty of navigation, and reliance on the idiothetic sensory channels. These findings offer insight into the basic science of human navigation and multisensory integration, and hold potential for practical applications in virtual environment design and locomotion with redirected walking.

Egocentric navigation network plasticity training extends functional connectivity of the dorsal stream to frontal areas of congenitally blind people

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Keywords: brain plasticity, sensory substitution device, connectivity, navigation, sensory deprivation, sensory training

We demonstrated that area V6, a retinotopically organized visual area located in the visual dorsal stream, is subjected to cross-modal reassignment plasticity. After a short training with the EyeCane sensory substitution device, area V6 of congenitally blind (CB) responds to auditory cue for egocentric navigation. Here we explored the functional connectivity plasticity of the visual dorsal stream. Resting state connectivity was used to investigate training induced brain connectivity changes in CB participants. CB participants were scanned during resting state sessions before and after the three-day training period. ROI-to-ROI analysis shows that training increased positive connectivity between the dorsal-stream and dorso-lateral-prefrontal (DLPFC) and anterior cingulate-prefrontal areas, while a negative connectivity between the dorsal-stream and medio temporal areas. Moreover, taking the hippocampus as seed, we found increased positive connectivity after training within areas of the medio-temporal lobe and anterior-cingulate prefrontal network, while negative connectivity with areas of the visual dorsal network and the DLPFC network. These newly established connections suggest increased training dependent neuroplasticity that may underlie the long-term plasticity observed in area V6 for processing auditory navigation cues, reflecting neural adaptation following training with the EyeCane. Our results show that navigation training can alter connectivity and induce long term plasticity between different networks. The increased neuroplasticity triggered by training the dorsal stream might serve as a potential strategy to mitigate cognitive decline, especially for Alzheimer research since degeneration affects mainly the navigation network until reaching frontal areas.

Vestibular Contributions to Sensory Predictive Mechanisms

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Keywords: Vestibular system, Sensory attenuation, Sensorimotor prediction, Galvanic Vestibular Stimulation, Multisensory integration

The vestibular system, traditionally associated with balance, is increasingly recognized as a key player in sensorimotor prediction. This study examines its role in sensory attenuation (SA)—a predictive mechanism that reduces the perceived intensity of selfproduced stimuli, aiding in the differentiation between self-generated and external sensory events. Using stochastic Galvanic Vestibular Stimulation (sGVS), a non-invasive method that disrupts vestibular processing, we tested its effects on an auditory comparison task. Participants judged the loudness of tones in two conditions: active (self-generated) and passive (externally generated), while receiving either sGVS or SHAM stimulation. Under SHAM, participants exhibited robust SA, perceiving externally generated tones as louder than self-generated ones. However, during sGVS, this effect was abolished, indicating that vestibular disruption impaired the brain's ability to predict and attenuate self-induced sensory consequences. These findings demonstrate that vestibular inputs are integral to predictive sensory mechanisms and that their disruption compromises sensory discrimination between self- and externally-generated stimuli.

Increase in visual reliability enhances judgements of audiovisual motion direction

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Keywords: Motion, MLE, Modality appropriateness, Attention, Individual variability

The ability to perceive and respond to multisensory motion cues is essential for survival. However, it remains unclear whether naturalistic motion perception relies on a statistically optimal integration of both auditory and visual motion, and how much each modality contributes to a unified motion percept. Here, we explore the combination of auditory and visual motion information under auditory-cued, visual-cued, and audiovisual-cued multisensory conditions using random dot kinematograms and amplitude-modulated broadband white noise. Using a 2-AFC task, participants (n=50) reported motion direction across varying levels of motion strength, allowing us to extract sensitivity to changes in motion direction. By comparing sensitivities across different cueing conditions, we found multisensory motion provides different levels of behavioral benefit depending on the sensory modality cued. Using maximum likelihood estimation, we examined the relative reliabilities of the auditory and visual motion information and found subjects rarely equally weigh both, with performance showing large heterogeneity. These relative reliabilities were predictive of multisensory performance across different cued conditions; vision provides more reliable motion information (JND=2.2, p=0.001), and visual bias, or an increase in visual reliability relative to auditory reliability, increases motion direction sensitivity in our task (p=0.0205). Our results support that humans perform statistically optimal, but visually biased, judgments on motion direction. This work will guide future neurophysiological studies on the behavioral and neural correlates of audiovisual motion perception in humans and nonhuman primates as well as enhancing perceptual quality in immersive environments.

The ontogenesis of socio-affective touch perception. Assessing valence and inferring relationships from observed tactile interactions.

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Keywords: Social touch, Development, Social cognition

Social touch is a very powerful means of communication and is particularly effective in providing information about social dispositions and affiliative relationships. Children can discriminate tactile stimulation with key social properties, such as strokes at CT-optimal speed. Yet, the ontogenesis of social inferences based on observing socio-affective touch is largely unknown. To fill this gap, 108 three to five year-old children (36/age-group) were tested on their capacity to draw inferences from observing tactile interactions between two individuals. More specifically, children were tested on three complementary tasks. Children rated the valence of a range of common socio-tactile behaviours (task 1). Children observed social touch varying in speed — CT-optimal touch, 6cm/s vs. CT-suboptimal touch, 18cm/s; and had to assess the valence of these observed tactile interactions (task 2); Finally, children had to infer affiliative relationships between two characters upon different tactile interactions (task 3). Overall, results showed that children as young as 3 years of age were able to appropriately rate the valence of common tactile interactions upon their observation (task 1), but also coherently distinguish tactile interactions based on their speed: rating CToptimal touch as nicer than CT-suboptimal touch (task 2). In contrast, only 5-year-olds succeeded in the inference task (task 3), suggesting a developmental dissociation between the ability to infer an affiliation relationship and the ability to assess the valence of observed tactile interactions, especially based on speed. The present study highlights the central role of actual but also vicarious touch in infants' socio-cognitive development.

Seeing the invisible. Crossmodal priming of images removed from awareness by continuous flash suppression

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Keywords: Visual suppression, Crossmodal priming

When the eyes view separate, incompatible images, the brain suppresses one of the images so that only the other is perceived. This interocular suppression can be prolonged by presenting a dynamic stimulus to one eye, resulting in continuous suppression of the other image. To index suppression strength, the contrast of the suppressed image is ramped up until it breaks into awareness. Using real-world images, we tested whether adding sounds that were either congruent or incongruent with the visual scene would alter the breakthrough threshold. This kind of high-level, semantic priming revealed no effect of congruency and no difference between bimodal and vision-only conditions, indicating no high-level crossmodal priming of visually suppressed images. Similar experiments involving suppression of low-level visual features (orientation and temporal frequency) did show crossmodal priming when paired with a tactile orientation or an auditory modulation. Because interocular suppression is thought to occur in primary visual cortex, the finding that visual features such as orientation and temporal frequency break into vision at lower contrast when primed with congruent crossmodal stimuli points to the presence of effective multisensory interactions at very early stages of cortical processing.

Talk session 7

Unpredictable Temporal Sequences Boost Multisensory Integration. Evidence from the Ventriloquism Effect and the Rubber Hand Illusion

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Keywords: Multisensory integration, Predictability, Ventriloquism, Touch, Body, Rubber hand illusion

In natural environments, sensory signals typically occur as continuous streams rather than isolated events; for example, during speech perception, auditory and visual cues (e.g., lip movements) evolve dynamically over time. Yet, research has focused on single bimodal events and largely overlooked the temporal dynamics of stimulus sequences. Multisensory integration may also be modulated by temporal predictability within such sequences: synchronous, bimodal input streams may be integrated more strongly when their temporal pattern is unpredictable, as their co-occurrence is unlikely to result from independent sources. Here, we assessed perceptual spatial attraction via the ventriloquism effect in visual-auditory (Experiment 1, N=45) and visual-tactile pairings (Experiment 2, N=45). Moreover, we assessed visual-proprioceptive recalibration ('proprioceptive drift') and body ownership in the rubber hand illusion (RHI, Experiment 3, N=45). In all experiments, stimuli were presented in either predictable or unpredictable temporal sequences (5s duration in Experiment 1 and 2, and 30s in Experiment 3). The ventriloquism effect was larger when sequences were unpredictable, indicating stronger multisensory integration, for both modality pairings. In the RHI, unpredictability significantly increased body ownership. Overall, our findings demonstrate that predictability affects the integration of simultaneous bimodal stimulus sequences. Stronger integration of unpredictable sequences suggests that the brain maintains expectations about the likelihood of the coupling between multisensory stimuli. The notion that unpredictable but temporally aligned streams originate from a common source may reflect an internalized representation of environmental regularities, shaped by lifelong sensory experience.

Using Deep Neural Networks to Study the McGurk Effect

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Keywords: Audiovisual, Speech, Incongruent, Illusion

A deep neural network (DNN) known as AVHuBERT is able to transcribe audiovisual speech with high accuracy, suggesting that it may be a useful model for human speech perception. If AVHuBERT is an accurate model of human perception, it should share human susceptibility to audiovisual speech illusions such as the McGurk effect, in which incongruent auditory and visual syllables are perceived as a third syllable. Different human observers vary greatly in their perception of the illusion but, across observers, adding auditory noise strengthens the illusion. To assess these properties, multiple variants of AVHuBERT were created by adding Gaussian noise to the weights of the fully connected layers in the first six transformer encoder blocks. Then, the multiple AVHuBERT variants were presented with twenty different McGurk stimuli with and without added auditory noise. There was high variability across model variants, with the illusory percept represented on about one-third of trials, matching the rates for human participants presented with the same stimuli. Adding auditory noise increased the strength of the McGurk effect across model variants, with higher noise levels resulting in more McGurk responses, as in human observers. A non-McGurk incongruent syllable pairing (auditory “ba” and visual “fa”) frequently resulted in visual dominant (“fa”) responses in AVHuBERT variants, as it did in humans. Similarities between the responses of AVHuBERT and humans to incongruent audiovisual speech, including the McGurk effect, suggests that DNNs may be a useful tool for interrogating the perceptual and neural mechanisms of human audiovisual speech perception.

A Stimulus-Computable Model for Audiovisual Perception and Spatial Orienting in Mammals

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Keywords: Audiovisual, modelling, humans, monkeys, rats, psychophysics, eye, tracking, time, space

Despite recent progress in multisensory research, the absence of stimulus-computable perceptual models fundamentally limits our understanding of how the brain extracts and combines task-relevant cues from the continuous flow of natural multisensory stimuli. In previous research, we demonstrated that a correlation detector initially proposed for insect motion vision can predict the temporal integration of minimalistic audiovisual signals. Here, we demonstrate how a population of such units can process natural audiovisual stimuli and accurately account for human, monkey, and rat behaviour, across simulations of 69 classic psychophysical, eye-tracking, and pharmacological experiments. Given only the raw audiovisual stimuli (i.e., real-life footage) as input, our population model could replicate observed responses with an average correlation exceeding 0.97. Despite relying on as few as 0 to 4 free parameters, our population model provides an end-to-end account of audiovisual integration in mammals—from individual pixels and audio samples to behavioural responses. Remarkably, the population response to natural audiovisual scenes generates saliency maps that predict spontaneous gaze direction, Bayesian causal inference, and a variety of previously reported multisensory illusions. This study demonstrates that the integration of audiovisual stimuli, regardless of their complexity, can be accounted for in terms of elementary joint analyses of luminance and sound level. Beyond advancing our understanding of the computational principles underlying multisensory integration in mammals, this model provides a bio-inspired, general-purpose solution for multimodal machine perception.

Multisensory integration of auditory and visual speech in the human superior temporal sulcus revealed with stereoelectroncephalography

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Keywords: Audiovisual, Speech, sEEG, Faces, Voices

Human speech perception is multisensory, integrating auditory information from the talker's voice with visual information from the talker's face. Studies of the neural basis of speech perception have implicated the superior temporal gyrus (STG) in auditory speech processing and the superior temporal sulcus (STS) in audiovisual integration. An especially revealing experimental technique has been electrocorticography (ECoG), in which electrodes placed on the surface of the cerebral cortex in neurosurgical patients record neural activity with high spatial and temporal resolution. Unfortunately, the STS is inaccessible with ECoG, leading to a paucity of knowledge about audiovisual integration. Recently, clinical practice has transitioned to stereoelectroencephalograpy (sEEG) electrodes that penetrate the cortex. We used sEEG electrodes to record from the STS and the STG during presentation of faces and voices with or without added auditory noise. A subpopulation of STS electrodes responded to both faces and voices with short-latency responses (100 ms for faces and 75 ms for voices). The STS exhibited responses predicted by multisensory theory, including larger and faster responses to multisensory compared with unisensory speech and nonlinear interactions between modalities. Across measures, multisensory benefit was significantly greater in the STS than the STG, supporting a key role for the STS in audiovisual integration during speech perception. A phonetic encoding model demonstrated bimodal STS and STG electrodes were selective for specific speech features, with enhanced selectivity for audiovisual speech. More accurate representations of phonetic features in superior temporal cortex are a potential neural mechanism for the perceptual benefits of audiovisual speech.

Topographic organization of auditory inputs to the mouse visual cortex

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Keywords: Audiovisual, Spatial, Sensory processing, Auditory cortex, Visual cortex

Sensory cortical areas primarily process information from their respective modalities but also receive cross-modal inputs, enabling multisensory integration and a unified representation of the external world. However, the organizational principles underlying these extensive cross-modal connections remain poorly understood. In this study, we investigated the anatomical and functional organisation of auditory cortex inputs in the visual cortex and examined whether they align with the organisational principles of the visual system. We found that distinct populations of auditory cortex neurons project to different visual cortical areas, segregating according to the dorsal and ventral visual processing streams. Notably, auditory cortex inputs to the visual cortex maintained an ordered projection pattern along the anterior-posterior cortical axis. Paradoxically, sound frequency information was homogeneously represented across the visual cortex, contrary to predictions based on the tonotopic organization of the auditory cortex. Instead, we found that sound location information was differentially broadcasted across the visual cortex. Specifically, sound azimuth and elevation were differentially encoded across visual cortical areas and streams. Furthermore, sound elevation was biased towards the retinotopic elevation of the higher visual areas innervated. These findings suggest that multisensory cortical projections are not only functionally segregated but also topographically aligned with the organisational principles of the target sensory area, ensuring spatially coherent integration of auditory and visual signals.

The Neuronal Mechanisms of Audiovisual Temporal Processing and Perception. How Parvalbumin-Expressing Interneurons Fine-Tine the Integration of Sensory Integration

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Keywords: Temporal perception, Interneurons, Rat, Optogenetics, Audiovisual integration

Our perception of ongoing events often relies on our brain's ability to integrate closely-timed auditory and visual information into a unified percept; a phenomenon linked to GABAergic neurotransmission within the audiovisual cortex. At present, however, the specific contribution of the various inhibitory neuron subtypes toward fine-tuning audiovisual perception remains elusive. In the present study, we used a transgenic rat model to investigate the causal role parvalbumin-expressing (PV) interneurons play in the integration and perception of audiovisual stimuli. In anesthetized rats, we (1) performed optogenetic photo-tagging to profile how PV interneurons respond to closely-timed auditory and visual stimuli, and (2) recorded the consequence of optogenetically silencing PV interneurons on the residual neuronal spiking activity in the audiovisual cortex. Although PV interneurons responded to both sensory modalities, unlike their non-PV neighbours, they did not integrate the audiovisual information at the single-neuron level. Moreover, optogenetic silencing of PV interneurons revealed a modality-specific effect on the residual neuron population; i.e., auditory- but not visual-evoked responsiveness was dramatically increased, ultimately causing impairments in temporal processing and multisensory integration. Consistent with these neuronal results, when PV interneurons were optogenetically silenced during an audiovisual temporal order judgement task, the rats' perception shifted, such that simultaneously-presented auditory and visual stimuli were now more often perceived as if the visual stimulus had been presented first in the pairing. Ultimately, by revealing the contribution of PV interneurons toward audiovisual integration, we have gained some mechanistic insight into how a unified percept emerges from closely-timed auditory and visual events.

Talk session 8

From Womb to World. Mapping Auditory and Crossmodal Learning in Adults and Newborns

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Keywords: Prenatal learning, Crossmodal learning, Neural entrainment, Auditory, Somatosensory

Human fetuses are exposed to auditory stimuli during gestation, shaping postnatal discrimination abilities. Sparse findings suggest that newborns can recognize maternal voice, native language and melodies to which they were exposed in the womb, by employing indirect measures. Here, we investigate how prenatal experience directly shapes unimodal and crossmodal learning using EEG-based neural entrainment. In adults, two between-subject groups were tested (N = 15 per group): one trained with an ascending melody and another group trained with a descending melody for 30 days before EEG testing. EEG responses were recorded using a 64-channel BrainAmp system while participants listened to both melodies and a vibrotactile version of the ascending melody. Data were analyzed using forward modeling with the multivariate temporal response function (mTRF) toolbox. Newborn data collection (that is still ongoing) follows the same paradigm: prenatal exposure starting from the 34th gestational week and postnatal EEG testing within 72 hours of birth. Here, we present only adults' data, but also newborn data will be presented at the time of the conference. In adults, cluster-based permutation testing ($p_{clust}<0.05$ corrected) showed greater TRFs for the trained melody, independently of the specific melody learned. Crossmodal results mirrored auditory findings, with stronger TRFs for the vibrotactile version of the trained melody ($p_{clust}<0.05$ corrected). These

findings demonstrate that adult auditory learning is measurable through neural entrainment and extends crossmodally. If confirmed in newborns, similar results will provide direct evidence of the role of prenatal sensory experiences in shaping intramodal and crossmodal learning in postnatal life.

Movement-dependent modulation of Multisensory Integration early in life. A combined EEG and kinematic study in newborns

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Keywords: Multisensory Integration, Newborn, Motor Development, EEG, Kinematics

When we observe freely moving newborns, we may notice that, among their spontaneous movements, self-directed ones are the most frequent. Influential accounts have pioneeringly hypothesized a crucial role of early self-exploratory movements in shaping a primitive bodily-self representation (Rochat et al., 2001). Indeed, self-directed movements may foster the observation of multisensory contingencies converging on one's own body, thus being at the origin of an early sense of self. Against this background, the present study aimed (1) to quantify the newborns' engagement in self-directed behavior and (2) to verify whether multisensory integration is enhanced following self- then externally-directed movements. To these aims, we recruited 30 (9-65 hours old) newborns and recorded (1) their kinematics during spontaneous movement and (2) their EEG responses to unimodal (tactile and auditory) and multimodal (audio-tactile) stimuli delivered after self- or externally-directed movements. Interestingly, kinematic data reveals a significantly greater proportion of self- than externally-directed movements, especially targeting the trunk. Crucially, EEG results show significantly greater superadditive responses (i.e., with enhanced ERP amplitude in bimodal than unimodal) following self- as compared to externally-directed movements. These converging kinematic and electrophysiological findings pinpoint the importance of bodily-targeted motor behaviour early in life, since it promotes intermodal perception. In conclusion, our results endorse self-directed behaviour as a crucial context fostering the emergence of bodily-self representation in typical development, thus laying the groundwork for investigating its possible alteration in atypical development.

Crossmodal spatial recalibration in six-year-old children depends on feedback

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Keywords: Audiovisual, Development, Recalibration, Space, Ventriloquism

Based on previous studies, we have recently postulated that multisensory integration precedes (unsupervised) crossmodal recalibration during development and hence that multisensory integration might be a prerequisite for crossmodal learning. We hypothesized that at early ages goal-directed actions toward multisensory targets are predominantly recalibrated based on feedback (i.e., supervised learning). To test whether children are indeed able to recalibrate spatial maps based on feedback prior to the emergence of unsupervised recalibration, we compared 6-year-old children (n=32) to a group of adults (n=32). Both groups participated in two sessions, in which they were adapted to a spatial disparity between auditory and visual stimuli to induce the ventriloquism aftereffect. Importantly, in one of the two sessions feedback about the localization responses was provided: All localization responses which occurred in the same direction as the spatially displaced visual stimuli were rewarded. The other session did not involve any feedback about the localization responses. In both sessions, crossmodal recalibration was assessed in subsequent unimodal auditory localization trials without feedback. As expected, we found significant crossmodal recalibration effects

in adults in both sessions. In children, however, recalibration depended on the order of sessions: We did not find a significant ventriloquism aftereffect in children who started with the condition without feedback. By contrast, and as hypothesized, children who started with the feedback condition showed significant crossmodal recalibration which carried over to the second session without feedback. These findings highlight a crucial role of supervised learning during ontogenetic development (e.g., via self-guided or caregiver-guided goal achievement).

How Children and Adults Integrate Spatial Information from Different Visual Sources

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Keywords: development, spatial skills, visual information integration

Spatial skills underlie how humans acquire, represent, organise, manipulate, and navigate their environment, and therefore are fundamental for survival and proper function. The development of spatial skills is deeply rooted in embodied multi-sensory experiences because children's immense and variable interactions with their environment shape their ability to mentally shift viewpoints and manipulate spatial information. However, little is known about how children learn to integrate spatial information from different sources of sensory information into an integrated spatial representation. Here, we used a perspective-taking task in which participants were asked to assemble Duplo block constructions based on four schemas taken from different viewpoints. To succeed, participants must gather critical spatial information from each viewpoint (e.g., depth cues) and mentally integrate all the sources into one coherent construct. Twenty-five Children (7-10 year-olds) and twenty-five adults built 8 constructions which differed in difficulty (number of blocks) and complexity (ambiguity of the visual information). We recorded participants' gaze locations using head-mounted eye trackers and tracked their manual actions using computer vision. Overall, children were less successful and efficient than adults in integrating the multiple viewpoints. Time-series analyses of the moment-to-moment interaction between participants' information gathering (looking patterns) and their motor actions (hand kinematics) indicated developmental changes in real-time strategies. Furthermore, participants' performance and strategy were affected by the ambiguity of the spatial information. Taken together, our findings suggest that the ability to integrate different sources of spatial information continues to develop through late childhood and depends on developmental changes in embodied perception-action interactions.

Decoding Multisensory Decision-Making Development from Childhood to Adolescence

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Keywords: Developmental Trajectory, Perceptual Decision, Making, Multisensory Decision, Making (MSDM), Bayesian Modeling, Hierarchical Drift Diffusion Modeling (HDDM), Critical Period for MSDM (9-12 years).

Multisensory processing is fundamental for perception and decision-making, and understanding its developmental trajectory remains a key area of research. To investigate how multisensory decision-

making (MSDM) evolves across childhood and adolescence, we conducted an experiment with 123 participants: 35 children (5–8 years), 59 children (9–12 years), and 29 adolescents/young adults (16–21 years). Participants categorized noisy visual (V), auditory (A), or audiovisual (AV) stimuli depicting faces and cars. Bayesian modeling of response time (RT)-based reliability weighting revealed that young children do not integrate sensory evidence optimally. In contrast, adolescents and adults exhibited mature, reliability-based weighting marking a developmental shift from suboptimal to optimal integration by 9–12 years of age. We introduced a novel composite metric that integrates accuracy and RT into a single measure to validate this transition. Using this metric, Hierarchical Drift Diffusion Modeling (HDDM) showed that in children, drift rates in AV trials did not exceed those of the optimal unisensory condition, suggesting immature MSDM mechanisms. Conversely, adolescents and adults demonstrated clear multisensory facilitation, favouring AV over unisensory processing. Additionally, we provide evidence that optimal MSDM requires unbiased sensory encoding, ensuring all cues are sampled equally, followed by selective weighting of the most reliable modality during decision formation. In young children, early unisensory dominance limits integration, while adolescents achieve balanced encoding and optimal weighting, identifying 9–12 years as the critical transition period to mature MSDM. This study introduces a novel computational framework to dissect MSDM development and pinpoints when, along the sensory-decision continuum, multisensory benefits emerge and stabilize in the developing human brain.

Associations Between Audiovisual Multisensory Integration and Reading Abilities in Autistic and Non-Autistic Children

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Keyword: Autism, Audiovisual, Reading

Autism is a neurodevelopmental condition defined by differences in social communication and restricted, repetitive patterns of behavior. Reading differences commonly occur in autistic children and impact their academic success. We sought to determine whether differences in audiovisual integration may explain differences in reading abilities in school-aged autistic and nonautistic children. Participants were 50 autistic children and 50 non-autistic children (8-17 years of age) matched groupwise on age and biological sex. Audiovisual integration was measured via a task assessing susceptibility to the McGurk illusion. Participants completed tests probing reading ability. Aggregate scores indexing decoding and reading comprehension were derived. Regression analyses were conducted to evaluate associations of interest and moderation. Autistic children showed reduced audiovisual integration ($t(98) = 5.399$, $p < .001$), and poorer reading comprehension ($t(98) = 5.817$, $p < .001$) and decoding ($t(98) = 6.007$, $p < .001$), relative to non-autistic children. These effects were large ($d = 1.1$, 1.2, and 1.2, for audiovisual integration, reading comprehension, and decoding, respectively). There were moderate, positive relations for the percent reported fusion with decoding ($r = 0.364$, $p < .001$) and reading comprehension ($r = 0.448$, $p < .001$), indicating that children with increased audiovisual speech integration tended to be better at decoding and comprehending. Associations did not vary according to diagnostic group. The present study examined links between audiovisual integration and reading abilities in autistic and non-autistic children. We found that ability to integrate auditory and visual information may be useful for explaining differences in reading. Implications of results will be discussed.

Talk session 9

When One Race Is Not Enough. Introducing the Relay Model to Explain Multisensory Response Times

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Keywords: Multisensory Integration, Reaction Time, Race Model, Perceptual Decision Making, Temporal Rule

Responses to bimodal signals are typically faster than those to unimodal signals, a phenomenon known as the redundant signals effect (RSE). To explain the RSE, Raab (1962) proposed the race model, suggesting that responses to two redundant signals are determined by the faster of two parallel decision processes. Despite the simplicity, race models exhibit remarkable explanatory power, successfully predicting response time variations based on stimulus onset and signal strength manipulations. However, Miller (1982) demonstrated that the observed RSE often exceeds race model predictions, leading to small but systematic violations of the race model inequality (RMI). These violations have long been interpreted as evidence against race models, challenging their adequacy in fully capturing multisensory integration. Here, we introduce the relay model, a novel extension of Raab's framework that reconciles these milestone findings. In this model, two race units operate sequentially, with the first unit providing a start signal for the second, which can be considered a mechanism analogous to two-factor authentication in the digital world. This simple modification preserves the explanatory power of traditional race models while naturally accounting for violations of Miller's bound. Constrained only by unimodal response time distributions, we demonstrate that the relay model captures all critical aspects of the RSE, with RMI violations emerging as an intrinsic property of relay-based processing. This framework offers a new perspective on multisensory decision-making and refines our understanding of the computational principles underlying the RSE.

Multisensory Benefits Measured with Distinct Motor Actions. Introducing a Novel Paradigm with Redundant Signals

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Keywords: Redundant Signal Effect, RSE, Race Model, Audiovisual, Response Times, Multisensory Benefits

Responses to bimodal signals are typically faster than responses to unimodal signals, a phenomenon known as the redundant signal effect (RSE). Traditionally, the RSE is studied using tasks that require participants to perform the same motor action when detecting targets in either modality. The RSE can be explained either by pooling models, proposing sensory evidence is integrated in a single decision unit with a shared response threshold to trigger the motor response, or by race models, proposing parallel processing in two decision units with separate thresholds. Distinguishing between these accounts has proven challenging, and particularly with respect to race models it would be beneficial to know whether a response to a bimodal signal was triggered by one or the other modality. To address this, we developed a new version of the task, requiring participants to press distinct buttons corresponding to the modality they detected first. In addition, we employed a signal onset asynchrony (SOA) manipulation as typically used in RSE experiments. In bimodal trials, we found that the proportion of button presses corresponding to a specific modality was predictably modulated as a function of SOA, confirming adherence to task instructions. Notably, the two-button task yielded RSE patterns consistent with predictions from the race account. Even though modalities were mapped to separate responses, responses violated Miller's bound, a finding often interpreted as evidence for pooling. Our results suggest that introducing a two-button instruction can clarify the mechanisms underlying the RSE.

Modelling the Integration of Visual and Vestibular Cues to Self-Motion under Temporal Conflicts

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Keywords: Visual, Vestibular, Temporal, Conflict, Mathematical Model

Behavioural and neurophysiological studies have shown that visual and vestibular cues for heading discrimination can be optimally integrated to improve response times and reliability. However, under cue conflicts, such as visual-vestibular temporal incongruencies, optimal integration may break down. Using a mathematical model we investigate the neural mechanisms underlying the successful integration of sensory information and breakdown of integration under conflict. We modelled visual and vestibular areas to simulate visual, vestibular, and visualvestibular neuronal processing and behavioural responses for a heading discrimination task under congruent conditions and under visual-vestibular temporal conflicts. We extend the Wong and Wang's two-variable decision-making model, which uses a system of non-linear ordinary differential equations to simulate neuronal processes in the intraparietal cortex and corresponding behavioural responses for a visual only task. The model tests a summation model indicative of integration. The summation model's behavioural outputs replicate published accuracy and reactions times for visual and vestibular trials. For temporally congruent visual-vestibular trials the behavioural output was consistent with optimal integration. For visual-vestibular trials with temporal conflicts the sum model results were consistent with behavioural findings showing the breakdown of multisensory integration is function of both conflict size and which was the leading sensory signal. Furthermore, the model's multisensory neural outputs were consistent with neurophysiological recordings, demonstrating its flexibility and utility for characterising different features of visual-vestibular integration. The findings show this model provides a novel framework to test the neural dynamics of multisensory integration and its breakdown.

Balancing Multisensory Integration. Modelling Neuronal Proportions in the Brain.

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Keywords: Audio, visual, mathematical model

Neurophysiological studies on multisensory integration have revealed a wide range of proportions in neurons that receive multisensory input. For instance, in ferrets only 8% of neurons in the primary auditory cortex respond to both auditory and visual stimuli, a proportion that increases to over 20% in higher auditory areas. In Rhesus macaques, higher-order areas like Medial Superior Temporal dorsal and Lateral Inferior Parietal exhibit even higher multisensory responsiveness, with up to 60% of neurons integrating multiple sensory inputs. Here, we present a mathematical multisensory model using differential equations to simulate the neuronal areas and give a behavioural responses for an audio-visual detection task. We manipulate the proportion of multisensory neurons in an area, to assess the impact on unisensory and multisensory reaction time and accuracy using drift diffusion analysis. The behavioural results showed that the predicted optimal drift rate for the model was for a proportion of 20% to 60% of the area being multisensory, while larger proportions resulted in more frequent detection errors. These findings agree with neurophysiological data, suggesting that the "Goldilocks zone" for multisensory neuron proportions lies within this range. We extend the model to examine how varying neuronal accumulation speeds affects multisensory integration. Our findings suggest that early sensory areas, which process information quickly, contain fewer multisensory neurons, while higher areas, where information accumulation is slower, have a greater proportion of these neurons. This supports the hypothesis that balanced multisensory integration is crucial for optimal behavioural responses, particularly in tasks requiring rapid decision-making.

Partial recurrence maximizes performance and minimizes wiring in multisensory circuits

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Keywords: Neural networks, Computational neuroscience, Theoretical modelling

Like many circuits in the brain, multisensory circuits are bidirectional and sparse. Meaning that: i) signals flow from sensory inputs to later areas and back, ii) between any two connected areas there exist some but not all pathways. In contrast, many computational models are either feedforward and unidirectional, or fully recurrent and so contain all possible pathways. As such, how multisensory network structure influences function remains relatively under-explored. Here, we address this in two steps. First, we designed a series of increasingly complex tasks in which agents must navigate, forage or hunt in simulated multisensory environments. We benchmarked these tasks using 7 classical models of multisensory integration. Second, we generated 128 distinct neural network architectures by augmenting a feedforward model with different combinations of backwards, lateral and skip connections. We term these architectures partially recurrent as signal propagation is bidirectional, yet sparse. Following training, with deep reinforcement learning, we found that different architectures differed significantly in their performance and robustness to noise. Though, surprisingly, many architectures performed as well as a fully recurrent network, despite having fewer pathways and hence a lower wiring cost. Finally, we demonstrate that these differences in performance are due to the fact that different pathways alter network training, input sensitivity and memory capacity in distinct ways. Ultimately, our results suggest that partial recurrence allows multisensory networks to maximize performance with minimal wiring. More broadly, our work, provides a general, normative framework for linking network structure to function.

Modality-specific EEG Oscillations Revealed by Mutual Information

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Keywords: Audiovisual, EEG, information theory

Extracting unisensory information from multisensory input is a fundamental function of the sensory systems. However, little is known regarding how modality-specific temporal dynamics are encoded during multisensory processing. Electrophysiological approaches (such as EEG and MEG) provide a temporal precision far superior to some other neurophysiological techniques (such as fMRI and fNIR), allowing researchers to investigate how temporal information of sensory inputs is encoded. Recently, information theory has demonstrated the powerful capability of capturing non-linear relationships carried by neurophysiological data. In this study, we recorded scalp EEGs in lightly anesthetized cats and adopted conditional mutual information (CMI) from the information theory as a novel approach to measure the internal reliability of EEG responses to a repeatedly delivered stimulus pattern. Difference in CMI values between the original and the time-reversed versions served as a quantification of temporal tracking during multisensory processing. Modality specificities in EEG oscillations of different frequencies were characterized in the multivariate dimensions anchored by unisensory responses recorded alongside. Our preliminary data analysis showed that the delta-band neural oscillation tracked the temporal structure carried in the visual stimuli, while the alphaband, the mid- and the high-gamma band tracked the temporal structure carried in the auditory stimuli. Our findings suggest that the EEG signal can serve as a neural signature of modality-specific encoding of temporal information carried by either unisensory input. It is also revealed that brain activities track stimulus timing in a frequency-dependent manner, while the overall rhythmicity of stimuli is not necessarily required.

Talk session 10

Multisensory Plasticity of Self-Other Boundaries in Behavioural Contagion. Insights into Bodily Attunement

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Keywords: behavioral contagion, self, other boundaries, multisensory integration, rubber hand illusion, temporal binding window

Behavioral contagion phenomena—such as spontaneous yawning or itching when observing others—are ubiquitous in human social interaction, yet their neurocognitive foundations remain incompletely characterized. This study investigates how multisensory temporal processing influences self-other boundary flexibility and subsequently affects susceptibility to contagious behaviors. We implemented a two-phase experimental approach. In Experiment 1 (n = 50), we assessed correlations between individual temporal binding window (TBW) width, susceptibility to the rubber hand illusion (RHI), and behavioral contagion responses. Experiment 2 (n = 30) established causality through perceptual training designed to narrow participants' TBWs, allowing us to measure consequent changes in embodiment experiences and contagious behaviors. Measurements included simultaneity judgment tasks for TBW assessment, RHI paradigms for embodiment quantification, and standardized contagion tasks recording spontaneous yawning and itching responses. Mediation analyses revealed that TBW width significantly predicted embodiment strength during the RHI, which subsequently modulated contagion susceptibility. Participants with broader TBWs demonstrated enhanced embodiment experiences and heightened behavioral contagion. Following perceptual training, participants exhibited narrowed TBWs, accompanied by corresponding reductions in both embodiment and contagious responses. These findings provide compelling evidence that self-other boundaries are malleable and fundamentally shaped by multisensory integration mechanisms. Our research illuminates the body's critical role as an interface between basic sensory processes and complex social cognition, demonstrating that more precisely defined bodily boundaries constrain susceptibility to behavioral contagion. These insights advance our understanding of social attunement mechanisms and offer promising implications for conditions characterized by atypical self-other distinctions, including autism spectrum disorder and schizophrenia.

When Vision Aligns with Touch but Not Audition. Sensory-Specific vs. Supramodal Priors in Speed Perception

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Keywords: auditory speed, visual speed, tactile speed, central tendency

Speed perception is vital for survival, yet sensory systems extract speed information differently. Vision relies on MT/V5 for speed processing, audition uses spectral and temporal cues, and touch integrates spatial-temporal cues across the skin surface. To better understand whether different sensory modalities share underlying neural representations, it is crucial to investigate speed perception across modalities. One approach is to examine the central tendency effect, which provides a framework to assess whether perceptual estimates are shaped by a common, supramodal prior or by modality-specific priors. We ran two experiments: in Experiment 1, using visual and auditory speeds, while in Experiment 2, visual and tactile speeds. In each experiment, participants had to estimate the speed in a baseline-unimodal session, and an experimental session of randomly presented stimuli that were

either auditory/, tactile, or visual. The average of each type of stimulus was different, and all differed from the overall mean, allowing us to test which influenced perception. The results revealed distinct effects between the two experiments. In Experiment 1, vision and audition were influenced by sensory-specific priors, showing differences between modalities in the experimental session but not across sessions within each modality. Experiment 2 indicated a shared global prior between vision and touch, with differences emerging across sessions within each modality but not between modalities in the experimental session. These findings suggest that while vision and audition rely on distinct priors and mechanisms for speed processing, vision, and touch share a supramodal prior, highlighting differences in multisensory interaction across perceptual domains.

Emotion Processing Differences in PTSD Extend Across Sensory Modalities. EEG Evidence

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Keywords: Audiovisual, Emotion, PTSD, EEG

Individuals with Post-Traumatic Stress Disorder show differences in processing of emotional information, including attentional biases towards trauma-/threat-related information. Previous research has relied on visual-only paradigms, but given the multisensory nature of emotion perception, there is a need to investigate emotion processing across multiple senses to fully characterise socioemotional differences in PTSD. The study presented here used an oddball paradigm to examine differences in audiovisual emotion processing between 21 individuals with PTSD, 21 individuals with a history of trauma but not PTSD, and 20 age-/sex-matched controls with no history of trauma. Participants performed a task where they had to identify rare emotional faces and voices (sad, happy or angry) among a stream of neutral stimuli. This task was performed in audio-only (voices only); visual-only (faces only); audiovisual congruent (faces-voices expressing the same emotion); and audiovisual incongruent (faces-voices expressing different emotions) conditions, while electroencephalography was used to record event-related potentials associated with neural processes of conflict/congruency detection (N200) and attentional allocation (P300). The main findings showed that individuals with PTSD exhibited enhanced P300 responses to emotional information across sensory modalities compared to trauma-exposed controls, and that larger differences were more likely to be observed for audiovisual rather than unisensory stimuli, potentially indicative of a specific multisensory pathology in PTSD. By demonstrating heightened responsivity to emotional information bearing no clear link to threat or trauma, our results align more with theories of generalised sensory hyperactivity in PTSD, compared to theories of attentional threat bias used to explain anxiety-related disorders.

Effects of Crossmodal Semantics and Rarity on Episodic Memory

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Keywords: Episodic memory, Incidental memory, Semantic Congruence, Recollection, Salience, Ageing

Semantic congruence across sensory modalities when encoding an event has been shown to enhance memory performance after short delays of seconds or minutes. However, the impact of crossmodal congruence on episodic memory over extended retention periods remains less established, particularly under incidental encoding conditions. Here, we present findings from four experiments (total N = 232) using the Dual-Process Signal Detection (DPSD) model to examine the effects of crossmodal semantic congruence at encoding, on recollection and familiarity for images. In all experiments, participants experienced 192 audiovisual congruent and incongruent events, and two days later were given a surprise memory recognition test on the images alone. In young adults, hearing characteristic sounds during the incidental encoding of object images significantly enhanced both recollection and familiarity, compared to hearing incongruent sounds. This finding extended to a group of older adults, who exhibited a comparable crossmodal congruence benefit despite an overall age-related decline in recollection. Finally, we addressed the resilience of this crossmodal memory enhancement against frequency imbalances between congruent and incongruent events (10–90%). While rare events were generally more memorable, this rarity effect had only a minor influence on the net gain of crossmodal congruence, affecting familiarity but not recollection. Together, these findings establish a robust crossmodal semantic congruence effect with the characteristic signature of long-term episodic memory, underscoring its significance for real-world memory processes. This study has been published in Packard, P.A., Soto-Faraco, S. Crossmodal semantic congruence and rarity improve episodic memory. Mem Cogn (2025). https://doi.org/10.3758/s13421-024-01659-9

Haptic and visual digit span

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Keywords: Vision, Haptics, Digit Span, Working Memory

Verbal working memory is often assessed using the digit span. Digits are usually presented in the auditory or visual modality. The span is how many digits are remembered in their correct positions in the sequence. The forward span (repeating the sequence in the presented order) is generally longer than the backward span (repeating the sequence in reverse order). There is some evidence suggesting that the digit span may depend on the encoding modality to some extent. Haptics is rarely used to recognise digits, and this could result in weaker encoding and consequently a shorter digit span compared to vision. We tested this hypothesis using the same task in vision and haptics. Digits 1-9 were presented sequentially in random order as raised 3D-printed shapes for 4 s each. Participants (n=30) either looked at the digits or explored them with the left or right hand. Next, they typed the memorised sequence either forward or backward. As hypothesized, the haptic span was shorter than the visual span. Left and right hands did not differ in span size, nor did the forward and backward spans. The serial position curves had typical U-shapes, with better performance for the first and last digits in a sequence. The haptic curves differed most from the visual ones in mid-positions. These findings show that the digit span is not independent of the encoding modality, suggesting that it does not represent purely verbal working memory.

Individual Differences in PROP Bitterness Responsiveness Modulate Visual Awareness of Food Stimuli

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Keywords: Food perception, Visual Awareness, Binocular Rivalry (BR), breaking, Continuous Flash Suppression (bCFS), Interoceptive Awareness

“Supertasters” are defined as individuals exhibiting broader sensory responsiveness that interests multiple sensory modalities, including taste, oral somatosensations, and olfaction. Considering the evolutionary importance and neural specialization of food perception, we investigated whether responsiveness to 6-n-Propylthiouracil (PROP) bitterness (taster vs. nontaster status) also modulates visual processing of food stimuli (highly processed sweet and salty items, matched for caloric content). We employed the breaking Continuous Flash Suppression (bCFS) and the Binocular Rivalry (BR) paradigms to measure unconscious processing and perceptual dominance to visual awareness, respectively. Participants (n=24, 54% female, mean age=48.5) were assessed for food familiarity and liking, and administered the Multidimensional Assessment of Interoceptive Awareness (MAIA) and the Eating Disorder Inventory (EDI-2). Sweet stimuli entered visual awareness significantly faster than salty stimuli (bCFS), and the PROP taster status was correlated to faster access for both sweet and salty stimuli. Additionally, the negative correlation between the access speed and the MAIA "Noticing" scale suggests a potential link between interoceptive awareness and unconscious visual processing of food stimuli. As regards perceptual dominance, the one of sweet stimuli was correlated with taster status. To our knowledge, this is the first study demonstrating that individual differences in taste responsiveness influence visual perception of food stimuli.

Posters

Poster session 1

#1. Auditory stimuli extend the temporal window of visual integration by modulating alpha-band oscillations

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Keywords: audition, auditory motion, head movements, vestibular system, proprioception, speed processing

In the multisensory environment, the interactions between inputs from different sensory modalities are not fully understood. Here, we conducted an electroencephalography (EEG) experiment to investigate how auditory stimuli shape the temporal window of visual integration in human subjects. Participants were presented with two consecutive visual flashes, either accompanied by an auditory beep or without, and were asked to report their perception of one or two flashes. Behaviorally, we found that the introduction of auditory input induced a longer temporal window for integration. Alpha frequency analysis further revealed that the presence of auditory stimuli led to poststimulus alpha frequency degradation, positively correlating with the prolonged temporal window, supporting the idea that alpha oscillations represent the temporal window of visual integration. Further exploration of prestimulus alpha oscillations revealed that auditory stimuli diminished the predictive role of prestimulus alpha frequency while enhancing the predictive role of prestimulus alpha phase in determining perceptual outcomes. To unveil the underlying mechanism, we developed a computational model based on the phase-resetting hypothesis and the perceptual cycle theory, successfully replicating key behavioral and neural findings. Together, our results suggest that concurrent auditory input extends the temporal window of visual integration by resetting the phase of alpha oscillations in the visual cortex, leading to alpha frequency degradation.

#2. Does prior trial information influence the perception of audiovisual motion?

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Keywords: Motion, MLE, Bayesian causal inference, Trial history

From a Bayesian perspective, the perception of audiovisual motion involves integrating sensory information and combining current sensory information with prior history. However, little empirical evidence supports a Bayesian approach to the perception of naturalistic, multisensory motion. This study investigates how the motion statistics and performance on the prior trial influence the perception of current motion information. Using random dot kinematograms and amplitude-modulated broadband white noise, participants (n=50) were instructed to report the direction of motion across auditory-cued, visual-cued, and audiovisual-cued multisensory conditions. We examined how both the actual and reported direction of the previous trial influenced the current trial and how this influence varied with motion strength and the different cued conditions. Our results suggest that for motion direction discrimination, the sensory statistics of the prior trial have little effect, whereas the response of the prior trial influences performance on the current trial in cued conditions. The effect of the prior trial response on the current response was dependent on the motion strength and cued condition, in which auditory cued motion discrimination was significantly influenced and visual-cued motion was not

(p<0.001, p=0.295). The spatial demands of direction discrimination allow us to explain the Bayesian results observed, as perception in visual-cued conditions shifts towards current sensory evidence while perception in auditory-cued conditions shifts towards performance history. A more extensive investigation into trial history effects, investigating cumulative trial history as well as other metrics of performance (e.g., response time) could further elucidate the mechanisms underlying motion perception.

#3. Examining the effects of exogenous cueing on audiovisual integration capacity

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Keywords: Audiovisual integration, Visual attention, Exogenous attention

The capacity of audiovisual integration can be quantified by exposing participants to situations where they are presented with numerous potential binding candidates before only one of these candidates is probed. Previous work has shown that integration capacity varies as a function of speed of stimulus presentation, stimulus factors (e.g., size and pitch), and previous experience. The current work examines the effect of exogenous visual cues on integration capacity. Participants completed an audiovisual integration task with eight visual stimuli arranged in a circle, with several stimulus polarity changes occurring rapidly. Some trials featured a green dot superimposed on one of the dot locations, serving as an exogenous spatial cue. This cue sometimes drew a participant's attention towards the integration. stimulus that would change on the critical trial, sometimes towards an invalid location, and other trials had no cue. Results indicate that there is no significant effect of cue presence when compared to no cue. However, the effect of cueing validity is significantly different dependent on speed of presentation ($p = .037$, $\eta p2 = .140$). This finding demonstrates a greater effect of cueing under faster rates of presentation (200ms) as compared to slower presentations (400ms, 600ms). This subtle cueing effect suggests that audiovisual integration may be penetrable by exogenous attention; this is in contrast to previous work in our lab that showed no effects of endogenous attentional cues on audiovisual integration.

#4. Revisiting Audiovisual Synchrony: A Comprehensive Re-Analysis of SJ and TOJ Data

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Keywords: Audiovisual synchrony, Secondary data analysis, Psychophysics

Audiovisual synchrony is essential for integrating sensory information from sight and sound. To study this phenomenon, two main tasks are commonly used: synchrony judgments (SJ), where observers report whether signals appear simultaneous, and temporal order judgments (TOJ), where they judge the order of presentation. Previous studies have reported inconsistent results between these tasks, raising questions about their comparability. In this study, we systematically reanalyzed 162 published datasets to examine the factors influencing audiovisual synchrony estimates. We focused on two key parameters: the point of subjective simultaneity (PSS) and the window of subjective simultaneity (WSS), which represent the lag at which signals are perceived as synchronous and the range of tolerable delays, respectively. By applying standardized statistical approaches to fit psychometric curves across different studies, we aimed to reduce variability due to methodological differences. Our analysis revealed that, contrary to previous reports, both SJ and TOJ tasks consistently show that the point of subjective simultaneity corresponds to physical synchrony. Additionally, we found that the window of subjective simultaneity scales linearly with the range of stimulus onset asynchronies, with broader windows observed in studies using a larger range of asynchronies. Notably, the window of subjective simultaneity measured with SJs and TOJs were highly correlated, suggesting a shared underlying mechanism. These findings highlight the importance of harmonizing methodological

approaches when comparing studies on audiovisual synchrony. While challenging previous assumptions in audiovisual synchrony perception, our comprehensive re-analysis provides a framework for more reliable assessments in future research.

#5. Detection of audio-tactile stimuli in a noisy sound environment

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Keywords: Audiotactile integration, Detection task, 3D sound environment, High order ambisonics

There is substantial evidence from cognitive science and neuroscience studies that multisensory audio-tactile stimuli are detected more quickly than their unisensory counterparts in silent laboratory environments. In natural settings, individuals perceive information within a sound environment that might modulate their behavioral response. In this study, we investigated the influence of a dense and complex noisy environment and its spatial definition on the detection of auditory and tactile stimuli. Twenty-nine participants performed a speeded detection task of auditory, tactile or audiotactile stimuli in a silent environment and while immersed in a noisy urban sound environment broadcasted in 3D ambisonic sound via a 24-speaker dome. The spatial quality of the sound environment, recorded in 4th-order ambisonic sound, was manipulated by using either 4th-order or 1st-order decoding, with the latter reducing sound spatial resolution. Participants' reaction times to the auditory stimuli were similar in the silent environment and the noisy sound environment with low spatial resolution. They were longer when participants were immersed in the noisy environment with high sound spatial resolution. Reaction times to the tactile stimuli were shorter in the noisy sound environments as compared to the silent condition, and were not influenced by the environment sound spatial resolution. Participants' reaction times to audio-tactile stimuli were similar in the three sound environments. Multisensory facilitation of detection was observed in all cases with larger gains in the noisy sound environments, and even more so when the spatial resolution of the sound environment was high.

#6. Time-window-of-integration model for the sound-induced-flash illusion

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Keywords: sound-induced flash illusion, race model, time window of integration

In the simplest version of the sound-induced flash illusion (SIFI), pairing a single visual stimulus with multiple auditory stimuli results in the perceptual illusion of multiple visual stimuli, called fission illusion (Shams et al. 2001). SIFI is commonly regarded as an indicator of the strength of multisensory integration (MI). Many studies demonstrate that susceptibility to the illusion depends on many factors, like exact physical stimulus parameters, participants' expectations, attention, age, and clinical/non-clinical population membership. One consistent finding is that the probability of an illusion peaks at stimulus onset asynchronies (SOA) of about 70 to 100 ms and then declines in a nearly monotonic manner. Bayesian Causal Inference (BCI) has been suggested as a comprehensive modeling framework for SIFI. However, a detailed mechanism underlying the SOA effects is not made explicit in the model. Here we combine a simple race mechanism with the notion of a temporal window determining whether an integration of visual and auditory events occurs in each trial. This time-window-of-integration model for the sound-induced-flash-illusion or, for short, SIFI-TWIN model, predicts the probability of an illusion to occur as a function of the temporal and physical stimulus arrangement. The probability of finally reporting a second, illusory flash is accounted for by combining a bias parameter with the integration probability. We report an application of the model to data from a study in our lab comparing the effect of using or not using hearing aids in a sample from elderly participants with the same degree of mild hearing loss.

#7. Behavioural and neurocomputational evidence for cross-sensory competition in bilateral visuotactile processing

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Keywords: visuotactile, switch cost, bilateral, attention, reaction time

Vision and touch provide essential information for environmental navigation and social interaction. While the benefits of integrating concurrent visuotactile cues are well-documented, the temporal dynamics of competitive interactions between these modalities remain less understood. In line with findings from audiovisual research, experimental evidence indicates that reaction times to unisensory visual or tactile targets on one hand increase following a cue of the opposite modality. Here, we ask whether these modality switch effects extend to the bilateral identification of visual and tactile stimuli, and explore their dynamics using a modeling framework based on interhemispheric visuotactile processing. Participants performed a speeded reaction time task to visual, tactile, and visuotactile targets, presented at varying inter-stimulus intervals on one or both hands. Switch costs resulted greater when unisensory stimuli of different modalities were presented sequentially on the same hand, rather than across hands, with significant effects of inter-stimulus interval, trial type (modality repeat vs. switch), and modality type (visual, tactile, or visuotactile). Therefore, we developed a computational model to simulate bilateral cross-sensory competition between visual and tactile pathways, performing sensitivity analyses on the neural connections likely responsible for within and between-subject variations in the data. Notably, both model predictions and behavioral data outlined a slowdown in response to the repeated presentation of simultaneous visuotactile targets, suggesting that cross-sensory inhibition may contribute to offline influences of vision on bilateral tactile perception. These findings shed new light on the temporal interplay between vision and touch, highlighting neurobehavioral constraints on cross-modal competition in bilateral space.

#8. Multisensory Processing and Redundant Signals Effect in a Steady-State Evoked Potential Paradigm

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Keywords: Multisensory, Frequency tags, Reaction times, Synchrony

Multisensory integration enhances perception and behaviour, often leading to faster reaction times when multiple sensory signals are presented simultaneously, a phenomenon known as the redundant signals effect (RSE). This facilitation suggests an interaction between sensory modalities, which can be quantified through violations of so-called Miller's bound. To investigate the neural mechanisms underlying this effect, we adapted the classic RSE paradigm for a steady-state evoked potential (SSEP) experiment, eventually allowing us to track the temporal dynamics of multisensory processing. In our paradigm, we used volume-modulated noise and phase-modulated Gabor patches as frequency tags to elicit steady-state responses in auditory and visual modalities (using 2.5Hz and 3.75Hz, respectively). Behavioural targets were defined as changes in carrier frequency and Gabor orientation, with detecting a change in either dimension requiring a response. We employed a 2×2 design in which the onset of behavioural targets was either synchronous or asynchronous with the frequency tags in vision and audition, respectively. Pilot data (n=5) indicate that unisensory reaction times are modulated by the synchronicity of targets with frequency tags, suggesting an interaction between ongoing oscillatory processing and behavioural responses. Critically, we observed the

expected RSE in all conditions, along with violations of Miller's bound, which provides typical evidence for multisensory interactions. These findings demonstrate the feasibility of our adapted paradigm for studying multisensory processing using SSEP and offer a novel approach to investigating how oscillatory neural activity shapes perceptual decision-making.

#9. The Multisensory Impact on Human Perception is More Robust and Reliable Than it Appears

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Keywords: Calibration, Superadditivity, Reliability, Psychophysics, Virtual reality, Enhancement, Detection, Localization

Human studies report substantial variation in the magnitude of the multisensory impact on perception (and substantial within-subject variation). This prompts questions about its reliability in different contexts and/or the possibility that individuals have different multisensory capabilities. This question is not only of general interest, but also poses significant problems for clinicians. Evaluating the effect of disease, trauma, and developmental anomalies on the brain's ability to coordinate information from different senses would require large numbers of subjects and be problematic when assessing different therapeutic intervention in any individual patient. Interestingly, these observations contrast with those from animal studies in which the multisensory effect is robust and reliable. One possibility is that differences are more apparent than real, and may reflect the precision with which task-relevant information in each sensory modality is calibrated. To address this possibility, we developed a virtual reality human analogue of the animal detection and localization task. A dynamic algorithm calibrated task-relevant information during testing. The multisensory enhancement obtained proved to be quantitatively similar to those obtained in animals in the free-field detection/localization task. Multisensory performance consistently exceeded the sum of the unisensory performance levels when weakly effective stimuli were provided and was stable across testing sessions. However, unlike the animal studies which require weeks of training, calibration, and testing, the present test required <35 minutes for human subjects to complete. This paradigm may provide a simpler approach for quantifying multisensory integration in different contexts and a more effective means of evaluating dysfunction and rehabilitation in clinical populations.

#10. Development and spatial modulations of the audio-tactile crossed-hands effect

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Keywords: Development, Crossed Hands Effect, Audio Tactile conflicts, Auditory spatial localization, Intermanual Distance

The Crossed-Hands Effect (CHE), a systematic cost in localization tasks performed with crossed hands, arises from a conflict between body-centered and external reference frames. However, the effect of hand posture on audio-tactile interactions is largely unexplored, and the role of inter-manual distance remains unstudied. Here, adults (n=12) and children aged 6 to 15 (n=24) performed an auditory localization task, where the target sound could come from either of two devices placed on each hand. The sound could be presented solo or paired with a synchronous vibration, delivered either to the same hand (congruent) or the other one (incongruent condition). The task was performed by varying both hand posture (crossed or uncrossed) and hands distance (close, medium, or far). When the sound was presented solo, the crossed posture led younger children to significantly increase auditory mis-localizations, showing an immature ability to integrate locations coded by

audition and proprioception. Congruent tactile stimulation resulted in near-perfect accuracy. Instead, the incongruent condition elicited the CHE across the lifespan; however, adults only displayed CHE with close hands (unlike children). In contrast with previous findings, we observed that the crossed posture made it harder to disassociate audio-tactile stimuli, an effect inversely related to age. These findings show that crossing the hands enhances audio-tactile interactions across development, with stronger tactile interference in younger participants; moreover, inter-manual distance counteracts tactile interference in adults, but not in children, unveiling a development of the ability to use spatial distance to resolve conflicts between body-centered and space-centered reference frames.

#11. Multisensory training improves performance across ages: A comparison between children with typical development and children with stroke using the Multisensory Integration Climbing Wall (MSICLIMB)

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Keywords: reaching time, children, stroke, technology, multisensory

The human brain combines multiple information from different senses to provide a comprehensive representation of the environment. Multisensory integration among sensory modalities improves response accuracy and speed compared to unisensory input in children with typical development (TD). Children with stroke are slower and less accurate in response to unisensory stimuli, due to impairments affecting motor and sensory systems and the noise associated to the deficit affecting multisensory integration. This study examined sensory processing differences between children with stroke and TD, assessing their improvement across ages. We evaluated sensory function through a perceptual task to establish a baseline, using the Multisensory Integration Climbing Wall (MSICLIMB) system. We used a portion of MSICLIMB (1.5m x 1.5m) consisting of 15 smart holds to deliver audio and/or visual stimuli. Participants were instructed to reach and grasp the correct hold by moving from a central position towards the target. Results showed that reaching time decreased with age (-0.018), with TD children (-0.007) improving faster than those with stroke (-0.015). Multisensory (-0.475) and visual (-0.297) conditions enhanced performance in children with impairments. Grasping errors also decreased with age (0.173), particularly in visual (0.266) and multisensory (0.167) conditions. These findings suggest that while TD children naturally respond faster to multisensory tasks, children with stroke show slower processing but improve over time with the task performance. Early multisensory training may accelerate recovery and support sensory-motor function restoration. This study will open new frontiers for personalized rehabilitation of motor and sensory deficits in children with stroke.

#12. Spatial Boundaries of Visuotactile Perception in Childhood: Insights from the Cross-modal Congruency Task

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Keywords: Visuotactile, Visuospatial, Development

The cross-modal congruency task has classically been used to investigate the visuospatial nature of own-body-centered multisensory perception. In adults, this demonstrates that visual distractor stimuli presented at a congruent elevation to tactile target stimuli on the hands can decrease reaction time

and error for speeded judgements of target elevation. Crucially, this beneficial 'cross-modal congruency effect' (CCE) becomes stronger when distractors are closer to the target, demonstrating the spatial attentional boundaries of visuotactile perception. Here we explored this effect in children, who experience continuous body growth and protracted development of multisensory integration and own-body spatial representation. Using a modified version of the classic paradigm, children (n=15, 6-11years) held the corners of a cuboid frame with index fingers/thumbs resting on a vibrotactile buzzer and LED. Visual stimuli were delivered as a 100ms flash, followed 100ms later by three 50ms tactile buzzes at 50ms intervals. Children made speeded elevation judgements by moving the whole frame upwards or downwards. Overall, children showed a clear main effect of elevation congruency, meaning a classic CCE with reduced reaction time and error for all congruent distractors ($p = .01$). However, a significant interaction with distractor side reveals that this congruency effect is overwhelmingly larger, and in fact almost exclusively present, for visual distractors on the same hand side as the tactile target ($p = .04$). This suggests that, for children aged 6 to 11 years, visuospatial attention facilitates implicit visuotactile processing similarly to adults, but within distinctly more narrow spatial boundaries around the hand.

#14. How probabilistic and biased is action planning over development?

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Keywords: Motor developmental, Planning, tool use, object manipulation, Problem solving, EEG, Eyetracking, motion tracking

A remarkable human behaviour is the ability to plan actions flexibly. This sensorimotor skill is achieved by keeping the initial contact with the object and the end goal in mind, even when the end goal stretches far into the future. Action planning begins in infancy and improves with age and experience. However, children show deficits in planning when the end goal is not immediately accessible to perception. We tested how these deficits relate to the biased and probabilistic nature of action planning. Children (n = 40) and adults (n = 28) completed two tasks: pound a peg using the hammerhead and turn on a lightbox by poking the handle into a button. We changed the hammer orientation and goal in a novel psychophysics procedure. To complete the task, participants had to perceive and account for the hammer orientation and the task-dependent end goal in their initial grip. For example, the hammer-and-peg task requires a non-habitual underhand grip when the handle points away from the dominant hand, whereas the handle-in-hole task requires this grip when the handle points toward the dominant hand. There was high inter-subject variation in goal-completion strategies. Individuals' grip choice varied with goal and hammer orientation and revealed a predictable but probabilistic distribution—participants grasped the hammer differently across trials with the same orientation and showed a bias towards habitual grasping. Planning was less probabilistic for non-ambiguous angles (0°/180°) and depended on the goal. Findings suggest developmental shifts in how action planning is probabilistic and biased under ambiguity.

#15. Multisensory illusion susceptibility is associated with poorer cognitive performance in healthy older adults across multiple domains of cognitive functioning

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Keywords: Sound induced flash illusion; Aging; Cognitive abilities; Pre-clinical decline

Identification of pre-clinical cognitive decline is important, however, current cognitive screening measures lack sensitivity. Multisensory illusions may be effective at identifying more subtle disruptions in overall brain network integrity that occur in early stages of neurodegenerative disease, given that multisensory processes require broad connections across sensory and cognitive domains of functioning. This study evaluated the associations between a multisensory illusion (sound-induced flash illusion; SIFI) and performance on different domains of cognitive functioning in older adults with no known cognitive impairments and normal vision and hearing. Twenty-eight older adults (M=72.3 years; 18F, 10M) who passed the Montreal Cognitive Assessment cut-off of 23 or greater were recruited, with recruitment ongoing. On critical fission trials, participants were presented with 2 beeps and 1 flash and asked to report the perceived number of flashes. The illusion was observed when 2 flashes were reported. Three different stimulus onset asynchronies (SOAs) of 100, 150, and 230ms were introduced in a blocked and counterbalanced order. Participants also completed standardized tests of inhibitory control (Stroop), working memory (Digit Span), and cognitive flexibility (Trails), as well as audiometric (PTA) testing and tests of visual acuity (ETDRS). Results demonstrated that higher SIFI susceptibility was associated with poorer inhibitory control, poorer working memory, and lower cognitive flexibility. There were no significant associations between SIFI susceptibility and hearing thresholds or measures of visual acuity. These preliminary results suggest that multisensory illusions may have some utility in screening for preclinical cognitive decline in those who pass traditional cognitive screening measures.

#16. Differences in visual and vibrotactile feedback for reaching movements

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Keywords: Sensory Substitution, Vibrotactile Feedback, Visuomotor

Simple every-day tasks, (e.g., reaching towards a cup) involve multiple senses, including vision (cup's location), proprioception (hand's location/posture) and touch (e.g., grasp stability). However, when using tools such as prosthetic devices, proprioception and tactile information are missing, even in cases in which the tool/device is actively controlled mechanically or by using electromyography. As a preliminary step towards a potential sensory substitution solution, we investigated vibrotactile stimulation for augmenting proprioceptive feedback in whole-bodied participants. Two groups of participants performed a computer-based pointing-task on a graphics tablet using their dominant hand. Vibro-tactile feedback was provided to their inactive arm using four vibration motors encoding the four cardinal directions. One group was provided with information about the broad direction (fixed intensity). The other group additionally received distance information (dynamic intensity) which was relative to the central starting point. We used a Pretest (visual-/tactile-only trials), Training (visuo-tactile with visual feedback decreasing over time) and Posttest (tactile-/visual-only, visuo-tactile) design. Preliminary results show that after training participants moved both faster and were undershooting less for tactile-only trials particularly in the dynamic intensity group. For visual-only, an improvement already occurred during the pretest and no further improvement was seen in the post-test. These results provide a first hint that vibro-tactile information might be useful even after a short training time. Future work will do more in-depth comparisons between different learning mechanisms (learning the space, learning the feedback, etc.) that may be involved.

#17. Sensory encoding drives auditory and haptic target reaching differences in the action planning stage

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Keywords: audition, haptics, sensorimotor integration, action planning

Reaching movements directed toward auditory targets demonstrate greater variability compared to those toward haptic or audio-haptic targets. This study investigated whether these differences arise during movement planning, online control, or both. Thirty-one participants performed reaching movements toward haptic, auditory, or audio-haptic targets positioned at 0°, 45°, and 90°. Premotor reaction time served as a proxy for target-related sensory information encoding, whereas electromyography beta power, derived via wavelet analysis, and motor reaction time as motor coordination indexes during movement planning. Initial hand direction, peak velocity, and endpoint variability indexed early and late online control. Bayesian analysis revealed delayed sensory encoding in the auditory condition but similar motor coordination across conditions. Concurrently, increased variability in initial hand direction, peak velocity, and endpoint error for auditory compared to haptic and audio-haptic targets. Bayesian structural equation modeling assessed the effect of sensory encoding and online control on the endpoint error variability. Sensory encoding and online control directly affected endpoint variability, with the strongest effect when reaching auditory targets. Results suggest that sensory-specific differences emerge during the planning phase, specifically at the level of sensory encoding rather than motor coordination. Initial motor commands are similar across conditions but are modulated online according to the available sensory information. The faster sensory encoding and better online control in haptics may be due to the target and reaching hand representation within the same sensory modality. Thus, planning strategies and online control are contingent upon the available target-related sensory information, with sensory encoding modulating the action planning phase.

#18. Exploring the role of external visual feedback in reaching movements to somatosensory targets

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Keywords: Somatosensory targets, Reaching, Visual contextual elements, Motor control networks, Sensory integration, Visuo, Motor control, Perceptual motor control

Visual information about the environment helps us navigate obstacles to accurately reach targets. It is unknown however, if this visual input also helps us perform movements to non-visual somatosensory targets (ST), for example, clapping our hands. Previous work indicates that movements to ST may rely on distinct control networks compared to movements to visual targets, and thus may rely less on visual cues. Healthy participants (n=8) reached toward unseen ST on their non-reaching hand, while fixated on an LED (left/right/centre) distal to the targets. Movements were performed in complete darkness, with and without a 3x3 LED array of visual contextual elements illuminated during movement planning. Movement trajectories and eye positions were recorded using high-resolution motion capture and electro-oculography, respectively. To assess the impact of visual contextual elements, movement-endpoint error and gaze-dependent error were analyzed. Analysis of endpoint error reveled that contextual elements had no significant effect on accuracy. Interestingly, the presence of visual contextual elements elicited significantly faster reaction times ($p<0.001$). These findings provide preliminary evidence that visual information may not be integrated into movement planning processes for ST and as such, the existence of distinct control networks for movements to ST is supported. Understanding how the nervous system modulates it's use of visual and somatosensory input will expand our understanding of motor-recovery of patients with somatosensory deficits. Results can also help improve adapted user interfaces, such as dynamic visual overlays in

augmented/virtual-reality, to improve performance. Future directions include studying movements to visual targets, and electroencephalography to record visual-evoked potentials.

#19. Sensory timing discrimination during interceptive movements

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Keywords: interception, temporal order judgement, sensory processing, visual impairment, child development

Interception refers to any goal-oriented motor action aimed at interacting with a moving object to catch, hit, or stop it. This ability enables crucial survival behaviors, it is essential in daily life activities and for social interaction. Vision is the primary sense involved in interception tasks to successfully predict object trajectory and timing. However, visually impaired individuals must rely on alternative sensory cues (e.g., auditory and tactile information) to perform interceptive actions. Despite the importance of interception and its clinical implications, research on this topic remains limited, particularly in children and in visually impaired individuals. To fill this gap, we developed and validated an experimental procedure in adult participants for later test in children. Specifically, we asked sighted participants to move a haptic robotic arm toward a target, as if they were bouncing a ball against a wall (i.e., the target). During the movement, a sensory stimulus (i.e., auditory, visual, or vibrotactile) was delivered with a multisensory device and participants judged whether it occurred before or after reaching the target (temporal order judgment task). We examined whether the point of subjective simultaneity (PSS) and the just noticeable difference (JND) change across sensory modalities. Adult participants successfully performed the task, with no differences in PSS and JND among sensory modalities ($p>0.05$). In future studies, we will investigate sensory-dependent changes in PSS and JND during the development of sighted children and the role of vision in visually impaired children.

#20. Metacognitive access to hand movement but not hand position

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Keywords: confidence, metacognitive access, proprioception, kinesthesia, somatosensory system

Perception is fallible, but sometimes we know when we err—we have metacognitive access to the accuracy of our perceptual judgments. Evidence from select exteroceptive senses suggests that metacognitive access is independent of task and sensory modality. Here, we compared metacognitive access across two distinct but tightly related bodily senses: kinesthesia–the sense of body movement– and proprioception–the sense of body position. Participants rested their nondominant hand on a motorized platform, hidden from view by an occluder. The hand was moved slowly along a predetermined horizontal path, centered at different areas across three sessions. To further mask kinesthetic information, the platform jittered rapidly along the vertical axis. In two kinesthetic tasks–direction discrimination and movement vector estimation–participants evaluated their hand's horizontal movement. In the two proprioceptive tasks–position discrimination and estimation in visual space–participants assessed their current hand location. After each discrete perceptual judgment, participants reported whether they had high or low confidence in the accuracy of that judgment. In the estimation tasks, they indicated a region of uncertainty around their estimate. Confidence judgments in both kinesthetic tasks traced the accuracy of the perceptual response. In contrast, confidence in proprioceptive judgments varied less systematically or not at all with response accuracy, even when we accounted for differences in overall task performance. The results indicate less metacognitive access to judgments of hand position despite almost full access to the passive movements that brought the hand to this position, revealing that metacognitive access can vary across modalities.

#21. The role of visual experience on spatial topographical constraints

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Keywords: Spatial representation, Visual experience, Spatial constraints, Bimanual action

Previous research has shown that spatial constraints guide bimanual coordination in sighted participants (Franz et al., 1991). To date no one has explored if these constraints extend to haptically guided actions or if they are a product of the visual system. Blind individuals often exhibit impaired spatial representations, particularly when the body is involved, therefore it is possible that spatial constraints do not influence their actions. To investigate this, we recruited early and late blind individuals, along with sighted controls, for a bimanual drawing task. This task has also been used to study spatial abilities in people with motor neglect (Garbarini et al., 2015). Participants drew lines and circles under four conditions: (1) unimanual, (2) bimanual-same (both hands drawing the same shape), (3) bimanual-opposite (each hand drawing a different shape), and (4) crossed-hands (crossing hands and each hand drawing a different shape). Sighted participants completed the task both with vision and blindfolded. We calculated the index of circularity (i.e. how circular each shape was) for each shape in all conditions. Our results showed that blind individuals were only partially influenced by spatial constraints, particularly when drawing lines. Their lines became more circular in the bimanual-opposite condition, but their circles remained unchanged. The effect was present for both shapes in the crossed-hands condition. In contrast to the blind, sighted participants replicated previous findings demonstrating spatial constraints. Importantly, sighted individuals performed similarly regardless of vision, reinforcing that spatial constraints primarily affect those with visual experience.

#22. Tests of use of a new cue to object weight in a speeded motor task

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Keywords: Weight perception, Perception and action, Learning, Movement

People use familiar visual cues, such as size and material type, to predict object weight, adjusting motor forces accordingly during lifting tasks. Arbitrary visual cues, like color, can also become weight predictors with minimal training, influencing preparatory motor forces. Most studies examining weight cues and object interactions rely on simple, undemanding movements, e.g., slowly lifting and placing objects. In naturalistic settings, movement trajectories can be unanticipated and performed rapidly. To our knowledge, no study has investigated how familiar and novel weight cues influence manual object interactions in a speeded, dynamic task. We designed a speeded task—a game—in which participants must rapidly move an object to squash virtual bugs appearing briefly at unpredictable locations on a touchscreen. The 'squashing' object, a cylindrical container, can be light or heavy. Weight is indicated by a familiar cue (volume of sand), a novel cue (stripe orientation), or no cue (identical containers). Because correctly predicting an object's weight allows for a better-planned movement with less need for online control, we hypothesize that performance will be best with the familiar cue, followed by the novel cue, and worst with no cue. In an initial feasibility study with 8 participants, significantly more bugs were squashed with the familiar cue compared to no cue, suggesting this paradigm can detect performance differences and capture the influence of multisensory information on naturalistic movements. In an ongoing full study, we include the novel cue for comparison and aim to clarify which mechanisms—speed, precision, or bias—drive performance differences.

#23. Shape-related biases in volume and weight perception

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Keywords: Weight perception, Size perception

In the shape-weight illusion, objects are perceived as lighter or heavier depending on their shape. For example, spheres feel heavier than tetrahedrons of matched weight and volume. Opposite biases occur in size perception: spheres look smaller than volume-matched tetrahedrons. If perceptually smaller objects feel heavier, this would be consistent with the size-weight illusion: the smaller of two weight-matched cubes feels heavier. However, perceived size does not account for the shape-weight illusion across all shapes. Surface area has thus been proposed as an alternative predictor of perceived weight. We measured the shape-weight illusion across four shapes (sphere, tetrahedron, cuboid, H-shape), presented in three sizes, and chosen to decorrelate surface area and perceived size. Participants (N = 30) provided magnitude estimates of each object's volume in a visual task, and of their weight in a visuo-haptic task. In the latter, participants grasped and lifted the objects using a handle with integrated force-torque transducers, allowing us to record finger forces and torques as sensorimotor correlates of the illusion. We found clear shape-related biases: cuboids and spheres were perceived as the largest and smallest shapes, respectively; spheres and tetrahedrons were perceived as the heaviest and lightest shapes. Thus, there were discrepancies between size and weight biases, but these were not explained by surface area. Instead, we found systematic differences in grip force and torque for lifting the different shapes, consistent with reports that rotational inertia influences perceived weight. We propose that bottom-up sensorimotor factors, in addition to perceived volume, contribute to the shape-weight illusion.

#24. Cursor control in target tracking: Delay adaptation does not transfer between discrete button press actions and continuous control

Van Dam, Loes C. J. [1], Kernig, Svenja [1], Lazarova, Karina [1], Ünal, Melisa [1], Gappa, Nicole [1], Straube, Benjamin [2], Wallis, Thomas A. [1]

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Keywords: Perception and action, Visuomotor control, Target tracking, Delay adaptation, Adaptation transfer

In modern life we frequently interact with technologies that present us with delays between our actions and the desired action outcomes. Such delays can be detrimental to visuomotor performance. Luckily, through delay adaptation these negative effects can decrease over time. Delay adaptation has been measured in various control modalities, ranging from discrete button presses causing beeps or flashes, to the continuous control of cursor items in target-tracking tasks. However, it is unclear whether these different types of actions can access the same adaptive state when the task is left unaltered. To answer this question, we investigated whether adaptation to a visuomotor delay on a cursor can transfer between different control modes for moving this cursor. Participants performed a target-tracking task in which the cursor was controlled either continuously using a stylus on a graphics tablet or in discrete steps by pressing the arrow keys on a keyboard. In separate blocks, the delay was added to the stylus or the button-press mode of cursor control. The levels of adaptation and transfer were measured by comparing performance pre and post adaptation using zero-delay test-trials for both cursor control modes. We found that delay adaptation occurred for both stylus and button-press modes, but observed no transfer between them. This indicates that delay adaptation is specific to the mode of cursor control used during adaptation, despite the tracking task remaining the same. This has implications for technologies with a back-up control system. When switching to a different control system, delay adaptation starts from scratch.

#25. Visual-tactile conflicts in delay adaptation: Higher reliance on tactile information in a sensorimotor duration reproduction task

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Keywords: Sensorimotor duration reproduction, Temporal sensorimotor recalibration, Visual, tactile interaction

The perception of time arises from a complex interplay between sensory inputs and motor actions. While the brain integrates multisensory information to construct a coherent temporal experience, discrepancies across modalities and sensorimotor feedback can affect this process. Previous studies suggest that delay adaptation is influenced by multisensory and motor timing integration, with tactile timing being more sensitive than visual timing. However, these findings are based on single-modality studies, leaving the mechanisms of visual-tactile integration and differences between unimodal and crossmodal stimuli unclear. To address this, we conducted two experiments using an adaptation-test paradigm. Participants reproduced a visual-tactile duration while experiencing action-effect delays. During adaptation, a delay of 150ms was introduced between the button press (motor action) and sensory feedback in one modality (visual or tactile), while the other modality remained synchronized. In the test phase both modalities were always presented, but variable delays (0–150ms) were introduced in either both modalities (Experiment 1) or only in one of the two modalities (Experiment 2). Results show a clear recalibration in response to a tactile delay, but not to a visual delay in these bimodal conditions. This indicates that the tactile modality dominated the duration judgements which is in line with the tactile information being more reliable in the temporal domain. Furthermore, this is consistent with previous work on unimodal reproduction tasks that showed a larger effect of tactile delay than visual delay. Together these results highlight the relative higher reliance on the tactile modality for sensorimotor temporal recalibration.

#26. Motor influence on multisensory audio-tactile perception within peripersonal space

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Keywords: Tactile perception, multisensory integration, movement execution, EEG, peripersonal space

Movement execution reduces tactile perception through gating mechanisms, influenced by factors like context, goal, and velocity. These factors can either enhance or suppress tactile processing, depending on its role in guiding movement. Tactile perception is also enhanced when sounds are presented near the stimulated body part, an effect associated with the peripersonal space (PPS). However, no study has examined how motor execution affects audio-tactile perception within PPS. To investigate this, we studied whether arm reaching movements influence the spatial extent of audio-tactile effects linked to looming sounds. Twenty-four participants either remained still or executed a forward right arm movement while perceiving looming sounds and receiving a tactile stimulus on their right index. They rated the intensity of this stimulus relative to a second one delivered immediately after the movement, with no sound. Psychophysical analysis revealed that, in the stationary condition, tactile intensity increased as the looming sound approached, consistent with multisensory facilitation in PPS. However, this effect disappeared during movement, with a slight opposing trend likely due to the spatial mismatch between the final hand position and the auditory stimulus. Preliminary EEG data showed time and frequency patterns linked to movement-related modulation of audio-tactile effects. Our findings suggest that tactile perception is influenced by sound distance, with enhanced multisensory integration at the closest point within PPS. Additionally, movement disrupts this facilitation, leading to suppression when the sound is near but the hand is distant, highlighting the dynamic interaction between motor execution and multisensory processing in space.

#27. The role of sensory consequences in movement replication

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Keywords: Proprioception, Motor control, Movement

Learning a motor skill requires adjusting unsuccessful movements and repeating successful ones. But how do humans replicate successful movements — by repeating its motor command or its sensory consequences? We tested 32 participants in an elbow flexion task without visual feedback of the arm. At baseline, they executed flexion movements to visual targets. We vibrated the triceps muscle (120 Hz), to induce an illusory muscle lengthening and corresponding target movement undershoot. Next, participants searched to hit invisible targets, receiving success-failure feedback. Upon success, they replicated the movement. Some successful trials included vibration, and we analyzed subsequent replication trials without vibration to differentiate between two hypotheses. If participants replicated sensory consequences, they would match the successful flexion angle. If they replicated the motor command, they would overshoot the successful flexion angle. We quantified this by a motor command replication fraction: the average angular change between successful trials with vibration and their subsequent replication trials without vibration, normalized by the baseline visual target undershoot. A motor command replication fraction of one indicates motor command replication, and a fraction of zero indicates replication of sensory consequences. Participants showed a vibration-induced undershooting, both when moving to visual targets (mean 3.7°, ± 1.8° SD) and when repeating non-vibrated successful movements (1.4° ± 2.0°). Crucially, participants showed a mean replication fraction of 0.4, ± 2.0 SD. We found no evidence for the hypothesis that participants repeated successful motor commands. We conclude the sensory consequences of a successful movement are taken into account for movement replication.

#28. Less reliance on sensory inputs during action: a greater role for priors in the sound-induced flash illusion while walking.

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Keywords: Active perception, Multisensory integration, Bayesian modelling, Central tendency, Locomotion

Walking is a complex, multisensory activity that involves continuous integration of sensory inputs, making it susceptible to temporal perception biases. One such bias is the sound-induced double flash illusion, where an individual perceives an additional illusory visual flash when the number of auditory beeps exceeds the number of actual flashes. This illusion is thought to arise due to the superior temporal resolution of the auditory system compared to vision. In this study, we investigated whether the influence of prior expectations related to central tendency differs between standing and walking. we had individuals experience one to three visual flashes (f) alone, auditory beeps (b) alone, congruent pairings, or incongruent fission pairings of flashes and beeps (i.e., 1f2b or 2f3b) while they were either standing or walking. Participants reported the number of beeps they heard when exposed to auditory beeps alone as a measure of baseline auditory ability. Otherwise, the participants reported the number of flashes seen. To assess the role of prior expectations, Bayesian models were fitted to the stationary condition, either including or excluding a central tendency prior. The prior inclusive model provided a better fit, and its prior weight was subsequently used to evaluate sensory weighting during walking. Participants weighted their central tendency prior greater when walking than standing still. This difference was larger when the incongruent sensory pairings included a single flash as opposed to two flashes. These results suggest a down-weighting of sensory input in favour of prior during active movement that is dependent on task difficulty.

#29. The influence of experience on sensory information needed for piano sequence learning

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Keywords: Motor sequence learning, Auditory, Audiovisual, Music

The contribution of different sources of sensory feedback to piano sequence learning has been extensively studied in experienced pianists. However, minimal research has focused on the use of sensory information in novice piano sequence learning. Our study investigated the role of sensory feedback in piano sequence learning in individuals with (experienced) and without (novice) previous piano learning experience. Novice (N=17) and experienced (N=10) piano players performed piano sequences across three different sensory feedback conditions: audiovisual, auditory-only, visual-only. On day one, participants performed a pre-test, an acquisition period, and an immediate retention test. During the pre-test, participants performed three sequences and received audiovisual feedback. During the acquisition trials, participants practiced each sequence at both 60BPM and 120BPM. Each sequence was randomly assigned to a sensory feedback condition (i.e., audiovisual, visual-only, or auditory-only). During acquisition, participants were provided with feedback about their sequence accuracy (i.e., correct or incorrect) and sequence asynchrony (i.e., timing between stimulus and response). The post-test assessed immediate retention by having participants perform each sequence with audiovisual feedback. Participants then performed a 24-hour delayed retention test, identical to the pre- and post-test. Analysis of the data revealed that both experienced and novice groups, significantly improved in both accuracy and asynchrony between the pre-test and post-test, and the pre-test and retention test regardless of the sensory condition in practice. When comparing between groups, experienced participants were significantly more accurate [$F(1.40, 34.08) = 4.52$, $p < 0.05$)] and synchronous [$F(1.17, 29.27) = 4.005$, $p < 0.05$] than novices.

#30. Proprioception allows integrating gravitational force in the planning of arm pointing movements: an EEG study

Godines, Aurélien [1], Mouchnino, Laurence [1, 2], Gaveau, Jérémie [3], Blouin, Jean [1]

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Keywords: Gravity, Proprioception, Planning, Pointing, Kinematic, EEG

The effect of gravitational force varies considerably during ongoing arm movement, depending on the arm's orientation relative to the vertical axis of gravity. This variation is most pronounced during vertical movements and negligible during horizontal movements. Considering the gravitational force during rapid arm movements most likely relies on the integration of gravity-related sensory inputs from the movement planning stage (proprioceptive, visual, and vestibular). This study specifically investigated if proprioceptive feedback from the arm contributes, and if this contribution is greater for non-horizontal movements. Based on the premise that the cortical sensitivity increases with task-relevant sensory feedback, we hypothesized that the somatosensory cortex's response to vibration-induced stimulation of the shoulder muscles during movement planning would be greater for non-horizontal movements. With their right arm fully extended and initially pointing straight-head at shoulder level, participants (n=18; 9F, 9M; mean age: 21 ± 3.92 years) produced rapid arm movements to targets in different directions (vertical up and down, 45° up and down, horizontal) upon illumination. All targets required 45° shoulder movements. Kinematic and EEG data were recorded. The 200 ms-vibration of the anterior deltoid started 100 ms after target onset (i.e., 270 ± 30 ms before movement initiation). Source analyses of the EEG signals showed significantly greater somatosensory cortical response for both vertical up and down directions compared to horizontal ($p<0.05$), with a trend towards significance ($p=0.08$) for diagonal up. This suggests that arm muscle proprioception is a key signal for the brain to account for effects of gravity on movements.

#31. Virtual bubbles, real insights: A novel approach to mapping peripersonal space in autism and beyond

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Keywords: Peripersonal Space, Autism, Multisensory Integration, Spatial, Motor

Peripersonal Space (PPS) is a dynamic sensory-motor interface critical for adaptive functions such as spatial navigation, motor planning, body schema awareness, and social engagement. Alterations in PPS processing have been linked to sensory-motor challenges in autism, affecting obstacle avoidance, object manipulation, and dynamic task recalibration. Understanding PPS in autism is crucial for addressing these challenges and developing tailored interventions. Our novel Bubble Pop task enhances PPS measurement by bridging temporal and spatial aspects, integrating elements of simultaneity judgment (SJ) tasks with reaching-based paradigms to dynamically capture multisensory integration (MSI). While traditional SJ measures emphasize temporal precision, our approach extends this by incorporating spatial coordination, providing a more comprehensive assessment of PPS flexibility and its neural and physiological underpinnings. Our task is both ecologically valid and designed to be simple to allow the inclusion of a broader profile of autistic participants. To investigate PPS mechanisms, we leverage VR/AR, motion capture, eye tracking, physiological monitoring, and neuroimaging to examine how sensory-motor integration shapes spatial perception and interaction. Preliminary pilot testing in a VR-based version demonstrates feasibility, and anticipated results include a detailed characterization of PPS variability in autism, offering insights into its role in adaptive responses. By linking PPS mechanisms to sensory-motor integration and functional outcomes, this research informs interventions aimed at enhancing spatial navigation, social communication, and sensory-motor coordination in autism. Beyond autism, our novel bubble pop task has broader applications for studying sensory-motor integration in the general population, with implications for neurorehabilitation.

#32. Validating the spatial fidelity of three-dimensional auditory simulation in a virtual audiovisual cave environment

Watson, Marcus [1], Rosencrans, Samuel [1], Mansouri, Samir [1], King, Mckenzie [1], Goyal, Shatakshi [1], Stein, Gordon [1], Tovar, David [1], Wallace, Mark [1]

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Keywords: Audiovisual localization, Simulation, AR/VR

The MELD Cave space includes an array of 24 speakers arranged around a 4m cube, intended to simulate sound sources anywhere in this cube using Ambisonics. How can we quantify the fidelity of the resulting simulation? We present two different ways to do this: spherical microphone recordings and pointing tasks. In both cases, we compare results from presentations using white noise bursts from single speakers (true sources) to those using spatialization (virtual sources). First, we compare the 19-channel recordings from a Zylia ZM-1E microphone, where the area between curves recorded from real and virtual sources represents the imprecision of the simulation. Second, we instruct participants to point at the perceived locations of sounds in the cube while we track their heads and hands, with their eyes open and eyes closed (visual and non-visual conditions). Differences in accuracy, precision, time of pointing initiation, and duration of pointing movements to real and virtual sources can be computed both allocentrically (world-centered coordinates) and egocentrically (head-centered coordinates), and these differences also indicate imprecision of the simulation. Both microphone and pointing analyses are used to quantify the fidelity of the MELD Cave's spatial audio

simulation, providing empirical justification for the “wow” factor one experiences when one first enters a truly accurate spatial sound simulator.

#33. Gamified exploration of a superfunctional virtual body

Johannsen, Leif [1], Pi, Yuke [2], Bird, Laura [3], Thurlbeck, Simon [3], Gillies, Marco [2], Pan, Xueni [2], Cowie, Dorothy [3]

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Keywords: virtual reality, body representation, motor decisions, motor development, childhood

Normally, we have a good idea whether we can jump over an obstacle of a particular height. How would it feel to gain the ability to jump to impossible heights without much physical effort? New virtual reality experiences offer users a chance to use enhanced ‘superfunctional’ bodies which allow them to virtually perform actions that are physically impossible in the real world (e.g. super-high jumps). Can users adapt to these experiences, and will they choose to use superfunctional actions in a VR environment? Deciding which action to perform among alternatives considers an action’s cost (mental or physical effort), and its expected benefit (reward). Any ‘optimisation’ strategy for action selection which trades off these factors may be age-dependent. The decisions determine subsequent motor experience, which shapes bodily knowledge. Using a full body, immersive VR environment, we investigated how short-term embodiment of a superfunctional body in a ‘jump and climb’ game alters the perception of one’s own real physical capabilities in thirty adults and thirty children (between 7 and 9 years). We expected children to explore their superfunctional capabilities of their virtual bodies (jumping superpower) more disregarding external reward, mental and physical effort. In contrast, adults were expected to follow an ‘optimisation’ strategy sensitive to the trade-offs between speed, offered external reward, mental and physical effort. Consequently, we expected children to demonstrate stronger sense of ownership over their virtual bodies and stronger aftereffects in the (mis-)representations of their bodies’ real functional capabilities. This presentation will summarize the results.

#34. Extends robots body representation with artificial tool embodiment framework

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Keywords: Tool Embodiment

Somatosensory perception enables humans to integrate handheld tools into their body representation, allowing blind individuals to explore environments using a white cane in darkness and aiding surgeons in performing operations with a scalpel under occluded vision. However, current robots lack feasible methods that can enable tool embodiment, which could integrate handheld tools into their sensing systems and extend their somatosensory capabilities beyond the limits of their bodies. In this work, we propose an artificial perception network to estimate the contact force and contact location between handheld tools and the environment using only tactile and proprioceptive sensing. Through experiments with a robot equipped with a tactile dexterous hand and comparative experiments with four human participants, the proposed framework achieved human-level position and force perception abilities. The correlation coefficients for position and force perception were 0.993 and 0.983, respectively, computed against ground truth data. These experimental results demonstrate the feasibility of achieving environmental perception without relying on visual inputs through the artificial perception framework and show that robots can extend artificial somatosensory capabilities to handheld tools, providing a reliable and precise perception method for future applications in human-machine interaction, dexterous manipulation, and embodied interaction.

#36. Real or Virtual? Gravity Influences Judgements of Face Realism

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Keywords: Gravity, Face perception, Virtual reality

In today's digital world, understanding whether the person we are looking at is real or a rendered avatar is surprisingly difficult. Background images might be useful in helping us to make such judgements, with faster responses when background scenes are congruent with the realism of the face (photograph on photograph background/render on virtual background, vs photograph on virtual background/render on photograph background). Our concept of realism, however, may be more complex than appearance alone, encompassing prior expectations of the environment such as gravity. Our brain constructs an internal model of gravity from multiple senses, which has a powerful influence on many tasks, with greater precision in object interception and motion judgements when objects obey the physics of expected terrestrial gravity. Here, we investigated whether visual gravity plays a role in judgements of face realism. Participants viewed photographs or renders of faces and were asked to classify whether the face they saw was a real person or an avatar as quickly and accurately as possible. Faces were presented on congruent or incongruent backgrounds. Backgrounds could be upright or upside-down, manipulating visual gravity in the scene. Background congruency had a significant impact on reaction times: participants were faster to classify face realism when the background was congruent with face type. Crucially, this was only the case for upright backgrounds, with participants equally fast in congruent and incongruent conditions when backgrounds were upside-down. These results add to our understanding of gravity's pervasive role in perception and cognition, demonstrating its influence on person perception.

#37. Decoding phonological features in the brain network for audiovisual speech

Rabini, Giuseppe [1], Lund, Giulia [2], Tommasini, Mirko [2], Mencaroni, Maria Laura [2], Mazzi, Giulia [1], Valzolgher, Chiara [1], Wurm, Moritz [1], Berger, Michael A. [3], Pavani, Francesco [1], Benetti, Stefania [1]

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Keywords: audiovisual speech, phonological features, MVPA decoding, fMRI

Speech perception relies on subtle but fundamental units known as phonemes—basic building blocks that enable us to recognize and differentiate language, from syllables up to words and sentences. In natural face-to-face communication, speech perception is further enhanced by visual cues, such as lip movements, which are the visual counterpart of phonemes, called visemes. Together, these elements contribute to the phonological representation of audiovisual speech. However, it remains unclear how the brain network involved in audiovisual speech perception encodes phonemes and whether its regions differentiate between distinct phonological features. Phonological traits such as Voicing, Manner, and Place of articulation traditionally describe phonemic similarities and distinctions. This study characterized the multimodal brain network supporting audiovisual speech perception and examined whether these regions differentiate phonological representations based on phonological traits. Twenty-four participants completed a behavioral task identifying and categorizing audiovisual consonant-vowel stimuli based on phonetic and visemic features, followed by an fMRI oddball paradigm using the same stimuli. We also developed models of phonological representational similarity based on acoustic, visual, and articulatory properties. The physical models only partially correlated with phonological trait-based models, suggesting the latter may reflect higher-level categorical representations. At the neural level, audiovisual speech perception engaged auditory and visual regions and part of the pre-/motor cortex overlapping with area 55b, recently linked to complex behavioral coordination. ROI-based multivariate decoding analyses indicated that phonological traits are only partially represented within the neural networks underlying audiovisual speech perception.

#38. Imagination and speech perception in noise: The role of contextual priors

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Keywords: autism spectrum disorder, auditory perception, speech perception, imagination, prior knowledge

Individuals with autism spectrum disorder have difficulty perceiving speech in background noise, particularly with temporal dips (e.g., Alcántara et al., 2004). This difficulty may arise from difficulties in temporal integration. In our previous study, we hypothesized that individuals with high autistic traits have difficulty perceiving speech in noise because they have impaired integration of auditory inputs using prior knowledge. We found that difficulties in perceiving high-familiarity words in noise were associated with imagination difficulties related to autistic traits because imagination requires the use of prior knowledge or experience (Tsuji et al., 2024). The present study investigated the relationship between speech perception in noise and the use of contextual priors learned over a short time span. We hypothesized that imagination difficulties would account for the difficulties in perceiving learned words, but not unlearned words. Japanese adult participants learned low-familiarity words, and then detected three types of target spoken words in noise: unlearned words, learned words detected after a delay, and learned words detected without delay. Contrary to our hypothesis, imagination ability was not related to detection performance in any condition. Therefore, the ability to use contextual priors learned over a short time span may not be related to perception of speech in noise.

#39. On the efficacy of temporal visual speech cues for comprehending degraded speech and for solving the cocktail party problem.

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Keywords: Audiovisual, Cocktail party, Degraded, EEG, Speech, Temporally, Modes

Audiovisual speech integration has been proposed to operate via two processing modes: a correlated mode – whereby temporally correlated visual speech cues enhance auditory cortical sensitivity; and a complementary mode – whereby complementary visual articulatory information enhances the categorization of auditory speech into linguistic units (Campbell, 2008). Here, we investigate under which conditions these modes aid in audiovisual integration. We hypothesize that temporally correlated visual cues (an ellipse tracking a speaker's mouth) should aid in attending to a target speaker in a cocktail party scenario. However, this same cue should not aid in comprehending vocoded speech, where temporal correlations do not provide the necessary complementary information. Subjects perform a word detection task as they are presented with either vocoded speech or a cocktail party paradigm in four conditions: audio only (A), visual speech only (V), audio and video of the speaker with an overlayed, blurred ellipse tracking mouth movements (audiovisual ellipse, AVE), or a clear video of the speaker with the audio (AVC). Preliminary data show that an ellipse improves speaker detection in a cocktail party scenario but does not aid comprehension of vocoded speech. We expect EEG tracking of acoustics in the target signal to be strongest when subjects have access to both correlated and complementary modes (AVC) but to be significantly weaker when only presented with a correlated visual cue (AVE). This pattern of results will support the differential ways in which correlated visual cues can aid in speech comprehension and highlight when complementary visual cues are required.

#40. Resting-state functional connectivity within the language network in deaf and hearing individuals

Vinogradova, Valeria [1, 2, 3], Manini, Barbara [2,4], Woll, Bencie [2], Cardin, Velia [2]

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Keywords: Deafness, Sensory experience, Language, Resting state, Functional connectivity, fMRI

Early deafness can influence the functional organisation of brain networks and is associated with heterogeneity in language experiences and language acquisition through the visual modality. Using resting-state functional connectivity (rsFC), we studied how sensory experience and language modality shape the functional architecture of the language network. We conducted analyses of rsFC in two datasets of hearing nonsigners (dataset 1: n = 17; dataset 2: n = 20) and deaf participants with different language experiences: those who were early or native signers (dataset 1: n = 18) or had diverse language backgrounds (e.g. acquired sign language at birth, or after acquiring English as the first language) and varying proficiency (dataset 2: n = 25). The analysis of rsFC between 16 regions of interest (ROIs) of the language network showed no significant differences between the groups within each dataset. We conducted Bayesian independent samples t-tests for the same connections to confirm the absence of differences. The majority of tests showed anecdotal to moderate evidence in favour of the null hypothesis. Finally, we compared similarity between group-averaged ROI-to-ROI connectivity matrices across all combinations of groups, applying the Mantel test of correlation between pairs of matrices. Significant and strong associations were confirmed between all pairs. Our findings suggest that different sensory experiences and language acquisition backgrounds do not lead to extensive differences in the rsFC of the language network. Acquisition of a natural language in any modality shapes the language network in a similar way across individuals with different sensory and language acquisition experiences.

#41. Can we translate colour through touch? Investigating touch-colour associations in the blind, colourblind and sighted

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Keywords: Touch colour synaesthesia, crossmodal correspondences, visually impaired, achromatopsia

Recent studies have revealed the existence of cross-modal associations between tactile sensations (e.g. “soft” or “cold”) and colours (e.g. “pink” or “blue”). These associations have been shown in touch-colour synaesthesia, a condition in which a sensation in one modality evokes a perceptual and automatic sensation in another modality. In non-synaesthetes, these associations are not perceptual and automatic, and a cross-modal association task feels “random” to them, but they do show a pattern when forced to choose a colour for a material. To explore the underlying mechanisms of touch-colour associations and the possible applications for translating colour by using touch for blind people, we study those associations in sighted, blind and colourblind individuals. First, we investigated whether intact sensory colour processes are necessary for touch-colour associations. We studied an achromatic observer, M.S., and a typically sighted control group (N=17). M.S. and the controls performed a forced-choice task where they touched a material and chose from two colour options which they associated with the material. When choosing from colour words, M.S. had similar associations between the material and the colour as controls. However, when M.S. chose from colour patches, he did not show associations similar to controls. The results suggest that touch-colour

associations can exist at a conceptual level. Building on these findings, we now aim to study touch-colour associations in blind individuals, who will report the associations verbally. To determine how verbal reporting, rather than using a colour picker, influences touch-colour associations, we are currently testing blindfolded participants.

#42. Synesthesia model: Musical pitch representation in Japanese junior high school students

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Keywords: synesthesia, cognitive process, metaphor, musical pitch, Japanese language

Japanese people conventionally describe musical pitch in terms of spatial height, whereas languages like Farsi represent pitch in terms of thickness. Most research on this phenomenon has been conducted in Western contexts, and findings indicate that infants and children do not show systematic cross-modal mappings for pitch. The current study investigates (i) to what extent Japanese junior high school students, who are accustomed to height metaphors for pitch in formal music education, represent the height-pitch association visually and verbally, and (ii) what cognitive processes are activated when they encounter unfamiliar space-pitch metaphors. First, the participants listened to three different-pitch sounds, visualized their relationship by drawing three circles, and verbally explained the reason for their drawing. They were then taught that Farsi speakers describe pitch as “thin” and “thick” and were asked to infer which words correspond to which Japanese words, “high” or “low”, providing verbal justifications for their reasoning. The results indicate that: (i) Japanese junior high school students strongly associate height with pitch, with some also evoking size-pitch and heaviness-pitch associations; and (ii) they can infer Farsi-like pitch mappings (low=thick, high=thin) by using other underlying but linguistically-backgrounded dimensions like heaviness as mediating concepts, although one student reversed the mapping providing a convincing explanation based on a “thickness-accumulation-height” association. These findings suggest that, while linguistically conventionalized height metaphors shape Japanese people’s pitch representation, other presumably pre-existing but linguistically-backgrounded associations can be evoked and foregrounded as mediators when people are asked how they conceptualize pitch or when they understand unfamiliar metaphors.

#43. Number of types of synaesthesia can be predicted by structural and functional neuroimaging data

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Keywords: Synaesthesia, Synesthesia, Neuroimaging, Machine learning

Synaesthesia is a neurological condition in which sensory input to one modality results in automatic, concurrent output in an additional modality (Cytowic, 1989). These additive multisensory percepts can be sorted into ten broad clusters: Personification, Sequence-space, Language-color, Visualized sensations, Language-taste, Smell-taste concurrents, Language-touch, Hearing-motion, Tickertape, and Mirror-touch (Ward & Simner, 2022). It has been suggested that synaesthetes have a distinct neurocognitive profile with a broad variety of cognitive and behavioral differences, but it remains debated whether the classification of being synaesthetic is binary or continuous (Deroy & Spence, 2013). It was recently shown that synaesthetes could be distinguished from controls using machine-learning methods with structural and functional biomarkers, and that subjects with more types of synaesthesia were more accurately classed (Ward et al., 2024). In the current study, we assess the performance of these 13 different brain-based biomarkers in predicting the number of types of synaesthesia exhibited by a given participant. This analysis specifically probes the 102 synaesthetes within the open-access dataset and the 13 biomarkers derived from subject-specific cortical

parcellations (Racey et al., 2023). Using machine learning methods (elastic net regression), we were able to find multiple biomarkers with high predictiveness and R-values significantly above chance levels for number of types of synaesthesia, including functional connectivity centrality, cortical thickness, intracortical myelination, and intracortical myelination centrality. This is the first “more” synaesthetic. project that explores whether it’s possible to predict if someone has more types of synaesthesia from their neural profile, and suggests that neural features reflect being “more” synaesthetic.

#44. Visual and Tactile Motion Cues Enhance the formation of Novel Object Categories: an Online Study

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Keywords: Object Categories, Multisensory Perception, Haptic Vibration, Object Motion, Online Testing

Multiple sources of information are used to categorise objects, including its shape, how it moves and feels. Yet how these cues are combined remains unclear. Particularly, the role of visual and tactile motion in the formation of novel object categories is unknown. We investigated whether visual and tactile (vibration) motion cues affect the categorisation and generalisation of novel objects under different cue reliability conditions. We hypothesized that visual and haptic motion cues would improve categorisation accuracy relative to object visual shape-only, particularly when shape was less reliable. We designed a continuum of novel 3D-shapes, divided into two arbitrary categories, each associated with distinct (and synchronised) visual and haptic motion cues. Both experiments were conducted online on smartphones. In Experiment-1, 46 participants learned to categorise 3D-objects in which all cues were 100%informative of category membership. In Experiment-2, 32 participants learned to categorise the objects when the informativeness of shape only was reduced (78%informative; visual and tactile motion cues remained 100%informative). Categorisation performance was measured across three conditions: shape-only, two-cues (visual and tactile motion), and three-cues (shape with visual and tactile motion). Accuracy increased with each additional cue, peaking in the three-cue condition. When shape was unreliable, multisensory integration sharpened category boundaries, with greater reliance on motion (visual and tactile) cues. Tactile-motion cues contributed more to accuracy than visual-motion cues, with good generalisation to novel exemplars. These findings suggest multisensory benefits in the acquisition of novel categories, particularly when shape is unreliable. Our study opens the possibility of conducting haptic online experiments.

#45. Visual Attention in Children and Adults during Visuohaptic Object Category Learning

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Keywords: Developmental Perception, Object Categories, Category Learning, Visuohaptic Crossmodal Perception, Eye, Tracking

How children learn to form object categories depends on their ability to selectively attend to relevant features, such as surface properties, that are diagnostic of category membership. Efficient categorisation requires the ability to identify relevant features across multiple senses. Previous studies suggest young children can attend to local features, but struggle to integrate them into a whole. By age eight, sensory cortices have matured, supporting global object processing and crossmodal transfer with adult-like efficiency. However, age-related differences in top-down mechanisms may still impact category learning under multisensory conditions. We compared 8–9-year-old children and adults in their acquisition of novel object categories. Eye-tracking was used to investigate selective attention to relevant features during learning. Participants attended to visual-only features (e.g., colour) and visuohaptic features (e.g., texture) under three learning conditions: when

they were preinstructed that they would be tested visually, haptically, or in either modality. Object categories were defined by two visual and two visuohaptic diagnostic features, alongside other uninformative features. After learning, participants completed a categorisation test in one of the specified conditions. Eye fixation duration and gaze patterns were analysed in relation to learning accuracy. Adults fixated longer on visuohaptic features when expecting a haptic or unspecified test, suggesting efficient exploratory behaviour. In contrast, children showed more distributed attention and reduced ability to focus on relevant features, regardless of the test condition. These findings offer insight into how multisensory objects are encoded during development and contribute to our understanding of how children acquire object categories from multisensory features.

#46. Multisensory presentation does not facilitate perceptual category learning

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Keywords: category learning, audiovisual, audition, vision, multisensory, learning

Categories in the natural world are inherently multisensory, yet studies of category learning often focus on learning in a single modality. It is not yet clear how learning may differ when information is presented in one modality or multiple modalities simultaneously. Here, we directly compared unisensory and multisensory learning of the same audiovisual categories (high vs. low temporal modulation rate; high vs. low spatial frequency). On each trial, participants were presented with pairs of auditory and visual stimuli either simultaneously (multisensory) or separated by 150 ms (unisensory; counterbalanced order across trials). The audio-visual pairs were identical across conditions. We tested learners' ability to generalize to novel auditory-only, visual-only, and multisensory stimuli. Overall, there were no significant differences across conditions in accuracy or reaction time during training or test. Unexpectedly, across conditions, learners had a slight bias towards the auditory modality (better performance for auditory than visual trials and responses to incongruent information across modalities was aligned more with the auditory modality). These results demonstrate the necessity of considering the role of modality in models of perceptual category learning. These results also conflict with some prior work in other learning domains that demonstrate multisensory facilitation of learning. While controlling for the information presented across conditions, multisensory stimulus presentation did not benefit learning compared to unisensory stimulus presentation. Together, these results suggest that to understand real-world multisensory category learning it is important to investigate learning beyond a single modality.

#47. Representations of the "bouba-kiki" effect in the early visual cortex

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Keywords: audiovisual, fmri, neuroscience, multisensory, sound symbolism

Sound symbolism, known as the "bouba-kiki effect," shows that humans make consistent associations between meaningless speech sounds and visual shapes. People typically associate words like "bouba" with rounded shapes and "kiki" with angular shapes, indicating a cross-modal link between speech sounds and visual features. While behavioral experiments have demonstrated sound symbolism extensively, its neural basis remains poorly understood. Building on research showing that early visual cortex can represent auditory stimuli, we investigated whether visual cortices are sensitive to implicit shapes conveyed by sound-symbolic speech sounds. We conducted an fMRI study with 24 blindfolded adults who listened to sound-symbolic words (rounded, spiky, and mixed) and rated their associated shapes. Using multivariate pattern analysis (MVPA) and representational similarity analysis (RSA), we examined neural activity in visual, auditory, and control regions. Behavioural results confirmed the bouba-kiki effect, with participants consistently matching "round" words to

rounded shapes and "spiky" words to angular shapes. The MVPA analysis revealed successful decoding of "round" versus "spiky" sounds in both primary visual cortex (V1) and primary auditory cortex (TE1.2). A whole-brain searchlight analysis also showed successful decoding in the right intraparietal cortex and left superior temporal gyrus. The RSA further confirmed a positive correlation between the distances of the sound-symbolic shapes across both neural and behavioral data. These findings demonstrate that early visual cortex and intraparietal cortex can represent associated shape from speech sounds even without visual input, suggesting that sound symbolism reflects genuine sensory and cross-modal associations in the brain rather than being a purely linguistic phenomenon.

#48. Touching Bouba/Kiki: Understanding touch-affect associations in textured surfaces

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Keywords: Bouba, Kiki, cross, sensory, texture perception, affective touch, roughness perception

The Bouba-Kiki effect, originally described as a cross-sensory association between visual shapes and linguistic sounds (e.g. Ramachandran & Hubbard, 2001), has recently been extended to the tactile domain in the absence of visual input (e.g., Feng et al., 2022). However, most research has focused on macro-level object shapes, with little attention to how surface texture influences Bouba-Kiki associations. Furthermore, the role of microstructural features—such as fine-scale variations in roughness—remains underexplored, particularly in relation to emotional and color associations of the object. In this study, participants explored textured stimuli varying in roundness and size, either with or without vision. They rated perceived shape (Bouba-Kiki categorization), and roughness, on a Likert scale and provided emotional and color associations. Results indicate that perceived roughness correlates with Bouba-Kiki judgments, with finer textures being rated as more pleasant, while coarser textures elicited higher arousal and were associated with brighter colors. The influence of vision was stronger when surface features were smaller, suggesting a scale-dependent interaction between visual and tactile processing. Overall, this study highlights how fine tactile dimensions, in addition to shapes, influence affective and sensory associations, offering new insights into the cross-sensory integration of micro and macro tactile features for sound symbolism.

#49. Exploring perceptual grouping in vision and touch

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Keywords: Gestalt, Haptic, Pattern discrimination, Similarity, Vision

The ability to group individual elements into a coherent whole is fundamental to our ability to make sense of complex environments. For example, individual objects parts must be correctly grouped together or segregated to aid object identification and recognition. However, compared to vision, relatively little is known about how Gestalt grouping principles operate for the sense of touch. To investigate this, young adult participants were tasked with matching patterns in a standard XAB design. Each pattern was asymmetric and consisted of a unique array of 16 bumpy bricks set within a smooth tile background. The bricks could be grouped into global patterns based on the Gestalt principle of similarity (via height and texture). Exploration was temporally constrained and conducted unimodally across vision and haptics. Additionally, each pattern was either continuous or disrupted by a randomly positioned barrier that was distinct both visually (via size and colour) and haptically (via size and height). Overall, visual performance was similar to haptic performance with high discrimination accuracy observed in both modalities. As expected, dissimilar patterns were easier to discriminate than similar patterns across modalities while the presence of a barrier did not degrade performance in either modality. Our results indicate that participants are successfully able to group individual elements into global patterns in both the visual and haptic modalities. This study will be

extended to older adults to investigate how healthy ageing impacts Gestalt perception in both the visual and haptic domains.

Poster session 2

#1. Audiotactile simultaneity perception in bilateral congenital cataract patients

Retnavarathan, Fermin [1], Nichols, Tara [1], Turkstra, Jordan [1], Morgan, Riley [1], Saini, Dasnoor [1], Silva, Andrew [2], Thompson , Benjamin [2], Gao, Xiaoqing [3], Lin, Haotian [4], Wong, Agnes [2] [5], Maurer, Daphne [1] [5], Niechwiej-Szwedo, Ewa [6], Shore, David [1]

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Keywords: Audiotactile perception, Simultaneity judgement task, Cross modal perception, Deprivation cataract

Despite correction shortly after birth, individuals born with bilateral cataracts demonstrate abnormal audiovisual but normal visuotactile simultaneity perception (Chen et al., 2017). This finding is intriguing given that vision is involved in both pairings. To explain this difference, Chen et al. (2017) proposed two hypotheses. The cross-modal calibration hypothesis states that the more reliable sense will calibrate the less reliable sense during development. Short-term visual deprivation caused by bilateral cataracts may have impacted the typical calibration of audition by vision in these patients impacting their audiovisual simultaneity perception. Alternatively, faster-than-normal auditory processing suggests the absence of vision may have allowed for the exceptional development of audition which would explain the abnormal audiovisual simultaneity perception in these patients. To evaluate these hypotheses, we tested audiotactile simultaneity perception in these patients using a simultaneity judgement task. We predicted results would provide support for the cross-modal calibration hypothesis as vision is not present in the audiotactile pairing. Thus, the typical calibration of audition by touch should not be impacted. Using the ALCALA model (García-Pérez & Alcalá-Quintana, 2012), we extracted eight parameters on which we compared performance from 14 patients and 42 age- and sex-matched controls. Preliminary results reveal no significant differences in performance between patient and control groups. However, visual inspection of the data highlight potential differences. The patient group shows large variation with patient performance separating into two visual groups. In support of faster auditory processing, there appears greater variability on the touch leading side. We are seeking additional patient data.

#2. Visual Activation During Imagination Increases in the Blind Following Vision Restoration: Two Case Studies

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Keywords: Retinal Prosthesis, Visual restoration, Ventriloquist, Imagination, Cortical Plasticity, Blindness

Ultra-low vision can be restored to the late blind with prostheses that electrically stimulate retinal cells. The Argus II relays visual information from a head-mounted camera to the retina, and is implanted in individuals with light-perception or less. Decades of profound vision loss can result in multisensory reorganization and structural atrophy of visual cortex, however it is yet unclear the extent that visual restoration can functionally reengage visual circuits. To address this, we collected fMRI data on two Argus II patients before and after implantation while they performed visual imagery tasks. Since the Argus II device cannot be activated in the scanner, participants were asked to imagine a visual object, or place during the task-active blocks, interleaved with rest phases without any visual imagining. Participants also performed a ventriloquist task, during which they localized a presented sound while visually imagining (task vs. rest). In the imagination task, the longer-using participant (44.5 months) showed a sole cluster of increased BOLD response in the right Lateral Occipital Cortex following implantation (contrast of task > rest, post > pre; thresholded $z>1.7$, cluster corrected $p<0.05$). A second, shorter-using participant (6.5 months) did not show this specific occipital BOLD difference, instead showing increases in the parietal cortex postcentrally and adjacent to the TPJ post-implantation. The ventriloquist task showed less of a clear pattern of activation, potentially due to task complexity. Overall, these case study results complement our recent cortical thickness research showing that higher visual regions can be reinvigorated following visual restoration in longer-using patients.

#3. Assessing the impact of mixed reality scotoma simulation on auditory and visual spatial perception

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Keywords: Simulated Impairment, Scotoma, Cross modal perception, Mixed Reality (MR)

Scotoma is a blind spot in the visual field that can influence both visual and auditory spatial perception. Previous studies demonstrated central scotomas can disrupt audio-spatial perception by biasing the sound localization toward the scotoma's position. Through current extended reality (XR) technologies, we can now broaden the investigation of these perceptual effects to individuals who are not inherently affected by scotoma, delineating the time required to induce such perceptual changes. This study examines how a simulated central scotoma, produced by a Mixed Reality (MR) immersive system designed to simulate real-time visual impairments, alters auditory and visual-spatial perception. For this, we recruited healthy adults, dividing them into simulated scotoma and control groups (both wearing the MR system). Participants performed spatial localization tasks with auditory and visual stimuli which were presented via a 5×5 touchpad speaker grid or a touchscreen. The scotoma group had 60 minutes of scotoma with MR during visuo-motor tasks and video watching, while the control group did the same without scotoma. Results show accurate visual localization in

both groups after the experience, with auditory localization exhibiting a central bias. Simulated scotoma participants demonstrated increased dispersion of responses within the affected visual field, indicating distinct mechanisms compared to the control group. The simulated central scotoma group showed a smaller central tendency compared to controls. These findings suggest that simulated scotoma through an MR immersive system induces cross-modal perceptual distortions, providing insights into sensory plasticity. The consequences of this study emphasize the need for innovative approaches to explore sensory interactions.

#4. Rehabilitating Amblyopia: Establishing Measures of Hidden Binocularity

Nichols, Tara [1], Retnavarathan, Fermin [1], Silva, Andrew [2], Chen, Xiaoxin [2], Thompson, Benjamin [2], Gao, Xiaoqing [3], Wong, Agnes [4], Maurer, Daphne [1], Niechwiej-Szwedo, Ewa [5], Shore, David [1]

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Keywords: Binocular Vision, Amblyopia, Vision, Motion Perception

Amblyopia represents a lifelong neurodevelopmental disruption of binocular vision, and thus depth perception. Lack of depth perception has implications for day to day living: reading, driving, and even walking down a flight of stairs can all be affected. Although individuals with amblyopia typically fail all standard clinical tests of binocular vision, a subset of these individuals demonstrated an intact Pulfrich illusion, which indicates some hidden binocularity (Maehara et al., 2019). The illusion manifests when a neutral density filter covers one eye while stimuli move horizontally across a display. The neutral density filter creates a delay in processing for the affected eye. This delayed processing introduces a spatial disparity between the two eyes, which creates the illusion of depth. To explore this idea of hidden binocularity, our team developed a novel battery of binocular vision tests, designed to probe the role of object motion in binocularity. Simultaneously, we developed a series of motor performance tasks. Based on the spared visuo–tactile simultaneity perception in individuals with deprivation amblyopia (Chen et al., 2017), we expect successful rehabilitation paradigms will require integration of touch, motion, and motor haptics. The presented data will focus on the measurement and validation of hidden binocularity in controls and individuals with amblyopia. Despite poor performance on standard clinical tests of binocularity, some individuals with amblyopia demonstrated hidden binocularity on some tasks in the battery.

#5. Impact of touch pleasantness on Braille reading

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Keywords: Braille, learning, emotion, tactile perception, visual impairment, neurophysiology

Braille has transformed reading and writing for the visually impaired, enhancing their quality of life. It remains a vital skill as visual impairments grow more common. Braille reading engages tactile perception and fine finger movements, involving the somatosensory and motor cortices, as well as connections with the limbic system for emotional processing. Despite this involvement of emotional pathways, previous research has often overlooked how touch pleasantness specifically affects Braille learning. This project aims to fill this gap by investigating how pleasant tactile sensations affects Braille learning. We suggest that using a surface perceived as pleasant will facilitate Braille reading. More specifically, pleasant surfaces will increase reading speed and decrease reading errors. To test this hypothesis, reading performance (i.e., reading speed and number of errors) will be measured

using the standardized MNREAD test in Braille, printed on surfaces with different textures. A tactile acuity test will also be included. Pleasantness will be evaluated through electrodermal responses and subjective hedonic judgment scales. Additionally, EEG will be used to examine the neurophysiological responses associated with these tactile stimuli. By gaining a better understanding of the interaction between tactile perception, emotions, and Braille learning, we hope to open new perspectives for improving Braille teaching methods. This new insight will also help us design more engaging tactile reading materials for visually impaired individuals.

#7. Spatial influence on audio-tactile temporal processing: insights from blindness and development

Amadeo, Maria Bianca [1], Cuppini, Cristiano [2], Tonelli, Alessia [1] [3], Tammurello, Carolina [1] [4], Setti, Walter [1] Campus, Claudio [1], Signorini, Sabrina [5], Cocchi, Elena [6], Bonino, Margherita [7], Tinelli, Francesca [8], Camicione, Paola [9], Serafino, Massimiliano [9], Gori, Monica [1]

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Keywords: Blindness, Space, Temporal perception, Audio, Tactile processing, Development

Determining the temporal relationship between multiple stimuli is a challenge for the brain, as some tolerance for temporal asynchronies is necessary to create coherent representations of the world. Based on implicit causal inference, we hypothesized that spatial features influence temporal processing, as stimuli from the same spatial location are likely perceived as originating from a common source and merged in time. Given that visual experience shapes sensory spatial maps, we expected it to modulate this effect. We tested 41 sighted and 26 blind children and adults (ages 6–55) in an audio-tactile temporal order judgment task. Participants judged the temporal order of an auditory and a tactile stimulus while their relative spatial coordinates were manipulated. Stimuli were delivered from either the same or different hands (somatotopic manipulation), with hands positioned either close together or far apart (spatiotopic manipulation). Sighted individuals showed age-related improvements in temporal resolution, whereas blind children performed at the level of both sighted and blind adults. Notably, spatial manipulations influenced temporal processing in sighted but not blind participants, regardless of age. Sighted individuals exhibited reduced temporal resolution and greater tolerance for asynchronies when stimuli were somatotopically or spatiotopically congruent. To explain these findings, we developed a biologically inspired neurocomputational model, which suggests that the results arise from spatially organized synaptic connections that require visual experience of spatially aligned audio-tactile stimuli to develop. This study advances the understanding of sensory processing, emphasizing the role of vision in shaping temporal mechanisms and providing insights for interventions in visual impairment.

#8. Neural correlates of multisensory spatial perception in visually impaired infants

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Keywords: multisensory, blind, infants, spatial integration

Multisensory integration supports early development of spatial representation, with visual experience being key in spatial perception. Examining the spatial congruence of multisensory stimuli provided to sighted and blind individuals may reveal how visual deprivation affects these processes. We investigated group differences in audio-tactile integration to assess multisensory processing and conflict to examine how auditory and tactile inputs are prioritized. Behavioural orienting responses and ERPs were recorded in 12 sighted and 12 severely visually impaired age-matched infants with congruent stimulation (to quantify the benefit of having multiple vs unique stimulations) on one hand and incongruent stimulation (to quantify sensory preference) on separate hands. In the congruent condition, both groups showed activation in integrative areas (centro-parietal (CP) and fronto-central (FC) within 180-220 ms, indicating multisensory processing. In an earlier time window (105-120 ms), sighted participants showed greater activation in temporoparietal areas (linked to audio processing), while SVI participants showed more activation in centroparietal areas (linked to somatosensory processing). In the incongruent condition, only sighted participants showed activation in CP and FC areas within 180-220 ms. In congruent conditions, we found correlations between ERPs and behavioural orienting responses; in incongruent conditions, only sighted infants showed correlations between both CP and FC ERPs (105-120 ms) and performance. In agreement with our previous behahioural (Gori et al., 2021), these results (i.e.the lack of cortical activation in the integrative area during conflict, the absence of correlations with performance, and the preference for somatosensory activation in congruent conditions in SVI infants) suggest that visual deprivation shapes early multisensory spatial representations. This work has been supported by the ERC MySpace

#9. Indexing Mental Imagery Using a Colour Identification Paradigm

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Keywords: Mental imagery, Attention, Working memory, Vividness, Sensory memory, Individual differences, Cognition, Perception

Visual Mental Imagery (VMI) is the ability to generate and maintain images in the mind's eye. Individuals vary from extremely vivid imagery (hyperphantasia) to none at all (aphantasia). However, most indices of VMI rely on subjective self-report measures (e.g., Vividness of Visual Imagery Questionnaire; Marks, 1973, B.J.Psych.). These measures are widely criticized for their subjective nature and often fail to predict performance on putatively imagery-based tasks such as mental rotation and spatial transformation. We developed an objective index of vividness to better understand individual differences and eventually explore the neural correlates of VMI. In our present study, participants completed a battery of internal representations questionnaires (IRQs) including the VVIQ, Spontaneous Use of Imagery Scale (Reisberg, Pearson, & Kosslyn, 2003, App.Cog.Psych.), and the Internal Representations Questionnaire (Roebuck & Lupyan, 2020, Beh.Res.Meth.). Participants then completed three blocks of trials identifying the colour of a displayed patch on a colour wheel. In the first block, the wheel was presented immediately after the participant indicated they had the colour in memory, while the second and third blocks had delays of 3 and 6 seconds, respectively. We then examined whether accuracy in colour identification (ACI) correlated with IRQ ratings. We expect individuals with higher vividness to demonstrate greater ACI, and for it to decline with increasing delays. Our critical assessment ultimately focuses on whether ACI correlates with subjective vividness ratings.

#10. The memory of aphantasics in a multisensory context: interaction between non-visual spatial and verbal strategies

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Keywords: Aphantasia, Visual working memory, Crossmodal correspondence, Memory strategies, Phonological loop

Research has demonstrated that aphantasics, who lack the ability to voluntarily generate mental visual images, exhibit comparable accuracy to non-aphantasics in visual working memory tasks. This finding has been ascribed to their reliance on non-visual spatial and verbal strategies rather than visual strategies. Here, we designed a continuous recognition paradigm to pinpoint how aphantasics exploited potential memorization strategies. During encoding, they viewed 72 images, each accompanied by a semantically congruent sound, incongruent sound or white noise. During recognition, they viewed another set of 72 images (half 'old' vs. half 'new'). We manipulated configural coherence (unified whole vs. segmented elements) to trigger non-visual spatial strategies, and asked participants to say a tongue twister during encoding to address potential verbal strategies. Both aphantasics and non-aphantasics reported whether they had seen each test image and associated confidence level (1-10). We found the performance under 'segmented' condition was better than "unified" condition. Aphantasics had comparable confidences but exhibited lower discriminabilities (d-primes) than non-aphantasics when both groups reported 'high-confidence'. A double dissociation was observed in the two groups when the role of "phonological loop" was considered: when the loop was undisturbed, aphantasics better recognized novel 'segmented' images than did the 'unified' ones. However, the disturbed loop (with tongue twister) has no impact on non-aphantasics but demonstrated a level-off of the advantage of reporting 'new' segmented targets for aphantasics. The current finding indicated that aphantasics primarily used non-visual spatial strategies to improve the memory performance, and an intact phonological loop could help to maintain this advantage.

#11. Effect and neurophysiological mechanisms of transcutaneous auricular vagus nerve stimulation for misophonia: A study protocol for a single centre double-blinded randomised sham-controlled trial

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Keywords: misophonia, treatment, transcutaneous auricular vagus nerve stimulation, taVNS, sensory difference

Misophonia is a sound sensitivity disorder characterised by extreme reactions to particular sounds like chewing and tapping. These sounds give rise to overwhelming anger, disgust and/or anxiety. Misophonia is a relatively newly discovered condition that has not yet entered into diagnostic manuals, and has no current standard clinical treatment. Transcutaneous vagal nerve stimulation has proved to be effective in similar sound sensitivity conditions like tinnitus as well as in commonly co-morbid conditions with misophonia such as depression. I will present our protocol for a single-centre double-blind trial testing the effectiveness of transcutaneous vagal nerve stimulation for reducing misophonia severity. Sixty participants with clinically-significant levels of misophonia will be recruited and randomly allocated to receive either real tVNS or sham tVNS. tVNS will be self-administered over four weeks and the primary outcome will be misophonia severity as assessed by the Sussex Misophonia Scale and the A-MISO-R. Secondary outcomes will monitoring MRI, questionnaires, and physiology pre- and post- tVNS administration. We hope that this clinical trial will contribute to a wider literature on the non-invasive treatment of aversive sensory differences.

#12. Neural dynamics of audio-visual spatial representations in working memory

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Keywords: audiovisual, spatial perception, working memory, EEG, decoding

When judging the relative location of stimuli from different sensory modalities (here auditory and visual) the brain needs to store their spatial location in working memory. It is unclear if these spatial locations are encoded in a modality specific or a shared, supramodal representation in working memory. We combined psychophysics and electroencephalography (EEG) with multivariate decoding and representational similarity analysis (RSA) to study the representations of auditory and visual space in working memory. In a two interval forced choice paradigm, human participants were presented successively with a first stimulus sampled independently from 5 possible locations along the azimuth (- 6, -3, 0, 3, 6 degrees visual angle, DVA) and a second stimulus at 3 DVA either to the left or right of the first stimulus. Across blocks, we factorially manipulated the sensory modality of the first (auditory, A vs. visual, V) and the second stimulus (A vs. V), yielding four block conditions: A-A, A-V, V-A, V-V. Participants reported which of the two successive stimuli was located more to the right. Overall, participants were more accurate (≧75%) and faster when comparing successive stimuli from same (A-A and V-V trials) than different sensory modalities (A-V, V-A). Currently, we investigate the neural processes underlying this modality switch cost.

#13. The role of motor control in echolocation performance: self-initiated vs. passive listening for object spatial localization

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Echolocation enables blind individuals to build spatial representations of their environment by emitting tongue clicks and analyzing returning echoes. Proficient echolocators optimize perception by adjusting click patterns and can also extract information from passively perceived echoes. Actively producing clicks improves the perception of room size for larger rooms. Yet it remains open whether self-initiated clicks, as compared to passively heard ones, would also modulate object localization accuracy, the temporal dynamics of neural representations, the number of clicks used, and the information accumulation rate. We investigated these questions by recording EEG activity while a proficient echolocator performed an echoacoustic localization task under two conditions: self-initiated, by pressing a key controlling the timing and number of clicks, and passive, with fixed sequences of evenly spaced clicks. In both tasks, participants listened to synthesized clicks and spatialized echoes from a virtual object 1 m away at azimuths ±5° to ±25° and reported its location (left vs. right). Our results revealed that object spatial localization was more accurate overall in the self-initiated (95%) vs. passive condition (85%), peaking at 2–5 clicks. Three-click trials were most frequently used (70%), and spatial precision was higher in the self-initiated condition (azimuth-thresholds 1.5° vs. 7°) in the 2–5 click range. EEG analysis further supported these findings, showing higher classification accuracy during the first two clicks in the self-initiated condition, suggesting that active echolocation enhances spatial perception and neural processing, likely due to the integration of motor and sensory cues optimized by focused attention on early acoustic information.

#14. A Kalman Filter model of echo-guided head movement

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Keywords: Echolocation, Blindness, Spatial Navigation, Computational Modelling

Human echolocation relies on the dynamic integration of auditory feedback and motor behaviour to localize sound-reflecting targets. Inspired by behavioural paradigms in which blind participants use echoacoustic clicks to localize objects, we developed a computational model to explore predictive updating during echo-guided target localisation. Specifically, we implemented a Kalman Filter (KF) as a control policy that estimates horizontal target azimuth from echo measurements and adaptively adjusts head orientation in one-dimensional space. Although not a direct model of neural computation, the KF serves as a dynamic state estimator simulating how noisy external cues can reduce spatial uncertainty through action. Measurement reliability was modulated by the angle between head direction and target azimuth, reflecting the directionality of echolocation emissions. This was modelled as a scaled cardioid function of azimuthal eccentricity, where larger head-target relative angles yield noisier echo signals., We tested the KF-guided model under two conditions: a test condition with clicks and a control condition without clicks. Simulated data from multiple participants revealed that the KF model achieved localization error and convergence rates comparable to real-world human data, while the control condition failed to converge. Learning dynamics showed consistent improvement across trials in the KF condition, absent in the control model. Curve fits to trial error profiles revealed reliable convergence dynamics. These findings suggest that simple predictive computational approaches can reproduce key aspects of echo-guided sensorimotor learning, offering a computational foundation for interrogating the mechanisms of echolocation ability in humans, and a framework for developing more complex biologically grounded models.

#15. Long-term use of click-based echolocation offsets detrimental effects of blindness on grey matter density in the human brain cortex

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Keywords: neuroplasticity, vision loss, sight loss, audition, similarity, grey matter, VBM, echolocation

Sight loss leads to complex neuroplastic change, including changes in grey matter density (GMD) in areas of the human brain cortex. It is not known, however, the extent to which these changes directly result from the sight loss, or whether they can be offset with long-term use of a novel sensory skill (e.g. echolocation). Here we used voxel-based morphometry to compare GMD in the human brain cortex across three groups of participants: people who were blind and had at least 10 years' experience in click-based echolocation (EE; n=12), and people who had no experience in click-based echolocation and were either blind (BP; n=20) or sighted (SP; n=30). We found that echolocators exhibited GMD comparable to that of sighted participants (SPs) in certain brain regions, particularly those associated with sensory-based navigation, such as the occipital place area and the hippocampal gyrus. However, in other regions, such as the primary visual and sensory areas (V1 and A1, respectively), their GMD resembled that of blind participants (BPs). Further analyses via whole-brain similarity measures suggest that patterns of GMD we observed in echolocators could be considered a 'hybrid' between sighted and blind. The results suggest that long-term use of echolocation by people who are blind is associated with changes in grey matter density that appear to offset certain detrimental changes in grey matter density observed in blindness. This highlights the potentially powerful effects of skill usage on brain organization.

#16. Optimizing signal parameters to enhance echoacoustic perception of objects in humans

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Echolocation is an active-sensing strategy used by bats, dolphins, and some blind humans, who listen to self-generated echoes to create mental representations of their surroundings. Bats and dolphins echolocate at ultrasonic frequencies and can thus access higher spatial resolution information compared to humans. When slowed to human-audible frequencies, ultrasonic echoes can be more informative to humans than unprocessed audible echoes. Here we explore how ultrasonic echoes can be optimized for human perception, using "Robin," a user-customizable echolocation device that emits ultrasonic signals, records their echoes, and slows them for playback. In this study, we investigated how the “slowdown factor” (a linear time-stretch/frequency-shift) applied to ultrasound signals affects echoacoustic object perception in humans. In E1, 25 novice-sighted adults performed a 2-AFC auditory match-to-reference task, distinguishing Robin-processed echoes from four different furniture objects presented pairwise at three slowdown factors (10, 20, 30). In E2, 15 novice-sighted adults performed a cross-modal, 2-AFC match-to-sample task, where they listened to the same object echoes from E1, and matched them to images of the corresponding objects. Overall, participants performed above chance across all conditions in E1, but only in the highest slowdown condition in E2. Greater slowdown improved performance on both unimodal and cross-modal tasks. These findings suggest that time-stretching ultrasonic echo temporal structure improves behaviorally relevant object perception cues. Ongoing work aims to leverage Robin’s customizable signal parameter space to identify specific acoustic cues best suited to different tasks and environmental features, paving the way for designing future echolocation-based aids for BVI individuals.

#17. Self-relevance influences audio-visual integration

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Keywords: Self, Audio, Visual integration, Sound, Induced, Flash illusion, Priors, Uncertainty, Social influences

Multisensory perception lies at the core of how we experience ourselves and the world around us. It shapes not only our understanding of our physical environment but also how we understand our self in social contexts. Much research has demonstrated the role of sensory integration for self-perception and embodiment – however, much less is known about the influence that our ‘self' has on multisensory integration. Can something as high-level cognitive constructs as social relation impact multisensory integration? Across three studies, we demonstrate the effects and explore potential mechanisms via which the self and social relevance influence multisensory integration. Using a sound-induced flash illusion (SIFI) paradigm, we show that, when stimuli were self-relevant, participants showed a reduced influence of a task-irrelevant auditory tone on visually perceived numerosity. We outline how this modulatory effect on the SIFI can result from prior expectations and sensory uncertainty. Here, by shifting the attentional focus to areas of high self-relevance, the expectancy of specific numerosities increases as the relative sensory uncertainty increases. This results in larger influences of self-relevance when sensory uncertainty is high, and we rely stronger on prior information. Together, our studies provide a new perspective on how our social environments can influence multisensory processing.

#18. Integration of tactile and proprioceptive signals through self touch

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Keywords: Self touch, Tactile, Proprioception, Bodily spatial perception

Multisensory integration is fundamental to maintaining a coherent perception of our body. While previous studies have explored multimodal integration within a single body part— such as tactile, proprioceptive, and visual information—we investigated how spatial information from another body part, specifically through self-touch, influences touch localization. Participants sat at a table covered by a screen. Beneath the screen, they placed their left hand alongside a rubber hand positioned 10 cm distally. Using their right hand, they rhythmically touched the rubber hand while an experimenter simultaneously touched the first joint of their left middle finger. This setup induced a “self-touch illusion”, where participants felt as if they were touching their own finger, even they are touching the rubber hand. We examined whether this illusion affected the perceived location of touch and the spatial perception of joint landmarks which are not touched. Results showed that the perceived touch location on the left middle finger shifted toward the rubber hand, suggesting that right-hand proprioception contributes to touch localization on the left hand. Additionally, the perceived positions of the left middle finger’s tip and second joint, where no touch signal was applied, shifted toward the rubber hand. However, this effect did not extend to other fingers (e.g., index, ring finger). Our results show that spatial information from self-touch influences touch perception and the local spatial structure of the hand by shifting the perceived location of the joints. This suggests that the proprioceptive information provided by self-touch contributes to the spatial perception of the touched body part beyond mere tactile localization.

#19. Somatotopic encoding in crossmodal spatial processing: Evidence from the visual Simon effect

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Keywords: Simon effect, Reference frames, Peripersonal space, Crossmodal, Spatial processing

Previous findings with the Simon effect have demonstrated that visual stimuli are coded in external space, while tactile stimuli are coded in somatotopic space. In what reference frame are visual stimuli in peripersonal space represented? We used a Simon effect paradigm in which participants responded using foot pedals to visual stimuli (red/green circles) presented near/far from their hands, positioned in different postures (hands crossed/uncrossed, on/off lap). If visual stimuli near the hands are processed using a somatotopic reference frame, we would predict a decrease in the typical external visual Simon effect in crossed versus uncrossed conditions. In Experiment 1, we found a visual Simon effect, but no evidence for a peripersonal Simon effect in this and later experiments. In Experiments 2 and 3, we added a task-irrelevant tactile stimulus that was always presented on the same side in external space as the tactile stimulus. Interestingly, adding this tactile stimulus led to a decreased visual Simon effect with the hands crossed versus uncrossed, suggesting somatotopic encoding even though the tactile stimulus was task-irrelevant. To examine the contributions of various spatial codes, in Experiment 4 we decoupled the location of the visual and tactile stimulus such that they would occur equally on the same/different side of external space. Results indicated that each stimulus code (tactile somatotopic, tactile external, and visual external) independently contributed to the observed Simon effect, with stronger weighting for tactile somatotopic and visual external codes. These results provide evidence that task-irrelevant tactile stimuli generate somatotopic spatial codes.

#20. A markerless 3D motion capture pipeline for upper-body tracking during ecological use of a robotic thumb

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Keywords: markerless motion capture, sensorimotor, robotic thumb, augmentation, naturalistic, whole, body movement

Understanding how the brain uses sensory information to drive actions is fundamental to neuroscience research. Improving our ability to quantitatively measure motor outcomes will provide valuable insights into how we perceive sensory input and how it influences our behaviour. Most studies typically focus on measuring simple movements (e.g., button presses), while our natural behaviour relies on complex, whole-body motor repertoires. Advances in markerless motion capture, leveraging deep learning-based body landmark detection, provide new opportunities for behavioural studies investigating sensory contributions to motor learning in naturalistic settings. However, accurate 3D tracking remains challenging due to hardware constraints, occlusions, and difficulties in detecting body landmarks in individuals with prosthetics or body augmentations. Addressing these limitations is critical for understanding how body representation is learnt, maintained, and updated through sensory experience. Here, we present a motion capture pipeline for tracking upper limb kinematics in individuals using a supernumerary robotic finger, the Third Thumb (Dani Clode Design), which extends the hand's motor repertoire. We outline key technical considerations, including camera selection (machine vision vs. webcams), spatial configuration, Arduino-based synchronisation, and calibration. Our approach extracts 2D joint coordinates via Google MediaPipe, followed by 3D reconstruction using Anipose. We outline considerations for improving tracking accuracy in the presence of wearable sensors and augmentation devices. Finally, we present preliminary data illustrating how markerless tracking captures fine-grained changes in upper limb kinematics as users acquire skill with the Third Thumb. Improved accessibility of markerless tracking opens new possibilities for studying sensorimotor processes shaping movement in diverse contexts.

#21. Sub-lexical processing of audiovisual speech constrains lexical competition.

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Keywords: EEG, Speech, Lexical competition, Language

As we listen to natural connected speech, we rapidly transform speech acoustics into linguistic representations. As that transformation begins and the brain makes inference on the articulations, so does a lexical inference process that updates as each phoneme is articulated. In challenging listening environments, this process can become disrupted by noisy inference at the phoneme level, leading to increased lexical competition and reduced word comprehension. Seeing a speaker's face and especially the shape of the articulators can restore comprehension, in part by constraining the competition to words consistent with both auditory and visual speech. There is evidence that vision can constrain inference at the lexical level, but it is unknown whether those effects can be attributed to sub-lexical interactions or whether constraint happens only after auditory and visual lexical processes are complete. In this study we fit and evaluate EEG encoding models of lexical competition that vary depending on acoustic and visual uncertainty, and the constraint imposed by their set intersection. We use linear modeling to predict scalp electrophysiology from input features that represent the lexical competition during auditory, visual, and combined audiovisual (i.e., set intersection of A and V) speech and at different levels of clarity (background noise). We find evidence that audiovisual lexical processing is affected by visual constraint as a word unfolds, indicating that the phoneme read-out that determines lexical competition and selection is likely a combined audiovisual process rather than one built upon multiple unisensory representations.

#22. Beat gestures bias lexical stress perception in autistic adults

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Keywords: audiovisual integration, autism, gesture, speech, multimodal integration

In face-to-face communication, speakers provide several visual cues that facilitate speech comprehension. Even simple up-and-down flicks of the hand, called beat gestures, affect speech recognition: a beat gesture falling on the first syllable (BeatOn1) of a minimal pair (e.g., “content”) biases towards perceiving a Strong-Weak (SW) stress pattern (e.g., the noun “CONtent”), while a beat gesture falling on its second syllable (BeatOn2) biases towards a Weak-Strong (WS) stress pattern (e.g., the adjective “conTENT”). These findings were observed in neurotypical individuals, leaving open the question of whether beat gesture and speech integration might be observed in autistic individuals. In fact, earlier research suggests that autistic children show attenuated audiovisual speech integration, while recent studies showed that autistic adults integrate speech and lip movements or meaningful gestures to the same extent as neurotypical individuals. In the present online large-scale study, we tested whether beat gestures bias speech perception similarly in autistic and non-autistic adults. Participants watched videos in which the speaker produced prosodically ambiguous minimal pairs along with a beat gesture (BeatOn1/BeatOn2), or with no beat gesture. Graded responses of perceived stress were acquired using a visual analog scale. Beat gestures affected speech perception (SW-bias for BeatOn1, WS-bias for BeatOn2) to a similar extent in both groups. The present results converge on recent findings challenging the notion that audiovisual integration is altered in autism. Rather, autistic adults appear to be able to integrate gestures and speech, which might benefit their daily communication.

#23. (When) does visual speech predict the acoustic signal? Characterising dynamic audiovisual asynchronies in continuous speech

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Keywords: audiovisual speech perception, temporal asynchrony, speech

A widely proposed idea in the field of audiovisual speech perception is that visual speech leads auditory speech by around 100-300ms (Chandrasekaran et al., 2009). However, whether these findings hold true for natural, continuous speech remains unclear. Here, we use cross-correlation time-delay analysis to investigate the relationship between lip aperture and broadband auditory envelopes in sentence-level speech (Aller et al., 2022). We establish that our analysis robustly characterises the temporal structure of audiovisual signals a) globally, b) dynamically (using sliding windows) and c) locally in windows centred on phoneme onsets estimated using forced alignment (Kisler et al., 2017). Using mixed effects modelling, we find that phone position and class (only in interaction with position) predict the magnitude of visual lead across >8000 phones in our dataset. Importantly, for word-internal and word-initial phones without a preceding pause, estimates of visual lead are not significantly different from zero. For prosodic-unit- and utterance-initial phones, on the other hand, statistical models confirm a substantial increase in visual lead of up to 100ms. However, these findings depend on phone identity: unvoiced phones (e.g. /t/) show a higher visual lead than voiced phones (/d/), visual lead is further increased for velar consonants (/g/) and front vowels (/æ/). Ongoing work will validate these results in a highly synchronised, multi-speaker narrative dataset. Overall, our results reinforce arguments from Schwartz & Savariaux (2011), that research on predictive processes in audiovisual speech perception should carefully consider the dynamic, natural statistics of audiovisual asynchronies.

#24. Speech modifications in response to real-time non-verbal visual cues of listening engagement and listener age: a comparison between younger and older adults

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Keywords: Speech production, Listening engagement, Face to face interaction, Ageing

We recently showed that speakers adjust the acoustic-phonetic characteristics of their speech based on real-time visible cues from the listener's body (e.g., facial expressions of confusion). Here we examined to what extent these situated conversational cues interact with the knowledge of the listener's characteristics (e.g., age) and how they can be exploited when aging. We investigated the contributions of these components to speech production during simulated face-to-face interactions. We asked 20 young adults to read sentences to a listener visible via a head-mounted display. Participants had no acoustic feedback from the listener's environment but knew their voice was heard with varying background noise. The listener, a confederate (either a young or an older adult), was shown in pre-recorded 360° videos with two levels of listening engagement (easy and hard listening). As visible listening engagement increased, young speakers raised their voice intensity, increased their utterance duration relative to the available time (speech proportion), extended pauses, and raised their fundamental frequency. Moreover, they displayed stronger speech proportion adjustments when speaking to the older compared to the young listener. Preliminary data from 12 older adults suggest similar effects of displayed listening engagement, but no main effects or interactions involving listener's age. These findings suggest that acoustic-phonetic adaptations in face-to-face interactions can be triggered by non-verbal cues of listening engagement, with their effect varying based on prior knowledge of the listener. These adjustments occurred spontaneously in the absence of any auditory experience of the listener environment. Notably, non-verbal cues are exploited in ageing adults.

#25. Investigating the Relationship Between Autistic Traits and Multisensory Integration in the General Population

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Keywords: Autistic traits, Multisensory integration, Restricted interests and repetitive behaviours

Autism is characterized by weaknesses in social communication and the presence of restricted interests and repetitive behaviours (RRBs). Autistic individuals also have sensory issues, including in multisensory integration, which are housed under the RRB diagnostic criteria. However, previous research indicates that these sensory issues also impact social communication in Autistic individuals. The purpose of this study was to determine whether the same is true in the general population. To do so, 124 adults (Mage=18.42) completed this study. Using a research domain criteria framework, adults with and without an Autism diagnosis were included in the study. Participants completed a speeded audiovisual detection task using Gabor patched presented at each individual's 50% unisensory detection threshold. Autistic traits were measured with the Broad Autism Phenotype Questionnaire (BAPQ). Participants' accuracy and response times on the speeded detection task were used to calculate multisensory gain. We found that in the general population, only our measures of RRBs correlated with participants' accuracy gain (r=.19, p=.033). However, when examining participants with a high likelihood of Autism according to the BAPQ, multisensory gain significantly correlated with RRBs (r=.73, p=.003), aloofness (r=.57, p=.033), and overall Autistic traits (r=.70, p=.005). These findings suggest that multisensory integration issues impact both social aspects of Autism and RRBs in individuals with high likelihood Autism, reflecting previous findings in populations of diagnosed Autism. However, differences in multisensory integration appear to only impact RRBs in the general population, more in line with the diagnostic criteria.

#26. Fundamentally different evidence accumulation in adult dyslexia during rapid audio-visual decision-making

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Keywords: Audio visual, Perceptual decision making, Computational model, Dyslexia

Dyslexia, a neurobiological language-based learning disorder, is defined by specific difficulties in the areas of reading and spelling. Recent evidence from simple, non-linguistic, audio-visual tasks in children with dyslexia casts doubts on the language-based focus of this disorder. Instead, these findings point towards considering a multifactorial model consisting of linguistic and perceptual differences. Computational investigations of the multisensory perceptual mechanisms explaining complex perceptual decision-making in adult dyslexia remain scarce. Here, we tested 40 adults with and 37 without dyslexia on an established audio- visual perceptual discrimination task that lacks linguistic content while recording electrophysiological data. Results show generally lower visual behavioural performance alongside similar enhancements when receiving additional auditory evidence in dyslexia. Neurally informed drift diffusion modelling demonstrates that aberrant behavioural performance is a result of supramodally slower evidence accumulation speed. Specifically, auditory evidence enhances the quality of neural evidence during the early sensory encoding stage in dyslexia, while it enhances later decision related neural evidence in those without the disorder. Adults with dyslexia also required more evidence to commit to a decision. These results suggest fundamental differences in neurophysiological perceptual processing of non-linguistic audio-visual stimuli persisting into adulthood, whereby they call the language-based nature dyslexia into question.

#28. Heart Evoked Potentials (HEPs) as a potential marker of imbalance between internal and external information processing in Developmental Coordination Disorder (DCD)

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Keywords: Developmental Coordination Disorder (DCD), Heart Evoked Potentials (HEP), EEG, sensory integration, resting state

Developmental Coordination Disorder (DCD) is a common neurodevelopmental disorder characterized by significant difficulties in the acquisition and execution of coordinated motor skills (DSM-V). Additionally, EEG studies indicate a possible imbalance between internal and external information processing, resulting as impaired sensory integration, which may underlie the motor coordination deficits observed in DCD (Tallet & Wilson, 2020; Tran et al., 2022; Meachon et al., 2024). Heart brain interactions shape how the brain perceives somatosensory stimuli, and how systolic cardiac signals have a facilitatory effect on motor excitability, in contrast to sensory attenuation (Al et al, 2020; Al et al, 2023). Overall, recent studies suggest that Heart Evoked Potentials (HEPs) are a reliable indicator of how effectively the brain monitors and integrates physiological signals (Banellis & Cruse., 2020; Coll et al., 2021; Al et al., 2021). EEG resting state data analysed in this study was collected as part of a previous project which included behavioural paradigms (Mayes et al., 2021). We investigate resting state data with eyes open (EO) and eyes closed (EC), from DCD and control populations. Using a nonparametric statistical approach, we performed cluster-based permutation tests (Maris & Oostenveld, 2007) to explore the differences in HEP amplitudes. When comparing EC-

EO fluctuations across DCD and control groups, our results show significant HEP modulations over parietal areas for the DCD group only. Given the known proprioceptive and interoceptive deficits in DCD, exploring HEPs in this population provides a valuable insight into the neural mechanisms underlying these sensory processing challenges.

#29. Musical ability relates sequential numerosity perception

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Keywords: Numerosity perception, Musical ability, Tactile

Sequential numerosity perception refers to the ability to estimate the number of objects presented visually, auditorily, or haptically without explicitly counting them. While individual differences exist in sequential numerosity perception, the factors contributing to this ability remain unclear. Previous research suggests that musicians outperform nonmusicians in processing temporal information across visual, auditory, and tactile stimuli. Given these findings, we hypothesized that individual differences in sequential numerosity perception are significantly related to musical ability. To examine this relationship, we conducted two experiments comparing two modality pairs: visual vs. auditory (Experiment 1, n = 23) and auditory vs. tactile (Experiment 2, n = 19). Musical ability was assessed using the Mini-PROMS, a short version of the Profile of Music Perception Skills. Sequential numerosity perception was evaluated by asking participants to estimate the number of presented stimuli, which ranged from 3 to 12. Analysis using a linear mixed model (LMM) revealed that in Experiment 1, higher musical ability was associated with greater accuracy in sequential numerosity perception regardless of modality ($t(426.00) = -2.57$, $p = .016$). In Experiment 2, a significant relationship was observed between musical ability and accuracy in the auditory modality, although no such relationship was found in the tactile modality (interaction : $t(350.00) = 3.22$, $p < .001$). These findings suggest that perceptual musical ability is significantly associated with sequential numerosity perception in the auditory and visual modalities, highlighting the potential influence of musical expertise on temporal numerical processing.

#30. Enhanced emotional effects of multisensory music experiences using novel audio to tactile conversion

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Keywords: Multisensory, Auditory, Tactile, Music, Emotion regulation

Tactile pairing with auditory stimulation has been shown to enhance various capabilities, including the intensity of the stimulus, its location, and its comprehensibility in noise. However the effect of adding haptics on emotional state is still poorly understood, despite the key role of bodily experiences on emotional states. In the current study we aimed to investigate the impact of a multisensory audio-tactile music experience on emotional states and anxiety levels. For this purpose we developed an in-house algorithm and hardware, converting audio information to vibration perceivable through haptics, optimized for music. We compare participants 'emotional experiences of music when provided with audio only versus audio-tactile feedback. We further investigate the impact of enabling participants to freely select their music of choice on the experience. Results indicate multisensory music significantly increases positive mood and decreased state anxiety when compared to the audio only condition. These findings underscore the potential of multisensory stimulation and sensory-enhanced music-touch experiences specifically, for emotional regulation. The results are further enhanced when participants are given the autonomy to choose the musical content. We discuss the importance of multisensory enhancement and embodied experiences on emotional states. We further lay out the potential of multisensory experiences towards producing robust representations and touch on the particular potential use cases for technologies which enable controlled multisensory experiences.

#31. Emotion Congruency Moderates Audiovisual Temporal Binding Window

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Keywords: Emotion, Temporal Binding Window, Multisensory Integration

Integrate auditory and visual information is essential for effective communication. One aspect of this integrative process is determining which external inputs to integrate, and which to parse. The temporal alignment of sensory inputs is a strong cue to bind, commonly measured as a temporal binding window (TBW), or the window of time within which one integrates sensory inputs across modalities. High-level features, such as semantic congruence or the congruence gender of faces/voices are also used as cues to bind. Only a small amount of research, however, has examined how these different cues interact with one another. In our present work, we measured the interaction between temporal cues and affective congruency on multisensory integration. Participants (N=125) watch audiovisual videos of a speaker saying a semantically neutral sentence with happy, angry, or neutral facial expressions and prosody. We parametrically manipulated the temporal alignment of the auditory and visual components and varied the emotional congruency of the facial expression and prosody. Participants performed a 3-alternative-forced-choice synchrony judgement task from which we calculated TBWs. We found that emotionally congruent trials were associated with wider TBWs, suggesting that the cue to bind provided by emotional congruency influences the system's tolerance for temporal asynchrony. We also found that congruent emotional stimuli were also associated with a wider TBW, which was not predicted a priori. One possible explanation is that stimuli with more environmental importance/salience may be associated with a lower threshold for binding, with the effect of advantaging the processing and perception of such inputs.

#32. Altered Perception and Altered Beliefs: The Impact of Multisensory Mystic Experiences on Metaphysical Beliefs and Analytical Rumination

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Psychedelics produce vivid and dramatic alterations across multiple sensory modalities. Even at sub-hallucinogenic doses, psychedelics such as psilocybin may evoke subtle perceptual shifts. These induced multisensory phenomena have contributed to growing public interest in "microdosing"—the practice of taking very low doses of psychedelics. However, the absence of standardized dosing protocols raises uncertainty about whether "effective" microdoses are truly sub-perceptual or large enough to cause impairment. This lack of standardization limits the reliability of reported benefits. Additionally, unblinding in psychedelic trials is a concern, as participants who recognize psychoactive effects may display expectancy effects. This study examines the role of expectancy in microdosing through a randomized, placebo-controlled trial of individuals with major depressive disorder (MDD). Thirty-four adults diagnosed with MDD attended weekly lab sessions. For four weeks, participants were randomized to 2mg psilocybin or placebo, followed by four weeks of open-label psilocybin. Depression symptoms were assessed through clinical interviews and self-report. To assess blinding, participants guessed their treatment condition during and after each session. Sobriety tests were administered during the pharmacological peak. In terms of sobriety, 31 of the 34 participants performed perfectly on all 9 assessments; only 2 participants in the active substance group produced less than perfect performance, scoring 4/5 on one of 8 occasions. In terms of breaking blind, 63% of those receiving psilocybin guessed correctly, while the placebo group was at chance (50%). Accurate guesses in the psilocybin group were often attributed to feeling altered, mood changes, and increased relaxation.

#33. Effects of Hand Pointing Movements on Visual and Auditory Spatial Attention

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Keywords: Hand movement, Movement preparation, Visual spatial attention, Auditory spatial attention, SSVEP, ASSR

Hand movements facilitate visual processing at the location of the movement goal, which suggests visual attention at the location where a hand indicates (e.g., Wu et al. 2023). There may or may not be similar facilitation on auditory processing. In order to examine the question, participants performed either a visual or an auditory discrimination task, with or without a pointing gesture in this study. An auditory or visual target was presented either at the same location as or at a different location from the one pointed by the hand. EEG signals (Steady-State Visual Evoked Potentials: SSVEP; Auditory Steady-State Response: ASSR) were measured during the experiment to examine the spatial distribution of visual and auditory attention. The behavioural results showed higher accuracy at the pointed location than at the other location in the visual task. However, this was not the case in the auditory task. Regarding EEG measurements, SSVEP amplitudes increased at the movement goal either during performing visual or auditory task. In contrast, pointing movements did not significantly affect ASSR amplitudes in both during performing auditory and the visual task. These findings indicate that movement preparation enhances visual processing at the movement goal while having only a no or at least much smaller effect on auditory processing. This selective enhancement of visual processing suggests close relationship between visual information and hand movements.

#34. Tracking synchrony in motion: Spatial and temporal integration of biological walkers and footstep sounds

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Keywords: biological motion, multimodal motion perception, spatial audio, multimodal synchrony

Human observers exhibit remarkable sensitivity to biological motion, particularly when presented as point-light displays. While prior research has primarily focused on the visual attributes of biological motion, real-world motion often co-occurs with action-relevant auditory cues. Semantically congruent sounds facilitate biological motion perception (Thomas & Shiffrar, 2010), and the ability to detect audiovisual synchrony is enhanced for upright point-light walkers compared to scrambled ones (Saygin et al., 2008). Building on this, we investigated whether upright point-light walkers facilitate audiovisual synchrony detection when both the walker and the sound dynamically change their spatial positions. Participants viewed upright and scrambled point-light walkers traversing a screen while listening to synchronized or temporally misaligned footstep sounds delivered through headphones. Their task was to judge whether the audiovisual stimuli were temporally synchronous. Our results revealed that observers detected synchrony more accurately and responded faster when viewing upright point-light walkers than scrambled ones. In addition, participants were slower and more accurate in identifying synchronous audiovisual stimuli than asynchronous ones. This may suggest that additional processing is needed in synchronous conditions due to the simultaneous presentation of stimuli from two modalities. These findings indicate that biological motion processing remains robust even when spatial information is integrated. Moreover, understanding the integration of biological motion and auditory cues can provide insights into multisensory perception deficits in clinical populations, where temporal binding mechanisms may be altered. Additionally, our results

could inform the development of more immersive environments and enhance human-robot interaction by improving the naturalistic integration of audiovisual cues in artificial systems.

#35. The impact of walking on a slope on early cognitive brain processing

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Keywords: EEG, ERP, brain activity, multisensory integration, dual task

Walking is not merely an automatic movement but relies on multisensory spatial and temporal integration involving interactions between motor and cognitive processes. It is largely controlled by optic flow providing crucial visual feedback of self-motion on the retina. Literature on cognitive-motor dual-task (CMDT) using walking as motor task has provided contrasting results: a decline in the concomitant cognitive performance; a decline or even facilitation in motor performance, all depending on brain resource allocation. Here, we aimed at investigating the CMDT effect on cognitive performance and underlying brain processing that modulates walking slope, using a discriminative response task (DRT) and event-related potentials (ERP) measures. To this aim, participants performed a DRT while walking on a treadmill under three conditions: uphill, downhill, and flat surface. Behavioural results showed no slope effect on response time and accuracy in the cognitive task. ERPs results showed lower amplitude in the early attentional processing (the N1 component) in the sloped conditions compared to the flat. Sensorial awareness (the pN1 component) showed larger amplitude in the uphill condition compared to the other conditions. Late cognitive processing (P3 component) was not affected by the slope. Results suggest that the sloped walking may reduce early, but not late attentional processing on a concomitant cognitive task. In addition, walking uphill may require greater sensorial awareness than flat or downhill walking likely to keep behavioural performance stable.

#36. The influence of speed on multisensory timing discrimination during active and passive movements

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Keywords: Active and passive movements, Speed, Temporal binding window, Temporal order judgement task, Audio, Tactile stimuli

Movements allow us to interact with the stimuli in a multisensory environment and to perceive information about the spatial and temporal relationships between objects. We can either move freely (active movements) or be guided by external forces (passive movements). During active movements, neural mechanisms, including efference copy and predicted sensory feedback, affect timing perception (Nishi et al., 2014). If active and passive movements involve different mechanisms, then these may be modulated differently by movement speed. In this work, we investigated this unexplored aspect, whether different speeds influence audio-tactile temporal binding window (TBW) during active and passive movements. We hypothesized better performance (higher precision) in active than in passive movements because of the presence of predictive sensory feedback. We also hypothesized that slower movements would provide more time to make a prediction. We asked blindfolded participants to perform a temporal order judgement (TOJ) task while moving actively their arm or being passively moved by a robotic haptic device named Haply Inverse3 at three different speeds. Performance was measured using the Just Noticeable Difference (JND). In line with our hypothesis,

when examining speed, we observed lower JND during slow compared to medium and fast speeds in active movements. When the actual movement of the subject was considered, we found a positive correlation between speed and JND. These results suggest that actual speed might influence participants' precision in timing discrimination, possibly because slow active movement enables successful prediction.

#37. Investigating the Role of Visual and Kinesthetic Information in Recognition Memory

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Keywords: Motor Control, Memory, Writing, Text, Proprioception, Recognition

Previous research suggests that active writing, where individuals generate writing movements, enhances recognition memory more effectively than static viewing. However, the specific contributions of dynamic and static visual input versus active motor engagement remain unclear. This study investigated the role of visual feedback and motor engagement in recognition memory by comparing three learning conditions: active writing, dynamic viewing, and static viewing. Neurologically healthy participants with no prior knowledge of Arabic encoded a list of Arabic words under three conditions: (1) static viewing, where participants viewed a static image of the word; (2) dynamic viewing, where participants watched an animation of the word being written; and (3) active writing, where participants wrote the word after observing a dynamic animation. Afterward, participants completed a recognition test, identifying previously presented words among distractors. Recognition accuracy, reaction time, and confidence ratings (0–100%) were recorded. Recognition memory was significantly more accurate after active encoding (84%) than static viewing (68%; $p = 0.034$). Although dynamic encoding (80%) resulted in more accurate recognition than static viewing, the difference was not statistically significant ($p = 0.068$). There were also no significant differences in recognition accuracy between active and dynamic encoding. Confidence ratings did not differ between conditions. This research highlights the importance of both active motor engagement and dynamic sensory feedback in the recognition memory. The findings have potential applications in educational strategies and rehabilitation programs, particularly for individuals with learning disabilities or cognitive impairments.

#38. The effect of visuomotor asynchrony while walking on a concomitant cognitive task

Moscogiuri, Martina [1], Perrone, Martina [1], Di Bello, Biancamaria [1], Costanzo, Raffaele [1], Strappini, Francesca [1], Sulpizio, Valentina [2], Di Russo, Francesco [1] [3], Pitzalis, Sabrina [1] [3]

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Keywords: EEG, ERP, brain activity, multisensory integration, dual task

Walking relies on sensorimotor integration of proprioceptive and visual signals known as optical flow. Our goal was to investigate whether this integration is affected by the temporal congruency between optic flow and walking speed. The study aims to explore differences in event related potentials (ERP) in response to a discriminative response task (DRT) during synchronous or asynchronous optical flow but invariant walking speed on a treadmill. This combination assimilable to a cognitive-motor dual-task, allows us to test the hypothesis that the perceived visual asynchrony in the motor tasks might influence the cognitive processing involved in the DRT. To this aim, we tested optical flow velocities that could be slower, faster or synchronous with respect to the subject's walking speed. Behavioral results showed that participants exhibited fewer commission errors (false alarms) in the slow condition. Consistently, ERPs results showed larger amplitude for the slow condition in early visual processing (P1) and sensorial awareness (pN1) components. Conversely, the ERP component associated to attentional processing (N1) was found to have a smaller amplitude during the slow condition, while the sensory-motor awareness component (pP1) showed a larger amplitude during the

fast condition. Results might possibly reflect greater visuomotor integration and cognitive processing related to the complexity of the fast condition and suggest a facilitation in the visual discrimination process during the slow condition. Overall, these results provide evidence that asynchronous optical flow may enhance visual, attentional and sensorimotor processing of a concomitant cognitive task, and could contribute to the dual-task brain effects.

#39. Perceptual bias in action: Auditory frequency modulation influences walking speed and distance

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Keywords: multisensory augmented feedback, sensorimotor, auditory biases, natural scene statistics

The temporal frequency of amplitude modulation (AM-frequency) of a sound is a relative cue for auditory speed perception, with sounds having higher AM-frequency being perceived as moving faster than lower AM-frequency sounds. This perceptual bias is likely rooted in natural scene statistics, where asperities in sliding objects generate sounds whose AM-frequency varies with speed (Senna et al., 2017). Here we investigated whether this bias can extend beyond perception, to affect speed and distance travelled in human locomotion. Participants walked blindfolded, were trained to cover a 20-meter distance while pushing one of three different measuring wheels. The measuring wheels were modified to implement a “wheel spoke card trick”, so that when participants pushed them, they produced either low, medium, or high AM-frequency sounds, thereby providing auditory feedback to their movement. Travelled distance and speed systematically scaled with velocity in a linear fashion: the higher the AM-frequency, the shorter the distance covered and the slower the walking speed. This happened because with higher AM-frequency, participants were biased into perceiving themselves as walking faster and thus reaching the destination sooner than they actually did, stopping earlier and slowing down to compensate. These findings offer a new handle to exploit perceptual biases for multisensory augmented feedback. By leveraging perceptual biases, augmented feedback can shape behaviour effortlessly, reducing the need for extensive training and allowing sensory feedback to naturally integrate with the other senses and guide movement.

#40. Interoceptive Sensitivity Modulates the Relationship Between Motor and Auditory Tempo Preferences

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Keywords: Interoception, Preference, Motor tempo, Auditory tempo

People have different preferences for tempo—some like it fast, while others prefer it slow. However, it remains unclear whether a person’s preferred movement tempo (e.g., finger tapping) correlates with their preferred tempo in auditory perception (e.g., the rhythm they enjoy in music), and the relationship between motor tempo and auditory tempo preferences is still debated. Here, we focused on interoception—the ability to perceive internal bodily signals—and examined whether interoceptive sensitivity modulates the relationship between preferred movement tempo and preferred tempo in auditory perception. In our experiment, 40 participants completed a tapping task to assess their preferred movement tempo. They tapped their index finger at a comfortable, self-selected pace for 30 seconds. Next, they performed a music tempo adjustment task, listening to 15 pieces of music and adjusting the tempo to match their preference. Finally, they completed a heartbeat counting task to assess interoceptive sensitivity. Based on their performance, participants were classified into either a low- or high-sensitivity group. We calculated repeated measures correlations for both sensitivity groups. In the low-sensitivity group, preferred tapping tempo and preferred music tempo were significantly correlated ($r_{mcorr} = .26$, $p < .001$), whereas no significant correlation was observed in the

high-sensitivity group (rmcorr = .08, p = .165). These results suggest that interoceptive sensitivity influences the relationship between motor tempo and auditory tempo preferences.

#41. Active multisensing framework for motor stereotypies in autism and neurotypicality

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Keywords: Active Sensing, Motor Stereotypies, Motion Kinematics, Neural Entrainment

We live in a world rich in input from multiple senses. One way we manage this information barrage is through active sensing, rhythmic motor sampling behaviors that shape the incoming sensory stream. This sensory filtering is hypothesized to occur through neural entrainment (rhythmic shifts of peak neural excitability to match sensory input), combined with phase-amplitude coupling ([PAC] phase of entrained oscillations modulate the excitability of local ensembles receiving sensory input). Another form of rhythmic behavior is motor stereotypies (STYs) — rhythmic, repetitive movements most prevalent in autism but also present in neurotypicals. While traditionally considered purposeless, first-person accounts suggest STYs help individuals self-regulate when sensory under/overstimulated. Our study aims to investigate these proposed coping effects of STYs by 1) exploring relationships between STYs and environmental stimulation across diagnoses and sensory sensitivities, and 2) linking active sensing mechanisms to STYs. Using motion tracking, motion classification, and ambulatory EEG, we will characterize autistic and non-autistic children exploring augmented reality environments with low, medium, and high sensory stimulation. We hypothesize motor rhythmicity depends on individual sensory sensitivities: hyposensitivity-reporting individuals showing increased rhythmicity during low-stimulation conditions and hypersensitivity-reporting individuals showing increased rhythmicity during high-stimulation conditions. We hypothesize that STYs regulate active sensing in both autistics and neurotypicals by entraining low-frequency neural oscillations, which in turn improve delta-gamma PAC. We predict reduced entrainment and delta-gamma PAC in autistic participants. This novel framework of STYs may inform how we design environments to tailor individual sensory sensitivities and assist autistics in developing more efficient sensing behaviors.

#42. Motor Control in Yoga: Does expertise reduce variability in muscle engagement?

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Keywords: Biofeedback, Motor control, Motor learning

Motor coordination during complex skills often converges on a few efficient solutions, minimizing effort and variability. Yoga provides a natural model to examine how expertise shapes these solutions because each pose imposes precise demands on muscular engagement, flexibility, breathing and balance. Yet outward alignment can mask divergent internal strategies that may elevate injury risk. We recorded surface EMG from eight muscle groups for ten experts and ten intermediate practitioners across 13 poses, each repeated eight times across two sessions. Pose-specific “muscle signatures” were extracted and compared within sessions, across sessions, between individuals and across expertise levels. We predicted experts would show lower within-participant variability across sessions, reflecting consolidated control, but greater between-expert diversity as they tailor solutions within the null space. Intermediates were expected to rely on less stable, overlapping strategies that vary more across trials and sessions. Preliminary analyses confirm high intra-session consistency in both groups, indicating rapid online stabilisation of patterns. Nevertheless, pronounced between-participant variability persists, attesting to multiple viable motor solutions. Experts—especially in poses that tax deep stabilisers—reliably reproduce their activation signatures across sessions, preferentially recruit core stabilisers and incur lower normalised activation cost. Intermediates display greater cross-session and inter-participant variability and often compensate with elevated anterior-deltoid and upper-trapezius activity, reflecting less economical control. These findings refine theories of motor redundancy by revealing how skilled performers simultaneously minimise variability and maintain

flexibility in natural tasks. The derived pose-signature metrics could inform personalised feedback systems to enhance safety and performance in yoga and other skill domains.

#43. Luminous dancing fairies in weightlessness: How gravity shapes consciousness

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Keywords: Vestibular Neuroscience, vEAR, Consciousness

In a 2012 ISS mission, astronaut Don Pettit described unusual sensory experiences as “flashes in my eyes, like luminous dancing fairies.” These could result from a mismatch between vestibular information and Earth’s 1g gravity, blurring the line between “reality” and “unreality” and triggering perceptual anomalies. Here we investigate these phenomena by simulating weightlessness using flotation on Earth. Volunteers were immersed for one hour in a floatation tank containing 10 inches of water saturated with Epsom salts, reducing the physical - and perceived - impact of gravity. We administered Visually Evoked Auditory Responses (vEAR) stimuli, which generate auditory sensations triggered by silent visual stimuli, both before and after the floatation session. Participants rated the strength of the auditory sensations elicited by video sequences presented for 10 seconds at the center of a screen within an occluded visual field. We found a significant increase in vEAR intensity after the floatation session. To further explore the role of vestibular signaling in consciousness, a second group of participants performed the same task while undergoing disruptive vestibular stimulation in a controlled lab setting. Similar to the floatation condition, we observed a significant increase in vEAR intensity during artificial vestibular stimulation compared to the sham control. We believe that the alignment between sensory signals from the vestibular system and the 1g gravity prior is crucial for maintaining healthy perceptual functioning. These findings provide valuable insight into how gravitational changes, such as those experienced in space, may disrupt our sensory integration and perception of reality.

#44. Stationarity perception depends on vestibular-oculomotor adaptation

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Keywords: Optic flow, Vestibular, VOR, Eye movements, Virtual reality

As we move, the images on our retinas move due to head and eye movement, but under normal circumstances we tend to perceive the world as stationary. However, perception of world stationarity will be compromised if there is a significant discrepancy between observed and expected optic flow. This occurs, for example, when getting used to new spectacles, but we normally adapt to these changes. Here we studied the relationship between oculomotor adaptation and perceived stationarity. We adapted observers’ vestibular ocular reflex (VOR) by exposing them to a virtual environment where a fixation point in an otherwise empty world moved with them when they turned their head ~15 deg to the left or right; movement direction on each trial was cued and randomized. The gain of dot motion decreased from 1 to 0.6 over the course of 150 trials. Trials with no fixation point (dark environment) were interspersed to measure VOR adaptation state. Joint analysis of eye and head movement responses on these trials indicated that many observer’s VOR adapted toward the targeted gain of 0.6. Before and after adaptation we measured each observer’s point of subjective stationarity (PSS), that is the scene motion gain perceived as stationary. On each trial, participants made similar cued head movements in a virtual world composed of a 3D cloud of spheres with a central fixation point and then judged whether the scene appeared to move with or against their head motion. Gain was varied trial to trial according to adaptive staircases to estimate the PSS. Before VOR adaptation, average PSS was not significantly different from a gain of 1, but afterwards, average PSS had decreased, indicating that VOR adaptation state influences stationarity perception. This suggests that VOR adaptation state should be monitored in users of extended reality systems.

#45. Cortico-motor coupling resulting from training-related extensive vestibular stimulation in dancers and slackliners

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Keywords: Tactile, Balance, Somatosensory processing, Gravitational reference frame, EEG

In vestibular patients with bilateral vestibular loss, we observed cortical facilitation of somatosensory inputs using gravity-related tactile information. This compensation through tactile inputs is interpreted as building up a gravitational reference to maintain equilibrium, similar to the function of an intact vestibular system. Conversely, training with extensive vestibular stimulation-induced neural changes, such as volume loss in cortical and subcortical areas dedicated to processing vestibular inputs, is a finding demonstrated in highly trained dancers and slackliners. This study examined 25 highly trained dancers and slackliners to assess whether their training with extensive vestibular stimulation is associated with the facilitation of the somatosensory processing in response to a translation of the support on which they are standing. The somatosensory cortex response to tactile stimulation of the plantar sole (i.e., SEP), evoked by the relative motion between the skin of the feet and the supporting surface (i.e., shear forces), is expected to exceed that of 21 age- and gender-matched controls. We computed cross-correlation between the SEP and the shear forces to assess corticomotor coupling. The results indicate greater and earlier cortico-motor coupling in athletes as compared to controls. This occurs during the initial period of the produced lateral forces. Multimodal cells, which integrate vestibular and somatosensory inputs, may have heightened their responsiveness to tactile stimulation in highly trained athletes engaged in vertiginous activities. Such cells are present, for example, in the somatosensory cortex and in the thalamus.

#46. The multisensory act of walking: Improving gait in challenging conditions via auditory cueing

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Keywords: walking surfaces, gait, multisensory integration, auditory cueing, dual tasking

Despite its automatic nature, walking is a multisensory act that is depended on the coordination of different body parts and systems. Walking can be affected by factors like the type of walking surface (i.e., rough, smooth) or a secondary task (i.e., using a smartphone; Blair et al., 2018; Tessari et al., 2023), while, most interestingly, even providing auditory cues resembling different walking surfaces can lead to gait changes (Turchet et al., 2013). In the present research, we investigated whether sounds that are correlated with rougher or smoother surfaces (high/low loudness or pitch; Peeva et al., 2004) can affect walking behavior during single and dual-task conditions (i.e., text messaging or not on their mobile). Gait variables were measured with motion sensors attached to the participants' shoes. The analyses showed that indeed auditory cues can affect walking. Specifically, high loudness and pitch sounds increased stride length and cadence in the rough surface condition, while low loudness and pitch sounds only increase stride length. The increase in these key determinants of gait speed suggests an improved walking pattern on uneven surfaces. Moreover, we obtained a significant interaction of the auditory stimulation with the secondary task, where low loudness cues increased swing phase and decreased double support compared to control conditions (white noise), a finding that can be associated with a more efficient walking pattern. Overall, our results support that auditory cueing during walking in different conditions can lead to improvements of gait in challenging conditions.

#47. Investigating the time course of verticality sensitivity changes during visuo-vestibular conflict

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Keywords: Vestibular system, optic flow, verticality, sensory conflict

Verticality is our perception of what is “up” and what is “down”, and is fundamental for spatial orientation and the perception of upright relative to gravity. Verticality relies on the multisensory integration of many cues, including visual and vestibular signals. Interestingly, sensitivity to verticality is affected by sensory conflicts between these modalities. When exposed to a roll optic flow, vision signals that the person is moving, while the vestibular system signals that the person is stationary. During and immediately after short exposures to visuo-vestibular conflict, sensitivity to verticality is decreased. However, little is known about whether and how verticality sensitivity adapts to sensory conflicts over time. Here, we investigated whether sensitivity to verticality fluctuated over prolonged visuo-vestibular conflict. Participants completed a verticality detection task, indicating whether upright or tilted lines were vertical or not. The task was completed continuously over 10 minutes while roll optic flow or random visual stimulation was displayed in the background. A signal detection approach was used to analyse participant responses, with measures of d’ and criterion calculated over six 90-second time windows. Preliminary findings indicate a reduction in vertical sensitivity immediately after roll optic flow begins, with d’ remaining low throughout exposure. This implies that visual-vestibular conflict affects a participant’s ability to distinguish between vertical and tilted stimuli, with no recovery of verticality detection over prolonged conflict. Future research aims to investigate the time course of recovery of sensitivity after prolonged exposure to visuo-vestibular conflicts.

#48. Misestimations of object size in depth during body tilt

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Keywords: Vestibular, Vision, Size, Distance, Depth, Tilt

When the body is tilted from upright objects are perceived as visually smaller or closer compared to when standing. Along with evidence from microgravity flights, it appears that the vestibular system might be involved in the encoding of the space around us with respect to gravity and that this space might be distorted. Even when upright there are distortions in perceived visual size/distance where objects far from the body are perceived as smaller/closer than they really are and near objects are perceived as larger/further. This is interpreted as a distortion of space towards reach space in which we primarily act. If visual space is additionally compressed while supine this might result in far space compressing towards reach space leading to a reduction in any distortions seen while standing. In the present study participants were asked to estimate the size of an object on a computer screen while standing or supine, while the object was presented close, far, or very far from the body. The participants only had access to monocular cues to size. Preliminary results show that when standing, perceived size is distorted across the different distances (slope differed from 0). When supine the perceived size of the objects decreased by ca. 8% and the slope no longer differed from 0. This might suggest that far space has compressed towards near space reducing any distortions in depth. This study adds to the growing literature indicating the vestibular system might be involved in the representation of space with respect to gravity.

#49. Adapting to gravity: The role of vestibular signals in physical reasoning

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Keywords: Internal model of gravity, Vestibular system, Galvanic vestibular stimulation, Physical reasoning, Adaptability

Our ability to interact with the world relies on anticipating physical events based on an understanding of physical laws. For millennia, humans have been exposed to Earth's gravitational acceleration of 9.8 m/s² (1g). The vestibular system plays a key role by monitoring head position in relation to gravity. By integrating vestibular signals with visual, proprioceptive, and visceral cues, the brain forms an internal model of terrestrial gravity. However, it remains unclear whether this model can adapt to different gravitational environments. Here we disrupted participants' vestibular signaling using Galvanic Vestibular Stimulation (GVS) while they engaged in a reasoning task. Participants strategically placed a tool within a 2D environment to guide a ball toward a target area. The ball's movement followed terrestrial gravity (1g), falling downward and accelerating as it descended. Our results show that GVS impairs physical reasoning when terrestrial gravity is integral to problem-solving, affecting both performance and strategic decision-making. This suggests that vestibular signals play a crucial role in maintaining an accurate internal model of gravity. But what happens when the physics of the environment deviate from Earth's gravity? To test adaptability, we modified the virtual environment's gravity to 0.5g or 2g. GVS improved reasoning performance in altered gravity conditions, though it did not affect problem-solving strategies. These findings suggest that vestibular input is essential for reasoning under Earth-like gravity and adapting to different gravitational forces. This has significant implications for understanding cognitive adaptability in altered gravitational conditions.

#50. Investigating the Effects of a Bimanual Elbow Exosuit on Weight estimation, Perceptual Learning, and Effort.

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Keywords: Perception, Augmentation, Sensorimotor adaptation, Perceptual learning

Exosuits, wearable soft exoskeleton devices designed to reduce muscle effort and delay fatigue, hold promise for industrial applications and assisting individuals with motor impairments by enhancing endurance and reducing strain. However, their effectiveness depends not only on biomechanical benefits but also on their impact on perceptual factors, like weight estimation and effort perception. This study investigates the influence of a bimanual elbow exosuit on weight estimation, perceptual learning, and effort. Participants completed two sessions (exosuit ON and OFF) while surface electromyography (EMG) monitored muscle activity as they engaged in three tasks. In Task 1, based on the size–weight illusion, participants lifted boxes of varying weights and volumes to estimate their weight, with preliminary results suggesting that illusion effects may diminish over time. Task 2 employed a reinforcement learning paradigm in a volatile environment, presenting participants with two boxes—one typically heavier and the other lighter—with weight contingencies that could change. Participants indicated whether the presented box was heavier or lighter, and early analyses revealed that learning patterns varied across conditions. In Task 3, participants chose between a low-effort, low-reward box and a high-effort box with variable, higher rewards. Initially, choices were similar, but over time, participants increasingly preferred the high-effort option when the exosuit was ON. Despite reduced muscle fatigue in this condition, perceived effort increased. These preliminary findings suggest a dissociation between behaviour, perception, and muscle activity. Within the examined time scale, exosuits may alleviate muscle fatigue and impact weight estimation but not necessarily reduce perceived effort.

Poster session 3

#1. Temporal adaptation of action-outcome predictions in schizophrenia is associated with altered neural processing in MFG and cerebellum

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Keywords: schizophrenia, sensorimotor temporal recalibration, cross, modal transfer, multisensory integration, cerebellum, fMRI

A fundamental ability of our perceptual system is to predict the (multi)sensory outcomes of our actions and adapt these predictions to changing environmental conditions. In schizophrenia (SZ), dysfunctions in this ability have been linked to difficulties in self-other distinction. This study investigated the neural correlates underlying the adaptation of action-outcome predictions to delays, whether this adaptation transfers to another sensory modality, and whether SZ patients exhibit alterations in these neural processes. Patients with SZ and healthy controls (HC) underwent fMRI while exposed to delays between active or passive button presses and auditory outcomes. Effects of this procedure on auditory perception (unimodal trials) and the transfer of adaptation to visual perception (cross-modal trials) were assessed using a delay detection task. In unimodal trials, HC exhibited reduced activation in left MFG after delay adaptation, particularly for active movements, whereas this effect was reversed in SZ. In cross-modal trials, delay adaptation in HC was linked to increased activation in bilateral cerebellum, especially for active movements, a pattern significantly reduced in SZ. These findings suggest that successful unimodal adaptation in HC might be reflected in reduced prediction error-related activity in MFG for delayed action-outcomes, while this process is disrupted in SZ. Moreover, our results provide novel evidence that additional effort of the cerebellum may be required to transfer adapted action-outcome timings across modalities, with impaired cerebellar cross-modal transfer processes in SZ. These neural alterations when adapting action-outcome predictions and transferring them across modalities may contribute to severe perceptual disturbances in SZ.

#2. Is Psychedelic Microdosing a Placebo? Findings from a Randomized, Placebo-Controlled Trial of Major Depressive Disorder

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Keywords: Psilocybin, Microdosing, Expectancy Effects, Altered Sensory Perception, Placebo, controlled trial

Psychedelics produce vivid and dramatic alterations across multiple sensory modalities. Even at sub-hallucinogenic doses, psychedelics such as psilocybin may evoke subtle perceptual shifts. These induced multisensory phenomena have contributed to growing public interest in “microdosing”—the practice of taking very low doses of psychedelics. However, the absence of standardized dosing protocols raises uncertainty about whether “effective” microdoses are truly sub-perceptual or large enough to cause impairment. This lack of standardization limits the reliability of reported benefits. Additionally, unblinding in psychedelic trials is a concern, as participants who recognize psychoactive effects may display expectancy effects. This study examines the role of expectancy in microdosing through a randomized, placebo-controlled trial of individuals with major depressive disorder (MDD). Thirty-four adults diagnosed with MDD attended weekly lab sessions. For four weeks, participants

were randomized to 2mg psilocybin or placebo, followed by four weeks of open-label psilocybin. Depression symptoms were assessed through clinical interviews and self-report. To assess blinding, participants guessed their treatment condition during and after each session. Sobriety tests were administered during the pharmacological peak. Participants correctly identified their condition above chance: 63% of those receiving psilocybin guessed correctly, while the placebo group was at chance (50%). Of the 34 participants, 31 passed all sobriety tests at all time points; three participants failed 1 of the 7 tests at one time point. Depression symptoms decreased over time, but there was no significant interaction with condition. Participants who believed they were taking psilocybin had greater symptom reduction, highlighting the influence of expectancy.

#3. Deep learning application to EEG reveals sensory processing differences in autism and schizophrenia

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Keywords: Multisensory Processing, EEG, Autism Spectrum disorder (ASD), Schizophrenia (SCZ), Deep Learning (DL), Convolutional Neural Network (CNN)

Understanding multisensory processing and its implications for neurodiversity has received a lot of interest in neuroscience (Li et al., 2022). Deep learning (DL) models now enable the extraction and visualisation of neural features (Roy et al., 2019), helping to identify patterns within EEG data and associate them with specific populations and conditions. Here, we harness the power of DL to investigate neural signatures of multi-sensory integration (MSI) and differences in MSI for individuals with Autism Spectrum Disorder (ASD) and Schizophrenia (SCZ). We collected EEG data from 23 individuals with ASD, 35 with Schizophrenia, and 32 Controls while they responded to audio (A), visual (V), and audiovisual (AV) stimuli. Using Convolutional Neural Networks (CNN), we classified and analyzed sensory processing differences (Aellen et al., 2021; Lawhern et al., 2016). Initially, to identify sensory processing differences between the groups, we compared the EEG responses across the three groups in the multisensory condition (AV) and found that the three populations could be reliably discriminated (77.46% accuracy for SCZ versus ASD, 75% for ASD versus CN, and 70% for SCZ versus CN). Next, to identify neural gains from multisensory processing, we compared EEG responses between multisensory (AV) and unisensory (A and V) stimuli within each group. We found that classifying AV versus V achieved the highest accuracy in CN, reaching 62.7%. Similar accuracies were found in ASD (61.9%) and SCZ (61%). Furthermore, when comparing AV and A stimuli, CN demonstrated an accuracy of 63%, while ASD and SCZ achieved 62.17% and 56.47%, respectively. Overall, our results suggest that CNN applications to EEG data can uncover spatiotemporal components of neural processing that can help classify neurodiverse populations. In future work, we intend to identify the discriminating EEG features and assess their interpretability and then explore novel visualization techniques to determine whether these features vary between groups.

#4. Spontaneous oculomotor behavior reflects the matching of tactile stimuli with body posture

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Keywords: tactile remapping, somatosensory processing, oculomotor behavior, eyetracking

An unexpected touch on the shoulder immediately triggers an orienting response towards the touched location. Although this reaction seems automatic, localizing a touch in space is more complex than we might think. In the somatosensory cortex, tactile stimuli are initially coded independently of body posture. They are further reported on a cognitive map used to match tactile coordinates with postural information, under the control of the posterior parietal cortex. However, the mechanism underlying such tactile remapping remains unclear. To uncover this mechanism, we recorded the gaze behavior of participants receiving tactile stimuli on the fingers of their right hand in a palm-down or palm-up posture. Tactile stimuli induced horizontal gaze shifts whose direction was determined by the external position of the stimulated finger relative to the middle finger. The comparison of the palm-up and palm down conditions showed that hand rotation reversed the direction of gaze shifts induced by each finger, except for the middle finger for which gaze remained central in both conditions, despite the rightward location of the hand. Eye-tracking data thus indicate that the gaze moves on either side of the axis extending along the middle finger during the localization of stimuli on the hand. We demonstrate a close link between the oculomotor and somatosensory systems, and show that the oculomotor system operates on an internal representation of the body that keeps track of postural information.

#5. The precision of ‘non-image’ cues to active self-movement depends on modality

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To interpret audiovisual motion, the brain uses a combination of sensory feedback (visual, auditory, tactile, proprioceptive, vestibular) and efference copy to account for self-movement. According to contemporary theories, combinations like these are determined by the precision of underlying neural signals, which also weights the influence of prior knowledge. Unfortunately, precision is difficult to evaluate for active self-movement (e.g. head rotation, walking) because this is under participant control. Recently we developed a technique that measures the collective precision of ‘non-image’ cues to self-controlled head rotation (i.e. proprioceptive + vestibular + efference copy; Haynes et al, 2024, JNP,132:389-402). We found that non-image precision measured using an auditory target was half of that measured using a visual target. Here we replicate this finding in a larger sample and suggest the additional ‘currency’ noise occurs because audition prefers displacement, while vision prefers speed. More steps are therefore needed to convert non-image cues into the appropriate units for hearing. But despite these differences, we find the same bias for vision and hearing: targets appear to move around 30% less when tracked by the head. This finding could reflect greater influence of a slow-motion prior as precision declines. However, our results show that precision is about the same for visual and non-image cues, whereas for hearing, the non-image cue is more precise than its auditory counterpart. The consequences for investigating motion perception in active observers will be explored.

#6. Is audiovisual integration associated with balance and motor responses in childhood?

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Keywords: Development, Balance, Audiovisual, Sound, Induced Flash Illusion

Audiovisual integration has been linked to balance and motor control. In older adults, less precise integration, assessed using the Sound-Induced Flash Illusion (SIFI), predicts fall risk (Setti et al. 2011) and in younger adults, postural stance influences illusion rate (Stapleton et al. 2014). We explored whether audiovisual integration is linked to balance and coordination in childhood. Ninety-three children aged 4-10 years completed three tasks; a balance task (balance on one leg with eyes open versus closed), a SIFI task (categorize how many onscreen flashes occurred, when paired with a congruent or incongruent number of beeps, at varying Stimulus Onset Asynchrony, SOA) and a timed-response task (touch as many onscreen targets in two minutes as possible). All three tasks showed developmental change. In the balance task, older children showed a greater benefit from balancing with eyes open versus eyes closed. In the SIFI there was a significant, predicted, effect of SOA (with illusions being stronger at shorter versus longer SOAs) and this effect became stronger with age. In the timed-response task, older children achieved a higher number of hits than younger children. However, accuracy on the SIFI was not predicted by balance difference scores, nor hit rate in the timed-response task, in any age group. Thus, although all three functions showed developmental change between the ages of 4 and 10 years there was not convincing evidence of links between these measures, suggesting that the previously observed relationship between balance and audiovisual integration might emerge in adulthood.

#7. Treadmill walking accompanied by simulated motion reduces perceived distances, likely through motion parallax from head bobbing

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Keywords: optic flow, distance perception, treadmill walking, locomotion, VR

A superimposed optic flow (OF) field reportedly causes objects to appear closer both during standing and treadmill walking. Here, we explored how simulated and active self-motion affect distance perception in virtual reality. In experiment 1, participants estimated egocentric or allocentric distances for objects that were 4, 5, or 6 m away or apart, in two separate tasks. In the sagittal-lateral task, participants estimated a sagittal distance by adjusting a lateral extent to match, and vice-versa in the lateral-sagittal task. Participants performed both tasks in three conditions: no simulated self-motion while standing (stationary), visually simulated forward self-motion while standing (OF only), and simulated motion with treadmill walking (OF+treadmill). Results to date show that in both tasks, there were no significant differences between the OF only and stationary conditions. However, the OF+treadmill condition estimates were significantly smaller than those in the other conditions for both sagittal-lateral and lateral-sagittal judgements. To investigate the role of stepping-induced head movements in the treadmill condition, in Experiment 2, we recorded and replayed participants' head bobbing ('simulated bobbing' condition). Results to date show significant differences only between the standing conditions and the conditions involving real or simulated head bobbing. We conclude that simulated motion does not affect estimates of egocentric and allocentric distances of 4-6 m in VR. Active walking decreased the estimated distance, but this was likely due to the motion parallax caused by head bobbing.

#8. Walking in Synchrony with Pitch-Altered Footstep Sounds Modulates Body Perception: Towards Investigating the 'Footsteps Illusion' in Real-Life Scenarios

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Keywords: Multisensory body perception, Auditory feedback, Body transformation experiences, Body representation, Bodily illusions, Wearable technology, Mixed, Methods

Auditory cues shape body representations, influencing behavior and bodily sensations. Laboratory studies show that real-time pitch alterations of people's footstep sounds while walking can alter perceived body weight, gait, and gender association. Could this "Footsteps Illusion" extend to complex, real-life scenarios? Towards exploring this, we examined whether a minimal setup-a smartphone playing pre-recorded footstep sounds through headphones- can induce similar changes in body perception in an outdoor setting. 28 participants walked outdoors synchronizing their steps to three pre-recorded footstep soundtracks: Control (original), High Frequency, and Low Frequency. Using a mixed methods approach, participants completed controlled and exploratory tasks. In the controlled task, they walked along a designated path while an accelerometer recorded gait. They reported body feelings, emotional experiences, and perceived weight changes through questionnaires, body maps, and a body visualizer task. Results showed significant differences in perceptions of body weight, emotional dominance, and gait patterns across conditions. In the exploratory task, participants walked freely while experiencing the High and Low Frequency conditions. Post-walk interviews revealed explanations of changes in body perception and sound associations, and explored how contextual factors (e.g., weather, surroundings, surfaces) influenced experiences. In addition to replicating previous research on the "Footsteps Illusion" with a minimal setup reaching wider populations, this study underscores how readily we attribute sounds synchronized with our movement to our body. The findings emphasize the value of mixed methods in ecological settings to account for contextual influences and individual differences, providing insights into the multisensory induction of body transformation experiences in real-life contexts.

#9. Multisensory integration of touch location and body posture for an additional robotic body part

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Keywords: Touch, Somatosensory, Proprioception, Artificial limbs, Sensorimotor, Body representation

Having an extra body part could expand our movement abilities, but it is unclear whether we can incorporate additional limbs into our brain's body representation. Multisensory integration of touch location with body posture is crucial for making movements to touched locations on our own body. In this study, we explored whether participants can integrate touch location and body posture for an additional robotic thumb, The Third Thumb (Dani Clode Design). We developed a marker-based motion tracking setup to record participants' pointing movements towards touch stimuli on the Third Thumb. In each trial, participants felt a touch stimulation from one of four vibration motors on the Third Thumb and used intrinsic touch information, i.e. touch sensations arriving at the connection of the Third Thumb with the side of their hand, to point towards the location on the Third Thumb they judged as the touch stimulus origin. Participants' vision was occluded during each trial and auditory cues

were masked. Six different Third Thumb postures were used. Participants could distinguish between different touch locations along the Third Thumb, demonstrating successful use of intrinsic touch for localisation, an ability previously shown for handheld tools. Pointing performance was worse for touch stimuli at the Third Thumb tip compared to other locations. Our results demonstrate that participants can distinguish touch locations on a robotic body part and combine this with its posture to program a movement to this spatial location. Our future research will explore whether this ability strengthens with intensive Third Thumb motor training.

#10. Dissociating Tactile Perception from Body Location: Evidence from the Mirror Box Illusion

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Keywords: Tactile localization, Body perception, Multisensory integration, Mirror box illusion

The tactile sensations we perceive typically align closely with where we perceive our bodies. Is it possible to dissociate the perception of body location from where we feel touch? We present a series of mirror box illusion experiments designed to dissociate perceived tactile and body location. The participant's right hand was positioned 15cm behind a mirror, and they viewed either their entire hand/arm (connected limb) or only their hand, with empty space where their forearm would be (disconnected limb condition). During synchronous tapping, asynchronous tapping or no movement conditions, participants were presented with tactile stimuli (either a monofilament or an unseen vibrotactile stimulus) or no touch, and reported the perceived locations of their hand, forearm, and touch. First, we found that people were significantly more likely to report feeling their hand in the mirror location compared to feeling touch in the mirror location. This provides evidence that the perceived location of the body and touch can be dissociated, and that referral of touch may be a more conservative process. Second, we found that this dissociation was maintained regardless of whether there was a crossmodal incongruence between the viewed/felt stimulus (monofilament) or there was no incongruence (vibrotactile stimulus), providing evidence that the dissociation could not be explained by crossmodal visuotactile incongruence. Finally, participants reported feeling two right hands more frequently when presented with more intense tactile stimuli, suggesting that stimulus intensity may influence embodiment.

#11. Multisensory Influence in Body Model: Blindness Leads to Larger Distortions of the Hand Representation

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Keywords: Body Model, Hand representation, Blind, Plasticity

The implicit body model is a mental representation of metric properties of one's body and is shaped by integrating multisensory information from proprioceptive, visual, and tactile information. It has been hypothesized that this metric model is developed over time through visual information about one's own body and interaction with the environment. In this study, we aim to understand how the absence of visual experience impacts the implicit hand representation of the body model. We employed a hand landmark localization task on three groups of participants (30 each): blind, blindfolded and normally sighted controls. The blind participants exhibited significantly greater distortions in hand representation compared to both sighted and blindfolded controls. They overestimated their hand width [94.6% compared to 54.3%] and underestimated their finger lengths [28.7% (±5.2%) compared to 18.9% (±3.8%) of sighted participants]. Further insights emerged regarding the impact of the onset of blindness. Late-blind individuals exhibited distortions comparable to congenitally blind participants (mean difference = 5 - 8%), suggesting a prolonged susceptibility to the lack of visual input in shaping

body representations. Interestingly, Blind individuals with high severity of blindness show smaller distortions compared to individuals with low blindness severity, indicating that partial visual information can lead to larger distortions in the body model. We hypothesize these distortions emerge as compensatory mechanisms within the body model in response to the anisotropic cortical representations, particularly in the context of expanded cortical regions that process tactile information in blind individuals.

#12. Detecting gravity: The role of vestibular signals in internalising terrestrial gravity

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Keywords: Vestibular Neuroscience, Gravity Detection, Internal Model of Gravity

It is difficult to imagine a more pervasive force than gravity. We have evolved in a constant 1g terrestrial gravity environment and our brain constantly integrates vestibular, visual, visceral and proprioceptive inputs to construct an internal model of gravity. This model allows us to navigate and interact seamlessly with our surroundings. Yet, how sensitive are we to variations in gravitational acceleration? To investigate this, we used a signal detection approach to quantify human sensitivity to gravitational acceleration when objects moved either congruently with gravity (downward) or against it (upward). In the first experiment, participants completed a gravity detection task in which a ball moved on a screen following either terrestrial (1g) or Martian (0.3g) acceleration, in both downward and upward directions. They were asked to determine whether the object's motion followed terrestrial or non-terrestrial acceleration. The results indicated higher sensitivity to detecting terrestrial gravity when the object moved downward compared to upward, with no differences observed in response bias. In the second experiment, we altered vestibular signalling by administering disruptive Galvanic Vestibular Stimulation during the gravity detection task. The results revealed a significant reduction in sensitivity to gravitational acceleration under artificial vestibular stimulation compared to the sham condition, particularly for downward motion. These findings confirm the presence of an internalized 1g model of gravity and highlight the essential role of vestibular signals in shaping this internal representation.

#13. MazeBuilder: A Virtual Reality Tool for Use in Spatial Navigation Research

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Keywords: Virtual reality, Spatial navigation, Software, EEG

The use of virtual reality (VR) in neuroscience research has grown steadily alongside wider availability of affordable head-mounted displays. In addition to benefits such as heightened realism and increased immersive experience, VR can be easily paired with neuroimaging. Yet, some access barriers related to programming knowledge and access to resources remain. We introduce MazeBuilder, a standalone open-access tool which allows researchers to easily create virtual environments and use them for spatial navigation research. In MazeBuilder the researcher can easily create, store, and present T-junction mazes with pre-designed trajectories. The environment reproduces the streets of a customizable city-like environment, that the participant navigates while

driving a car. Additional background visual and/or auditory stimulation can be rendered, thus making it suitable for multisensory research. MazeBuilder also incorporates a screening workflow to reduce participant drop-out due to cybersickness. The environments can be rendered through commercially available VR gear (goggles, steering wheel, pedal) or just on a computer monitor and keyboard. We demonstrate the software capabilities in two illustrative experiments with behavioral and EEG data. The first study demonstrates entrainment, assessed via Steady State Visual Evoked Potentials and Cross Coherence. The second study examined time-resolved episodes of oscillatory activity related to relevant navigational variables. The next version of MazeBuilder will incorporate a free roaming mode, in a grid-like environment, with customizable landmarks.

#15. Walking modulates numerosity detection within the subitizing range at the step rate

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Keywords: action, perception, stride cycle, subitizing, walking

It was recently discovered that visual sensitivity while walking undergoes a cyclic modulation at the step rate, being best in the swing phase between steps (Davidson et al., 2024). This was shown for a basic visual detection task, but it is unknown whether similar modulations would occur for an attentionally demanding task. Here we test this using numerosity perception. Numerosity processing shares areas within the parietal system used for magnitude perception and is a perceptual attribute contributing to the planning and execution of actions (Walsh, 2003). Estimating numbers in the subitizing range (<5 items) is thought to require attention, unlike the higher 'estimation' range (Burr et al., 2010). We asked participants to perform a detection task looking for a specific number (target) in a serial presentation of visual stimuli by pulling one of two triggers. The stimuli were clouds of black and white dots and were displayed using a VR headset as participants either walked across a large room or stood still in a stationary condition. A group-level analysis showed a modulation of numerosity performance at the stride cycle (around 2 cycles per stride) and consistent in phase (peaking late in the swing phase). Results from the stationary condition showed comparable performance overall but no modulation. Our result in the walking condition adds to other recent studies showing that perception oscillates during locomotion at the step rate.

#16. Distance-dependent distortions in haptic spatial updating following lateral translation

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Keywords: Haptic Perception, Spatial Updating, Proprioception, Spatial Cognition, Sensorimotor Integration, Spatial Memory, Object Localization

When moving one must continuously update one's internal spatial representations to interact effectively with the environment. Although most literature has focused on visual spatial updating, haptic perception—derived from tactile, proprioceptive, and kinaesthetic signals—and haptic spatial updating remain underexplored. A well-known finding in haptic literature is that the accuracy of haptic localization decreases as the distance from the observer increases. Concurrently, translations in a visual context—whether lateral, forward, or backward—are frequently undercompensated, leading to systematic misestimations of object displacement relative to self-motion. These findings motivated the investigation into whether the increasing error in haptic localization with distance is further exacerbated by the undercompensation of translations during visual spatial updating. Participants haptically explored the locations of manipulanda positioned at preselected locations. After encoding their positions, participants either underwent a translation (leftward. rightward, forward or backward) or remained stationary at various positions for five seconds before repositioning the object. Positions of observers and targets were recorded by an Optitrack system. Under stationary conditions, participants repositioned manipulanda with high accuracy and precision, although accuracy declined

slightly with increased distance. In contrast, following a translation, participants placed manipulanda farther away, opposite to their self-motion direction—a finding that contrasts with visual spatial updating, where translations are typically undercompensated. These results suggest that haptic spatial updating may overcompensate for observer translations, leading to a systematic mislocalization in which known object positions are perceived as being farther away than they truly are.

#17. How do the sensory features of Virtual Reality impact its success as a pedagogical tool?

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Keywords: Virtual Reality, learning, presence, audio visual integration, children

Immersive Virtual Reality (IVR) is a tool with many unique features, including multisensory capabilities. A recent review of studies using IVR with children found that IVR contributed to positive learning outcomes (di Natale et al., 2020), however a systematic understanding of how sensory features contribute to the success of an IVR learning experience is still limited. This study explores how the inclusion of a dynamic soundscape in an IVR experience contributes to factual recall, engagement (Othman et al., 2011) and a feeling of presence in the IVR environment (Slater et al., 1994), as well as how individual differences in children's sensory processing might influence the learning experience. Individual differences in audio-visual integration were measured using a flash-beep task (Hillock et al., 2011). There was high factual recall on the MCQ quiz (out of 15) in both the SoundOn (M = 9.89) and SoundOff (M = 9.70) conditions, but no significant difference between the conditions, p = .388. There were greater feelings of presence reported in the SoundOn (M = 4.05) compared to the SoundOff condition (M = 3.78), p = .017. Participants with larger audio-visual temporal binding windows (TBWs) scored lower on the MCQ quiz, but reported higher feelings of presence. These findings suggest that different factors underpin children's learning and presence; and that sensory processing differences affect IVR learning experiences.

#18. From Human Touch to Robotic Perception: Human-Robot Emotion Communication Through Artificial Somatosensation

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Keywords: Tactile, Emotions, Human, Robot, Visual, Sensory, Motor

Human touch conveys emotional information, yet its role in human-robot interaction remains underexplored. This study aimed to understand how humans communicate emotions through touch and apply this knowledge to enhance robotic sensing. The objectives were to identify tactile patterns associated with emotional communication, enable robots to discriminate emotions conveyed through touch, and investigate how visual perception of robot anthropomorphism impacts tactile interaction. Fifty-four participants (27F/27M) conveyed nine emotions—positive, negative, and neutral—through touch to anthropomorphic and non-anthropomorphic robotic devices. Each device was equipped with artificial skin embedded with sensors mimicking human tactile mechanoreceptors. These sensors captured the dynamic attributes of emotional touch, allowing the extraction of spatiotemporal sensorimotor patterns shaped by communication motor strategies. These patterns trained MiniRocket classifier enabling the artificial skin to recognize tactile emotions. Behavioral measures, physiological data, and self-assessments were collected to analyze communication characteristics. Analysis revealed that different tactile strategies produced distinct activation patterns in robotic skin sensors, forming a tactile lexicon of emotional communication. Participants conveyed positive emotions with

greater confidence and accuracy ($p<0.001$), reflected in behavioral, physiological, and self-assessment responses; aligned with classifier's emotion recognition achieving 86% accuracy. Participants preferred the anthropomorphic device, which impacted motor behavior employed to communicate emotions ($p<0.001$), emphasizing how integration of visual and somatosensory cues shapes social interactions with artificial agents. These findings highlight the role of multisensory integration in emotional touch perception. This emphasizes the need for bio-inspired somatosensory technologies, combining visual and tactile cues in designing socially intelligent robots for more effective, emotionally intuitive interactions.

#20. Coping Through Hearing: An Exploration to Relief Social Anxiety Through Music Intervention - Real Time Biofeedback Binaural Beats as an Example

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Keywords: Binuaral beats, Music intervention, Social anxiety, Biofeedback, Sonification, Computer, Mediated communication, Heart rate variability

This study developed a PC-based auditory biofeedback system to examine the effectiveness of two proposed binaural beat (BB) intervention designs in alleviating social anxiety under the context of computer-mediated communication (CMC). The interventions, heartbeat sound plus binaural beat (HB+BB) design and nature sound plus binaural beat(N+BB) design, are controlled by real-time heart rate (HR) signal to enhance anxiety reduction. 8 participants underwent a within-subject experiment. It utilized the Trier Social Stress Test Online (TSST-OL) paradigm that simulates online job interviews to induce anxiety, followed by a recovery phase in which the participants would be exposed to the HB+BB and the N+BB respectively as a post stressor intervention for each of the two trails. Subjective anxiety levels were measured using the State-Trait Anxiety Inventory (STAI-S), while physiological responses were assessed through heart rate variability (HRV) parameters, including RMSSD, LF/HR ratio, and stress index. Results indicated significant reductions for both design in subjective anxiety; however, only the N+BB design demonstrated a substantial physiological response as indicated by higher RMSSD values in heart rate variability (HRV), suggesting a parasympathetic activation and greater efficacy in promoting relaxation. Meanwhile, the HB+BB design showed minimal post-intervention physiological change. Qualitative feedback revealed that participants found the N+BB music more soothing and less distracting. These findings highlight the potential of a real-time auditory biofeedback system using N+BB design as an effective intervention for reducing social anxiety in high- pressure CMC scenarios, warranting further exploration of its underlying mechanisms and applications in anxiety reduction through the multisensory approach.

#21. Expecting pain: How individuals with phantom limb pain integrate sensory evidence

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Keywords: pain, reinforcement learning, expectations

Phantom limb pain (PLP) is a prevalent yet poorly understood neuropathic condition following limb amputation. Research has predominantly focused on cortical explanations, leaving the roles of cognitive and peripheral processes less explored. This study investigates how individuals with PLP integrate sensory evidence to shape pain expectations. We hypothesize amputees will show impaired learning, due to more rigid expectations and dissociation between movement and sensory experience, with greater deficits in those experiencing higher PLP. We employed an aversive learning paradigm where individuals with and without an amputation associated visual cues with painful or non-painful thermal stimuli. Task 1 involved three cues linked to hot, warm, or random stimuli, with

expectancy, pain ratings, and electromyography recorded across passive (no movement) and active (phantom movement) conditions. Task 2 had two cues, with a high (volatile) and low (stable) contingency switch rate conditions (expectancy recorded). Reinforcement learning models will quantify trial-by-trial expectancy updates to assess individual differences in pain-related decision-making. Descriptive preliminary control data suggests successful learning in both tasks. In task 1, controls shows better learning in the passive condition, which we believe will be amplified in the amputee group. Expectancy biases are present in controls but are expected to be stronger in PLP participants, who may overestimate pain for innocuous stimuli. Phantom movements could further amplify these biases. In Task 2, controls adapt well to stable contingencies but struggle with volatile ones. We predict amputees will have even greater difficulty with volatility due to more rigid association formation from their pain experience.

#22. Using Virtual Reality for Studying Audiovisual Multisensory Integration Across Distances

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Keywords: Multisensory integration, Audio Visual, Depth, Temporal binding window, Virtual reality

We investigate audio-visual temporal integration across distances within an immersive Virtual Reality (VR) setup using the HTC Vive Pro 2 head-mounted display. Eleven participants perform a simultaneity judgment task at 3 different distances: 80 cm, 2.1 m, and 5 m, completing 120 trials per condition. Trial sequences are managed through a modified Updated Maximum Likelihood adaptive method (Shen et al., 2012) extended to handle non-monotonic functions, specifically the Skewed Normal. To verify the onset of auditory and visual stimuli (SOA), we calibrate the system by recording visual and auditory signals via a photodiode and direct audio captured from headphones. As a first result, we detect a stable delay of 60 ±12 ms which was corrected in Unity scripts, achieving accurate SOA delivery within ±11 ms (which is the frame duration of the 90 Hz visual display). Behavioural results show a significant decrease (pValue = 0.029) in the Point of Subjective Simultaneity (PSS) across distances. This shift towards audio-leading delays could reflect the different propagation speeds of sound and light. Furthermore, the visuolead Temporal Binding Window (TBWv) significantly increases (pValue > 0.001) with distance, possibly due to reduced stimulus intensity at farther distances, consistent with previous studies comparing TBW for high and low intensity stimuli. Across all conditions, TBWv is consistently larger than audio-lead TBWa, aligning with existing literature. These results support VR as a reliable tool for studying multisensory integration across space and demonstrate the efficiency of our adaptive method for non-monotonic functions in reducing the trials number.

#23. Recall of Information Learned Through Tactile Interaction: A Comparison of Virtual Reality and the Real World

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Keywords: virtual reality, sensory interaction, memory recall

Unlike traditional interfaces, which are keyboards, mice, and mechanical dials, VR (virtual reality) immerses the user in the experience. Instead of just looking at the screen, users can interact with a 3D experience. It, therefore, simultaneously simulates as many senses as possible, such as vision, hearing, and touch (Javaid et al., 2024). However, retaining information learned after a VR experience is still controversial compared to real-world interactions. Since we actively connect our skins to objects, usually with our hands, to recognize objects and their features (Bremner & Spence, 2017), real-world tactile and visual interactions allow for a more direct relationship with the objects, while VR may be more limited. Although literature has made contributions to understanding learning and memory in VR environments, certain gaps remain. Many have focused only on comparing visual and

tactile stimuli within VR, without examining how information learned in VR settings relates to real-world memory performance, or how it compares to learning that occurs in real-life settings. Therefore, this study aims to fill these critical gaps by measuring and comparing memory performances in both VR and real-life environments that consider cross-modal interactions. This study compares data related to memory recall, such as names of the objects, the accuracy of feature definitions, and the metamemory levels of the participants for each object. Participants are assigned to one of six groups, each experiencing different conditions (e.g., tactile-only, visual-only, combined, or VR variations). As a result, this study may provide some important insight for memory research in virtual reality.

#24. EEG frequency-tagging captures neural integration of bilateral periodic thermonociceptive stimulation

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Keywords: EEG, pain, intermodulation, frequency, tagging

Frequency-tagging is a technique that allows to objectively isolate neural responses to sustained periodic stimulation at the frequency of the stimulation and its harmonics, measured using electroencephalography (EEG). For thermonociceptive stimulation, this has only been done unilaterally. Extending this approach to a bilateral stimulation would allow to design novel and effective cognitive tasks, as well as enable us to investigate the potential presence of an interaction between the neural processing (i.e. neural integration, identified at the intermodulation frequencies n*F1 ± m*F2) of the thermonociceptive stimuli within the same modality, or even across different modalities in future investigations. We applied ultra-slow sustained periodic sinusoidal thermonociceptive stimuli cycling between 35°C and 50°C concomitantly and bilaterally to the volar forearms of 20 participants at the frequencies F1 (0.25 Hz) and F2 (0.333 Hz), while recording neural activity using a 64-channel scalp EEG setup. The frequency-transformed, baseline-corrected and group-averaged data were z-scored to assess whether significant periodic responses to the stimuli were present at F1, F2 and the intermodulation frequencies. Clearly distinguishable responses were found at F1, F2 and consecutively at their first 5 harmonics ($z>1.64$, one-sided, $p<0.05$), with activity being predominantly centered at the scalp vertex. Using the same criteria, periodic responses were also found at the intermodulation frequencies (e.g. at F1+ 2*F2). This study demonstrates for the first time that bilaterally delivered sustained periodic thermonociceptive stimuli elicit periodic neural responses at both stimulation frequencies. Additionally, we provide evidence of an integration between the neuronal groups responding to these concomitantly applied stimuli.

#25. Investigating the time course of nociceptive mapping with contact-heat evoked potentials

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Keywords: Somatotopic, Spatiotopic, Nociception, Pain, Temporal order judgment, Electroencephalography

Background and aims: To respond effectively to bodily injury, it is necessary to correctly localize pain. Nociceptive inputs can be mapped using a somatotopic reference frame corresponding to a neuronal representation of the skin surface. However, that map can be ineffective because it does not consider the relative position of the body's limbs. Recent behavioural studies showed that nociceptive inputs can also be mapped according to a spatiotopic reference frame, i.e, by integrating proprioceptive feedback and taking external space as a reference. This experiment explores the neurophysiological mechanisms of this dual mapping of pain. Methods: Contact heat stimuli were applied in pairs, one on each participants' hand, with different and random time intervals, including simultaneous trials.

Participants judged which of the two hands they perceived as first stimulated, with the hands in either an uncrossed or crossed posture. The crossed hand posture is intended to create a conflict between the somatotopic and spatiotopic representations and therefore highlight the dual mapping of nociceptive inputs. Using electroencephalography, event-related brain potentials (ERPs) will be recorded in response to simultaneous heat stimuli. Results: Despite participants having performed the task with more difficultly with their hands crossed, magnitudes of the vertex N2 and P2 components of the ERPs were not significantly different between the two task conditions. Other brain responses evoked by contact heat stimuli will be analysed in more detail. Conclusions: This experiment highlights the complexity of the spatial localization of pain, a topic still poorly investigated.

#26. Chill or warmth: Where will you stand closer to me?

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Keywords: Temperature, interpersonal space, social perception, virtual reality

Interpersonal space (IPS) defines the personal boundary within which social interactions feel comfortable. It flexibly adjusts, shrinking with familiar faces and expanding with strangers. Previous studies suggest environmental temperature could influence IPS, as warmth may be linked to comfort and cold to exclusion, though direct evidence is limited. We investigated this hypothesis by combining Virtual Reality (VR) with climate chambers. Participants (N = 60; 50% female) were immersed in a virtual room with a human avatar. They approached the avatar, first stopping at a comfortable distance (IPS), then moving closer until discomfort arose (IPS permeability). Each completed 48 trials across three temperature conditions: cold (8 °C or 18 °C), neutral (24 °C), and hot (28 °C or 38 °C). Half experienced mild temperatures (18 °C, 24 °C, 28 °C), and half experienced extreme ones (8 °C, 24 °C, 38 °C). Generalized linear mixed models showed weak temperature effects, with a trend for women to contract IPS in warmth and expand it in cold ($p = 0.08$), while men showed the opposite. However, stronger effects emerged for participants and avatar's gender. Women showed shorter IPSs than men ($p < 0.001$), and all participants stood closer to female avatars than male ones ($p < 0.001$). IPS and permeability also decreased over time ($p = 0.003$; $p = 0.006$), suggesting growing familiarity. These findings indicate that gender and familiarity play a greater role in shaping IPS than temperature, even under extreme conditions—challenging common assumptions that temperature influences social distance.

#27. Making sense of Fibromyalgia: Investigating perceptual processing across modalities in Fibromyalgia

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Keywords: Perception, Fibromyalgia, Chronic pain

Emerging evidence has associated the widespread chronic pain experienced by people with fibromyalgia with altered basic bodily perception, including tactile discrimination. More recently, self-reported differences in discrimination ability (perceptual ability) have been reported in people with fibromyalgia across different sensory modalities. This suggests that fibromyalgia may reflect a global disturbance in sensory processing. The primary aim of this study was to investigate whether differences in subjective perceptual ability across modalities in fibromyalgia are also apparent on objective measures. A secondary aim was to explore potential discrepancies between subjective and objective measures of perceptual ability in fibromyalgia. Intensity discrimination thresholds for tactile, auditory and painful stimuli were measured in 18 people with fibromyalgia and 23 healthy controls. Participants also rated their confidence in their discrimination ability trial-by-trial and completed the

Sensory Perception Quotient as measures of subjective perceptual ability. Despite limited statistical power and an apparent floor effect for tactile intensity discrimination, we observed a trend for smaller intensity discrimination thresholds across the auditory and pain modality in the fibromyalgia group, indicative of enhanced perceptual ability in fibromyalgia. Additional trends suggested a relationship between overestimating perceptual ability and increased fibromyalgia symptoms for the pain modality. There was also a trend for fibromyalgia participants' confidence ratings to more accurately differentiate between correct and incorrect discrimination responses. This suggests that altered meta-cognitive processes may play a role in fibromyalgia. Future research is needed to test a larger sample size to explore the heterogeneity of perceptual and metacognitive processing across modalities in fibromyalgia.

#28. Pain and touch differentially modulate corticospinal excitability, independent of afferent inhibition

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Keywords: Pain, Touch, Corticospinal excitability

Tactile inputs can suppress motor output through afferent inhibition, typically assessed by examining the effects of afferent stimulation on transcranial magnetic stimulation (TMS) induced corticospinal excitability (CSE; Tokimura et al., 2000). Afferent inhibition provides a model for understanding how somatosensory inputs and states modulate motor and sensorimotor processes essential for adaptive responses. This insight has clinical relevance to the management and treatment of some pain states given that they are frequently associated with disrupted corticospinal motor networks and sensorimotor disturbances. We conducted two experiments to examine the modulation of CSE and afferent inhibition by touch and pain. In Experiment 1 (N=20), a single electrocutaneous stimulus preceded a TMS pulse over the right first dorsal interosseous (FDI) hotspot in the primary motor cortex (M1) at different temporal delays (TDs; 15, 25, 35, 45, 60 or 160 ms). This revealed significant inhibition of CSE at 25, 35 and 160 ms TDs ($p < .001$) and facilitation at a 60 ms TD ($p < .05$). Moreover, these effects were unaffected by the duration of electrocutaneous stimulation (0.2 vs 0.4 ms; $p = .28$). In experiment 2 (N=20), we examined the effects of moderate tonic cutaneous heat pain on corticomotor and sensorimotor processes. Moderate heat pain was delivered to the left forearm during the same afferent inhibition paradigm as in Experiment 1. Heat pain significantly inhibited CSE compared to painless conditions ($p = .02$), while afferent inhibition remained unaffected ($p = .18$). Therefore, pain and touch selectively modulate corticomotor processes. Specifically, heat pain reduces CSE while tactile sensorimotor interactions remained unaltered. These results support the notion that heat pain directly affects the motor cortex and, in this context, such modulation is not mediated by touch.

#29. The Effect of Olfactory Cues on Recall and Recognition Memory in both Younger and Older Adults

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Keywords: Olfaction, Aging, Memory

The “Proust Effect” is a phenomenon in which odors are thought to stimulate elaborative autobiographical memories (Green et al., 2023, Current Opinion in Psychology). To date, little research has systematically explored the extent to which olfactory cues affect recall and recognition memory performance, particularly across the adult lifespan. Older adults often experience age-related sensory and memory decline, but also often demonstrate heightened multisensory integration. Here we investigate whether there are multisensory benefits to recall and recognition memory when adding congruent olfactory cues to visual objects, and whether any such benefits are greater in older compared to younger adults. We used a virtual reality visual search task to examine the effects of object-associated smells on younger (n=48) and older (n=48) adults’ memory. Participants first completed a visual search task in which they located objects in a virtual home including both unimodal (visual-only) and bimodal (visual+olfactory) conditions. Following the search task, participants completed a recall task (naming the objects they searched for) and a scene recognition task (recognizing a change in the scene in which the object had appeared). For both age groups, the addition of olfactory cues improved object recall similarly, but did not affect scene recognition. A follow-up study is currently exploring whether the effect of olfactory cues on memory is further influenced by task demands (comparing single vs. dual task performance). These findings advance our understanding of the effect of olfactory cues on memory performance with potential implications for memory-focused interventions and applications (e.g., training, education, rehabilitation).

#30. Understanding chemosensory mental imagery: Initial validation of the Chemosensory Mental Imagery Questionnaire (CMIQ)

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Keywords: Chemosensory perception, Mental imagery, Questionnaire

Multisensory experience extends beyond perception – it lives vividly in mental imagery. However, little is known about mental imagery within the multiple aspects of the chemical senses (namely, smell, taste, flavour, and mouthfeel). Research shows at least some aspects of chemosensory mental imagery, specifically olfactory imagery, varies with age, cultural background, sensory function, and expertise level while also playing a critical role in driving food craving. To date, various questionnaires have probed people’s mental imagery of chemosensory experience, but there is currently no comprehensive questionnaire that taps into the full range of everyday chemosensory experiences. Furthermore, no study has investigated how familiarity and frequency of exposure to a wide range of chemosensory experiences are linked to the self-reported vividness of chemosensory mental imagery. To address these gaps, we present the preliminary version of a novel questionnaire, the Chemosensory Mental Imagery Questionnaire (CMIQ). Participants completed the CMIQ which assessed smell, taste, flavour, and mouthfeel, alongside familiarity and exposure frequency ratings for each experience. Initial results showed acceptable internal consistency and test-retest reliability, specifically significant correlations with established measures, though factor analysis revealed structural challenges requiring further refinement. Nevertheless, exploratory analysis revealed that both ratings on familiarity and frequency of exposure were positively correlated with the self-reported vividness of imagery across domains, extending previous findings on familiarity and vividness beyond orthonasal olfaction. This work represents an important step toward developing a tool for investigating multisensory integration in chemosensory imagery, with potential future applications in food innovation, sensory disorder assessment, and cross-cultural variation.

#31. The taste of coffee is modulated by the spatially isolated tactile stimulus

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Keywords: sensation transference, crossmodal, taste evaluation

Sensation transference refers to the crossmodal phenomenon where a sensory experience from one modality is influenced by a sensory input from another. Previous research demonstrated that the cup of smooth texture reduced the acidity and dry aftertaste of coffee, compared to the cup of rough texture. However, it was unclear whether such the sensation transference derived from the tactile or visual texture since the participants were not blindfolded. The present study examined (1) whether the taste of coffee is modulated only by the tactile texture of the cup under a more controlled situation, and (2) spatial characteristics of such the sensation transference. In Experiment 1, participants with blindfold first drunk coffee from the rough (smooth) cup and then drunk from the smooth (rough) cup. They evaluated the taste of the second coffee with reference to the first one. The results demonstrated that participants evaluated the acidity of coffee from the smooth cup lower after drinking from the rough cup, even though they drunk the same coffee. In Experiment 2, we spatially isolated the tactile stimulus from the gustatory stimulus, asking participants to touch the rough/smooth paper on their one hand while drinking coffee on their opposite hand. We obtained the same results as in Experiment 1. The current findings suggest that (1) the acidity of coffee is relatively reduced only by the tactile smoothness, and further that (2) such the sensation transference occurs even when the tactile stimulus is spatially isolated from the taste stimulus, or not coffee-related.

#32. Exploring the effects of food familiarity and information type on food desire and memory recall

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Keywords: novel food, consumer behavior, recall performance

Existing literature shows that consumers' willingness to try unfamiliar foods depends on the amount of information provided about these products. However, the effects of specific types of information, such as food content and health benefits, remain insufficient. In addition, despite the widespread belief that novel stimuli are easier to remember, studies on recalling novel foods' names are limited. This study investigates the impact of various types of information (content of food and health score) on individuals' willingness to consume unfamiliar foods and their recall performance. In addition, the study assesses participants' metacognition by prompting them to indicate how sure about their recall performances for each food. Using a 2 (food familiarity: familiar-unfamiliar) x 3 (information type: name only, name and food content, name, food content, and health score) mixed factorial experimental design, the study evaluates university students' desire to try novel foods and to assess their performances for recalling these items. This study aims to offer valuable insights into the relationship between information types related to foods and participants' willingness to eat, as well as the recall performances for novel food options. Furthermore, it seeks to enhance the existing literature on how different types of information influence food choices and to provide new perspectives on how memory processes are affected by familiarity. Additionally, this study suggests the possibility that having content information about unfamiliar foods may make it easier to choose foods that suit different dietary preferences if they also have content information.

#33. Visual search in a complex surrounding is immediately improved when paired with a synthesized audio cue algorithm

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Keywords: Multisensory enhancement, Visual, Audio, Spatial Perception

Locating target objects within complex visual environments can be challenging, particularly when multiple distractors are present at varying azimuthal angles, heights, and depths. This study investigates the impact of spatialized auditory cues on target detection in 3D space, assessing both the influence of localized sound on visual search and the effectiveness of the TopoSpeech-3D

algorithm in time-dependent tasks without prior training. We conducted an experiment in an acoustically treated environment equipped with Higher-Order Ambisonics and a cave-style visual projection system. Participants (N=36) completed a timed target localization task under three conditions: 1) Visual-only (V), 2) Visual with a non-localized audio cue (VC), and 3) Visual with a fully localized TopoSpeech-3D cue (VS). The TopoSpeech-3D algorithm combined a HigherOrder Ambisonics setup for decoding azimuthal positions, depth cues via a subtractive synthesis model, and height differentiation using pitch-height correspondence. Results revealed significantly faster response times in conditions with added auditory cues, with the shortest response times occurring in the VS condition (V vs. VC: $t = 7.8$, $p < 0.001$; V vs. VS: $t = 12.4$, $p < 0.001$; VC vs. VS: $t = 6.6$, $p < 0.001$). No significant differences in response angle errors were observed across conditions. These findings highlight the critical role of spatialized audio in enhancing visual search efficiency. It further highlights the immediacy with which certain sensory correspondences can be implemented within models for spatial auditory models. Implications for assistive technologies, and immersive multisensory system design.

#34. Multisensory continuous psychophysics: Integration of visual and audio cues for direction perception

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Keywords: Continuous Psychophysics, Direction Perception, Audiovisual Integration, VR

A novel paradigm originating in Vision Science, Continuous Psychophysics, promises to revolutionize experimental design by coupling a continuously changing stimulus with a continuous response. Here, we provide proof-of-concept for how this paradigm can be used to study multisensory integration by replicating the known result that visual and audio information is integrated for direction perception. We used a simple tracking task in which stationary participants tracked a drone in Virtual Reality by continuously pointing a controller at it. The drone changed direction from left to right and right to left relative to the observer' (within 45° of their straight-ahead) on a random walk. Visibility was manipulated using a visual fog, which could be absent, light or heavy, and the drone emitted a humming sound during some segments to provide auditory cues. Sensory precision was higher when sound was added to the visual stimulation, except for the NO FOG condition, where a ceiling effect may have prevented us from detecting benefits of multisensory integration. Replicating this known effect of auditory cues enhancing direction perception confirms that Continuous Psychophysics can be used in this context and opens up a wealth of directions for future investigation into precision, accuracy and the time course of multisensory integration.

#35. Contribution of displacement, duration, and velocity on auditory and audiovisual motion direction perception in macaque monkeys

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Keywords: audiovisual, motion, auditory, macaque, NHP, visual

Motion perception is a key aspect of sensory processing that enables successful interaction with the environment. While visual motion perception has been extensively studied, little is known about the determinants of auditory and audiovisual motion perception. Our study explores how the perception of auditory motion direction changes with manipulations of low-level stimulus parameters in nonhuman primates (NHPs). Macaque monkeys were trained to perform a 2-AFC task in which they judged the direction of noisy auditory motion stimuli. We systematically manipulated stimulus duration, velocity, and displacement to evaluate their respective influence on motion sensitivity. Displacement had the greatest impact, while the relative influence of duration versus velocity depended upon the duration of

the stimulus. These findings suggest that auditory motion direction is most likely processed by a snapshot mechanism, in which stimulus velocity is inferred by sequential snapshots of auditory stimulus location, rather than by velocity-selective motion detectors similar to those found in the visual system. Additionally, we investigated whether this finding remains true under audiovisual conditions. To our knowledge, this study is the first to characterize the influence of low-level stimulus parameters on auditory and audiovisual motion perception in awake, behaving NHPs, and forms the basis for future neurophysiological investigations.

#36. Does tactile acuity predict haptic object perception in younger and older adults?

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Keywords: Ageing, Haptics, Lifespan, Psychophysics, Tactile

Previous evidence suggests that although individual sensory systems are impacted by ageing, perception may be preserved in older adults via compensatory processes either from higher cognition (e.g. memory) or multisensory inputs. Although this compensation has been demonstrated mainly for vision, given than tactile function is associated with important, everyday abilities, surprisingly little is known about the links between sensory and perceptual abilities in touch as we age (e.g., balance, grasping etc.). In particular, it remains unclear whether haptic object recognition in older adults is directly linked to tactile sensitivity in the periphery or whether the ability is maintained through other mechanisms. To address this issue, we conducted a series of tests to measure tactile sensitivity and haptic object perception in a sample of both younger and older adults. All participants first completed demographic, handedness, health, cognitive and lifestyle data. We then used a comprehensive test battery to examine, using standard psychophysical methods, spatial tactile acuity, shape discrimination (e.g., 2D shape and curvature) and object perception (3D objects) and variability in performance across age. Our results supported previous findings for age-related differences in tactile acuity, with a decrease in tactile sensitivity with older age. Moreover, we found a greater influence of age on 2D than 3D shape tests. In general, we found that tactile sensitivity did not consistently predict haptic perception, suggesting compensatory processes. Our findings may inform various areas of application, including the age-appropriate design of objects used by the hand.

#37. Multisensory aesthetic perception: A qualitative-quantitative study with eye-tracking and video-capturing on visuo-tactile interactions with material textures

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Keywords: Perception, Multisensory perception, Multisensory aesthetics, Visuo, tactile perception, Visuo, tactile aesthetics

In real-world interactions, material textures elicit a complex interplay of sensory modalities, predominantly vision and touch. Recent scientific endeavours have focused on advancing our comprehension of material perception, to clarify the roles of visual and haptic systems. Despite these efforts, the understanding of bottom-up and top-down processes in visuo-tactile aesthetics and their interaction remains limited. We conducted an in-depth study exploring visuo-tactile sensory perception, interactions with everyday material textures. Thirty right-handed participants with normal, corrected vision evaluated various textures using a Touch Perception Task and provided qualitative feedback using a think-out-loud protocol while engaging in visuo-tactile interactions with the materials. Our integrated approach combined self-reports on sensory, affective experiences, personality traits, need for touch. Additionally, eye-tracking technology recorded fixation and pupillary responses, complemented by video analyses of participants' exploratory hand movements while engaging with

material textures. We used pupillometry data, exploration time, observed prototypical hand movements to classify different sensory, affective responses towards material textures. Stimulus valence was retrieved by analysing think-aloud protocols which were recorded during visuo-tactile explorations of the material. Distinct hand movements, which deviate from the traditional lateral motion used in texture assessments, were identified. These movements are potentially driven by cognitive, affective, and aesthetic motives. Notably, individual differences were substantial, showing idiosyncratic ways to approach materials exploration alongside different combinations of liked, disliked materials. By integrating physiological and behavioural data, this study aims to deepen our understanding of the cognitive and affective interplay in visuo-tactile multisensory experiences, thereby enhancing our knowledge of sensory integration processes.

#38. Optimal visuo-haptic integration for size perception with noisy haptic cues

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Keywords: Multisensory integration, Vision, Haptic, Maximum Likelihood Estimation, Noise

Human agents have been shown to integrate visual and haptic information in a statistically-optimal fashion, by weighting each information by its reliability. So far, previous experiments had always added noise to the visual cues, in order to equalize visual reliability (high) with haptic (low) reliability. The present study aims to further characterize the rules of multisensory integration, by varying visual and haptic reliabilities. To that aim, we will ask healthy adults (target n = 10) to perform a psychometric size-discrimination task. Visual, haptic, and visuo-haptic objects (rectangular 3D shapes) will be presented by means of a simulated visual environment (computer screen) and a haptic interface (Omega 7.0). Participants will be presented two successive objects, a standard stimulus (width: 64 mm) and a comparison stimulus (width: standard ± 1, 2, 3, 5, 8 mm), and will be asked to estimate which object is the largest. Cue reliabilities will be manipulated using visual sharpness (normal vs blurred) and haptic stiffness (“hard” [3000 N/m] vs. “soft” [1000 N/m]), respectively. Visuo-haptic conflicts (-2, 0, +2 mm) will be used to induce sensory reweighting. According to pilot observations, visuo-haptic noises tend to increase the JND measurements. Data collection will take place in March-April. The main experiment will test whether visuo-haptic integration is optimal for the different combinations of noisy and non-noisy unimodal cues.

#39. Discrimination of texture patterns is better for 'disordered' than 'ordered' elements in both touch and vision

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Keywords: Categorisation, Discrimination, Gestalt, Perception, Vision, Aesthetics

According to Gestalt psychology, the organisation of patterns plays an important role in visual perception and patterns that are more easily perceived and discriminable are often also preferred. Using tactile tiles with embossed dots, we have previously shown that randomly organised patterns are more discriminable by touch than ordered patterns, a surprising finding given the differences in 'perceptual fluency' (Ziat et al., 2023). Here we extended this finding to the visual modality. We created a continuum of 10 images of novel texture patterns (i.e., black dots on a white background, ranging from highly ordered to highly disordered patterns). First, we investigated whether stimuli adhering to Gestalt principles shape participants’ preferences. Participants rated the likeability of each texture pattern using a seven-point Likert scale. In a separate experiment, we then tested whether these stimuli were more easily discernible depending on their pattern organisation. To that end, participants first performed a discrimination task followed by a categorisation task, in which they had to categorise each pattern as either 'ordered' or 'disordered'. We found an overall preference for

ordered patterns. Participants performance also indicated the successful categorisation of novel visual texture patterns with a distinct boundary. Moreover, discrimination performance to patterns at the category boundary was better than the most ordered images, suggesting categorical perception. However, patterns categorised as 'disordered' were overall easier to discriminate than 'ordered' patterns, replicating the findings from the tactile task. Our results suggest that enhanced perceivability and adherence to Gestalt principles impact visual aesthetic preferences but are not necessarily predictive of texture discrimination in either touch or vision.

#40. Haptic recognition of cross-sections in visually impaired and sighted adults

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Keywords: cross sectioning, haptic, blindness

Cross-sectioning is a task demanding participants to identify the two-dimensional internal shape of cross-sectioned 3D solids. From a cognitive perspective, this task requires strong spatial representation of objects and mental manipulation of two and three-dimensional figures. While previous research underscores vision's role in developing perception of objects' spatial features, the relationship between this spatial skill and visual impairment concerning cross-sectioning tasks remains unclear. The present study aims to clarify the haptic spatial representation of objects in people with visual impairment using haptic 3D-printed version of the Santa Barbara Solid Test. Our sample consisted of four groups of adults: early blind (N=11), late blind (N=8, after 6 y.o.), low vision (N=5, vision acuity between 3/10 and 1/20) and blindfolded sighted (N=13). All participants were asked to haptically explore and recognize cross-sections of 3D-printed solids (n=10 trials) and to identify the associated correct section among four 3D-printed options. We performed a logistic regression considering accuracy (correct vs incorrect) as outcome and group as a predictor. The group (i.e., onset of blindness) resulted as a significant predictor for task performance. In particular, early blind participants show lower probability to identify the correct cross-section of solids compared to the other groups. In line with previous research, these findings show that visual deprivation in the first years of life affects the development of effective haptic spatial skills, highlighting the need for tailored rehabilitation programs, particularly in the context of multisensory spatial reasoning.

#41. The interference dynamics of multisensory distractors: Statistical regularity vs. proactive suppression

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Keywords: Multisensory Distraction, Statistical Regularity, Proactive Suppression

Multisensory stimuli are typically processed more efficiently than unimodal stimuli. However, the impact of multisensory distractors on task performance and the potential modulation of this effect by statistical regularity or proactive suppression remain poorly understood. In this study, participants performed central visual discrimination tasks while ignoring peripheral unimodal or multisensory distractors that were either semantically congruent or incongruent with the targets. Experiment 1 revealed that audiovisual distractors caused greater interference compared to unimodal (auditory) distractors. Experiments 2 and 3 manipulated the spatial probability of distractor location (75%) and predictive cues (75%), respectively. The results indicated that while both audiovisual and auditory distractors elicited significant interference, audiovisual distractors consistently produced larger interference than unimodal distractors. Statistical learning improved performance for both unimodal and multisensory distractors in high-probability locations compared to low-probability conditions. In contrast, endogenous attentional cues were ineffective in inhibiting distractor interference, suggesting limited top-down control over crossmodal distraction. These findings demonstrate that audiovisual

distractors consistently induce greater interference than unimodal distractors and that multisensory distractors can be effectively inhibited by statistical regularity learning but not by proactive cueing.

#42. Multisensory integration enhances confidence but impairs metacognitive efficiency in localization tasks

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Keywords: Multisensory Integration, Confidence, Metacognition, Cross Modal Matching

Multisensory integration reduces sensory uncertainties by combining cues. Although it is believed that reduced uncertainty leads to higher confidence, whether these benefits extend to subjective confidence reports and metacognitive efficiency is unclear. Previous research has predominantly focused on visual tasks, documented better metacognitive efficiency (quantified by M-ratio) to show enhanced ability of monitoring one's own performance, leaving open questions about potential differences in confidence reporting between visual and auditory modalities when task performance is controlled. In this study, participants completed visual, auditory, and audiovisual localization tasks. Task performance was maintained at 76% accuracy using an adaptive staircase, and visual and auditory noises were calibrated to be equal. Reaction times were slowest in the auditory task and fastest in the audiovisual condition, indicating that auditory localization was inherently more challenging. Despite these differences, confidence ratings were similar for the visual and auditory tasks, whereas the audiovisual condition elicited higher confidence on both correct and incorrect trials. Notably, the smaller difference in confidence between correct and incorrect responses in the audiovisual condition suggests a diminished ability to track performance. Furthermore, M-ratios were comparable between visual and auditory tasks but were lower in the audiovisual condition, with correlations among the three conditions. The absence of differences in meta-noise between the auditory and visual tasks further supports the existence of a shared metacognitive mechanism across modalities. In summary, while multisensory integration boosts overall decision confidence, it concurrently reduces metacognitive efficiency relative to unimodal performance. Distinct sensory channels may contribute to a common metacognitive mechanism.

#43. Investigating The Effect Of Response Autocorrelation On N-Back Analyses Of Serial Dependence

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Keywords: serial dependence; n-back; response autocorrelation; continuity field

Serial dependence is a perceptual bias where the current perception is attracted toward the recent perceptual history, giving form to a spatiotemporal continuity field. The first studies on serial dependence, which accounted for the stimuli history only, found that in reproduction tasks such continuity field could span for up to 10-15 seconds in the past. However, more recent evidence has shown that not only the stimuli delivered, but also the responses given contribute to the serial dependence effect. Here, we show through simulations that the effect of past responses, if not accounted, can lead to spurious long-term associations between current response and past stimuli. Then, we propose a method to contain the risk of finding a spurious effect of past stimuli by taking the residuals of the fit of the previous response onto the current response as dependent variable. As an example, we apply the proposed method on a dataset from a seminal work (Fisher, J. & Whitney, D.,

Nature Neuroscience, 2014). The application of the method shows that the serial dependence effect found in that study may in fact be shorter than previously reported, spanning for up to 5 seconds instead of 15. Our results show the importance of considering the response autocorrelation when analyzing serial dependence effects, even if only stimuli are taken into consideration in the experimental paradigm.

#44. Body structural representations of the glabrous and hairy skin surface: Evidence from the in-between task

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Keywords: Tactile perception, Body Structural Representations, Glabrous and Hairy skin

Knowledge about body representation is drawn from different sensory modalities but relies strongly on tactile information. The body structural representation (BSR) is a visuospatial map of the body in which the spatial configuration of different body parts is defined (Schwoebel & Coslett, 2005). Recent evidence has demonstrated that BSR is not fixed but can be dynamically updated by external factors such as changes in body posture (Tamè et al., 2017). However, the extent to which different skin regions (glabrous vs. hairy) modulate access to the structural representation of the hand remains unclear. To address this, we conducted two experiments using an adapted version of the "in-between" test (Kinsbourne & Warrington, 1962), where healthy individuals received tactile stimulations on the fingertips and estimated the number of unstimulated fingers between the two touched ones. In Experiment 1 (N=30), the skin region (glabrous vs. hairy) and hand posture (palm up vs. palm down) were varied across conditions. In Experiment 2 (N=30), hand posture was held constant (palm down), while the stimulated skin region was manipulated. Results showed a significant difference in fingers' numerosity estimation between the glabrous and hairy skin stimulation. Specifically, participants estimated greater numerosity in the glabrous skin condition regardless of hand posture, but this effect was only evident when non-adjacent fingers were stimulated. This suggests that the access to the BSR of the hand depends on the skin surface stimulated and is updated as a function of the anatomical distance between different body parts.

#45. The spatial reach of affective touch: Investigating the role of CT-fibers in peripersonal space representation

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Keywords: Multisensory integration, Somatosensory system, Affective touch, Peripersonal space, CT, fibers

Peripersonal space (PPS) is defined as a sector of space surrounding the body, serving as a sensory-motor system for hand-object interaction. This portion of space, delimited by our skin and the reach of our limbs, is mapped through the integration of multisensory stimuli arising from the body. Although touch is crucial for the multisensory integration processes within PPS, only a few studies have explored the distinct contributions of the sensory system's dual pathways. These are represented by large myelinated Aβ nerves enabling fast discriminative touch and C-Tactile unmyelinated fibers involved in the low-pressure, slow, caress-like tactile stimulation. To overcome these lacks, we carried out three experiments in which participants underwent audio-tactile tasks, each designed to assess PPS processing under different tactile conditions. In Experiment 1 (Classic Task), we estimated PPS through the traditional task in which participants responded to discriminative tactile stimuli at different temporal delays while ignoring looming sounds. In Experiments 2 (Discriminative Task), we adapted the Classic Task by using an auditory cue as a target stimulus, while administering the discriminative tactile stimulation. This allowed us to assess PPS boundaries by reversing the sensory modality of the

target stimulus, with no difference found between Classic and Discriminative Tasks. In Experiment 3 (Affective Task), we used the same protocol as in Experiment 2 applying affective touch. Results showed that PPS boundaries in the Affective Task were significantly larger than both Classic and Discriminative Tasks, suggesting the unique role of caress-like touch in shaping body-space representation.

#46. Effect of visuo-haptic discrepancies on compliance perception in a virtual environment

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Keywords: Compliance perception, Crossmodal effects, Tangible objects, Virtual reality

Compliance perception plays an important role in both object identification and manipulation. Through daily experiences, we learn to associate the felt softness with the visual deformation that occurs when we interact with objects. Previous studies have used sensory discrepancies between vision and touch to investigate how multimodal signals are merged into a coherent percept. However, designing an experimental environment that allows precise and accurate manipulation of the visual and tactile feedback remains challenging. In this study, we explore how visual and tactile cues contribute to compliance perception in a virtual reality environment. Virtual reality permits precise control over sensory feedback, allowing us to introduce subtle mismatches between what participants see and feel. Participants interact with tangible soft objects using either their dominant hand and their non-dominant hand, while their visual representations are manipulated in virtual reality. By compressing the physical object, they see a virtual object that either deforms identically or presents a conflicting deformation. With this setup that enables realistic haptic behaviour in several conditions, we aim to explore how people compare the reliability of the visual and tactile cues and the resulting sensory weights. More specifically, we hypothesize that using non-dominant hand will decrease reliance on touch and that a too large incongruence of visual representation will reduce its influence.

#47. Touch in conflict: enhancing movement control with tactile external cues

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Keywords: Touch, Sensory conflict, Vision, Movement control, Attention, Interoception, Exteroception, EEG

Touch bridges perception and action by combining exteroception, which provides information about the environment (e.g. texture), with interoception, which monitors bodily states (e.g. movement direction), to guide our interactions with the world. However, in a visuomotor task with conflicting visual and somatosensory input (mirror paradigm), the processing of somatosensory information compromises movement control. In this context, interoceptive touch increases the sensory conflict, disrupting performance. Given the brain's ability to prioritize relevant sensory cues, we explored whether adding an external spatial component to touch could reduce the effect of interoceptive touch. Seventeen adults traced the contour of a white-textured 2D shape on a smooth black surface (interoceptive and exteroceptive-spatial cues) with their index finger, receiving either direct or mirror-reversed visual feedback. A control group (n=17) traced a white shape with the same texture as the black surrounding surface (interoceptive cues). We hypothesized that spatial exteroceptive cues would improve tracing accuracy with mirror-reversed vision. Indeed, finger kinematics revealed significantly greater tracing accuracy when spatial exteroceptive cues were present compared to when only interoceptive touch was available. EEG source analyses showed distinct sensorimotor strategies. The presence of spatial exteroceptive cues significantly increased the activity of the

sensorimotor cortex while tracing with mirror compared to direct vision. Conversely, in the absence of spatial exteroceptive cues, the visual cortex showed significantly increased activity, suggesting enhanced reliance on visual information. Our results suggest that the presence of external tactile information, congruent with environmental visual input (here the shape), can reduce sensory conflict and enhance movement control.

#48. The facilitation of sensory processing in presence of approaching stimuli suggests a combined influence multisensory integration and arousal

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Keywords: Peripersonal space, visuo, tactile integration, contact anticipation, looming, attention

Our ability to interact with the world depends on anticipating contact with nearby objects, a process associated with the facilitation of neural responses to touch when an object enters the space around the body allowing physical interaction, known as peripersonal space (PPS). The facilitation of responses to touch have also been evidenced at the behavioral level. However, this behavioral facilitation does not strictly occur within PPS. We hypothesized that this broader facilitation is due to heightened arousal induced by approaching stimuli, even when they are still outside PPS. To test this hypothesis, we required participants in two experiments to react promptly not only to tactile stimulation but also to auditory and visual stimulation presented at different moments along the trajectory of a looming visual stimulus. Reaction time facilitation, compared to a unimodal baseline where sensory stimulations were presented in isolation, emerged from 1.5 m away and intensified as the visual stimulus approached. While all sensory modalities showed comparable facilitation outside PPS (1.5–0.9 m), tactile facilitation became stronger within PPS (<0.9 m). These results suggest there is specific visuo-tactile facilitation within PPS but with additional modulation due to an arousal-driven increase in alertness equally affecting all modalities regardless of distance. This highlights the dynamic interplay between arousal and peripersonal multisensory processing in facilitating behavioral responses to touch.

#49. Peripersonal space in the city: Validation of measures of audito-tactile integration on a smartphone

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Keywords: Reaction time, Looming sound, Spatial hearing, Binaural rendering

Peripersonal space is commonly studied using audiotactile integration paradigms, where reaction times (RTs) to a tactile stimulus are measured in the presence of a concurrent looming auditory stimulus. While social and environmental factors significantly influence peripersonal space, laboratory-based protocols often lack ecological validity, limiting their applicability to real-world settings. To address this limitation, we adapted the experimental procedure developed by Hobeika et al. (2020) for use on a smartphone. This mobile setup allows for the investigation of multisensory integration in diverse environments and populations. The experiment measured RTs via screen vibrations, providing a practical alternative to traditional laboratory equipment. In a validation study, healthy volunteers held the smartphone in their left hand, wore headphones, and tapped the screen with their right index finger in response to vibrations. Looming and static sounds, rendered using generic head-related transfer functions (HRTFs), were presented to control for expectancy effects. By isolating expectancy-related influences from the proximity-driven audiotactile effect, we obtained results comparable to those observed in controlled laboratory conditions. Further testing across different smartphone models and environmental contexts is required to ensure the robustness and generalizability of this procedure. This mobile approach presents a promising tool for studying

peripersonal space in naturalistic settings. It enables large-scale dissemination of experiments, facilitating research on multisensory integration in everyday life.